

Content of „The Human Body; An Introduction to Structure and Function” modified for exam requirements 2018.04.10.

## ~~1 Biology of the Cell 1~~

### ~~Introduction 2~~

#### ~~Number, Size, Shape, and Properties of Cells 2~~

~~Number, Size, and Shape 2~~

~~Properties 3~~

~~= Metabolism and the Generation of Energy 3~~

~~= Reproduction and Life Expectancy 3~~

~~= Sensitivity to Stimulation and Response to Stimulation 3~~

#### ~~Structure of the Cell and Cell Organelles 4~~

~~Basic Structure 4~~

~~Cell Membrane 4~~

~~Cytoplasm and Cell Organelles 6~~

~~= Endoplasmic Reticulum (ER) 7~~

~~= Ribosomes 7~~

~~= Golgi Apparatus 7~~

~~= Lysosomes 8~~

~~= Centrioles 8~~

~~= Mitochondria 8~~

~~The Cell Nucleus 10~~

~~= Chromosomes and Genes 10~~

~~= The Genetic Code 13~~

~~= Protein Synthesis 15~~

~~= Duplication of Genetic Material (Replication) 18~~

#### ~~Cell Division (Mitosis) 18~~

#### ~~Reduction or Maturation Division (Meiosis) 21~~

#### ~~Exchange of Materials between the Cell and Its Environment 24~~

~~Composition of the Extracellular Fluid 26~~

~~Composition of the Intracellular Fluid 26~~

#### ~~Membrane or Resting Potential of a Cell 27~~

#### ~~Solid and Fluid Transport 28~~

~~Diffusion 29~~

~~Osmosis and Osmotic Pressure 29~~

~~Filtration 31~~

~~Active Transport 32~~

~~= Combined Solid and Water Transport 32~~

~~Endocytosis and Exocytosis 32~~

## ~~2 Genetics and Evolution 39~~

### ~~Genetics (The Science of Heredity) 40~~

~~Genes, Chromosomes, and the Genome 40~~

~~The Allele 40~~

~~Dominance, Recessiveness, and Codominance 41~~

~~Phenotype and Genotype 41~~

~~The Mendelian Rules 41~~

~~= The Rule of Uniformity (Dominance) 42~~

~~= Rule of Segregation 44~~

~~= Rule of Independence 45~~

~~Autosomal Dominant Hereditary Transmission 46~~

~~Autosomal Recessive Hereditary Transmission 48~~

~~Sex-linked Inheritance 50~~

~~= X Chromosome-linked Dominant Inheritance 50~~

~~= X Chromosome-linked Recessive Inheritance 50~~

~~Mutations 51~~

~~= Gene Mutations 53~~

~~= Chromosome Mutations 53~~

~~= Genome Mutations 53~~

### ~~Evolution (The Science of Development; Phylogeny) 55~~

~~The Concept of Evolution 55~~

~~Factors in Evolution 55~~

~~= Selection 55~~

~~= Mutation 57~~

~~= Recombination 58~~

~~= Gene Drift 58~~

~~= Isolation 58~~

~~Evidence for Evolution 59~~

~~= Embryological factors 59~~

~~= Homologous Organs 60~~

~~= Rudimentary organs 60~~

~~= Atavism 61~~

## ~~3 Tissues 67~~

### ~~Epithelial Tissue 68~~

~~Surface Epithelia 68~~

~~= Shape and Arrangement 68~~

~~= Surface Differentiation 71~~

~~= Cell Junctions 71~~

~~Glandular and Sensory Epithelia 72~~

### ~~Connective and Supporting Tissues 72~~

~~Connective Tissue 73~~

~~= Functions 73~~

~~= Connective Tissue Cells 74~~

~~= Intercellular Matrix (Ground Substance) 74~~

~~= Loose Areolar (Interstitial) Tissue 75~~

~~= Dense Fibrous White Connective Tissue 75~~

~~= Reticular Connective Tissue 76~~

~~= Adipose (Fatty) Tissue 77~~

~~Supporting Tissue 78~~

~~= Chordate Tissue 79~~

~~= Cartilaginous Tissue 79~~

~~= Bone Tissue 80~~

~~= Contrasting Bone and Cartilage 85~~

### ~~Muscle Tissue 85~~

~~Smooth Muscle Tissue 86~~

~~Striated Muscle Tissue 87~~

~~= Skeletal Muscle Tissue 88 **(NOT: 91-96)**~~

~~= Cardiac Muscle Tissue 96~~

### ~~Nerve Tissue 97~~

~~The Neuron 97~~

~~The Nerve Impulse (Action Potential) 100~~

~~The Synapse 101~~

~~The Glia Cells (Neuroglia) 105~~

– Blood–Brain Barrier of the Central Nervous System (CNS) 105

The Nerves 106

– Regeneration of Peripheral Nerves 107

#### **4 The Locomotor System (Musculoskeletal System) 113**

**Axes, Planes, and Orientation 114**

Axes and Planes of the Body 114

Nomenclature of Positions and Directions 114

**General Anatomy of the Locomotor System 116**

The Bones 116

The Joints 117

– Immovable Joints (Synarthroses) 117

– Movable Joints (Synovial Joints, Diarthroses) 118

– Slightly Movable Joints (Amphiarthroses) 120

– Types of Joint 120

– Joint Mechanics 122

~~Function and Structural Principles of Skeletal Muscle 123~~

~~The Tendons 127~~

~~Auxiliary Structures of Muscles and Tendons 127~~

~~**Special Anatomy of the Locomotor System 129**~~

~~The Skeleton of the Trunk 129~~

~~– The Spinal Column 130~~

~~– The Rib Cage (Thorax) 138~~

~~The Muscles of the Trunk 140~~

~~– The Back 141~~

~~– The Chest Wall 141~~

~~– The Abdominal Wall 147~~

~~– The Diaphragm 149~~

~~– The Pelvic Floor 149~~

~~The Upper Extremity 153~~

~~– The Shoulder Girdle—Bones, Joints, Muscles 153~~

~~– The Free Upper Limb—Bones, Joints, Muscles 156~~

~~The Lower Extremity 166~~

~~– The Pelvic Girdle and the Pelvis—Bones, Joints, Muscles 166~~

~~– The Free Lower Limb—Bones, Joints, Muscles 171~~

~~Head and Neck 184~~

~~– The Neck (Collum) 184~~

~~– The Head (Caput) 185~~

~~– General Aspects of the Skull 186~~

~~– The Muscles of the Skull 193~~

~~– The Jaw Joint (Temporomandibular Joint) 194~~

#### **5 The Heart and Blood Vessels 205**

**The Heart (Cor) 206**

Shape and Position 206

Structure of the Heart 208

The Conduction System 214

The Coronary Vessels 215

Systole and Diastole 216

Cardiac Output (CO) 218

Nerve Supply of the Heart 218

Heart Sounds and Heart Murmurs 219

Resting and Action Potential of the Heart 220

– Differences between Cardiac and Skeletal Muscle 221

~~The Electrocardiogram (ECG) 221~~

~~– ECG Leads 222~~

~~– ECG Tracing 223~~

~~– Heart Rate 224~~

~~Blood Pressure 225~~

~~– Measurement of the Blood Pressure 225~~

~~Examination of the Heart 226~~

~~**The Vascular System—Structure and Function 228**~~

~~The Blood Vessels: Arteries, Veins, and Capillaries 228~~

~~– The Structure of Arteries and Veins 228~~

~~– Structure of the Capillaries 229~~

~~Lymph Vessels 229~~

~~Systemic and Pulmonary Circulation 231~~

~~The Fetal Circulation 234~~

~~The Arterial System 234~~

~~The Venous System 238~~

~~**The Vascular System—Physiological Principles 244**~~

~~Flow, Pressure, and Resistance in the Vascular System 244~~

~~Distribution of the Cardiac Output (CO) 245~~

~~Regulation of Organ Perfusion 245~~

~~– Autoregulation of Vascular Tone 246~~

~~– Nervous and Hormonal Control of Vascular Tone 246~~

~~Reflex Regulation of Circulation and Blood Pressure 247~~

~~– Pressure and Stretch Receptors 247~~

~~– Regulation 247~~

~~– Postural Hypotension 248~~

~~– Shock 248~~

~~Capillary Circulation 249~~

~~– Substance Exchange between Blood and Tissues 249~~

~~– Edema Formation 250~~

~~Venous Return to the Heart 250~~

~~– Impedance of Venous Flow 251~~

#### **6 Blood, the Immune System, and Lymphoid Organs 259**

**The Blood 260**

Functions of the Blood 260

The Cells of the Blood 262

– The Erythrocytes 262

– The Leukocytes 263

- The Platelets 266
- Blood Groups and Blood Transfusions 266
  - = Blood Groups 266
  - = Blood Transfusion 267
  - = The Significance of the AB0 System 267
  - = The Rh Factor 268
- The Plasma 269
  - = Plasma Proteins 270
  - = Low Molecular Weight Plasma Constituents 273
  - = Plasma Electrolytes 273
- The Erythrocyte Sedimentation Rate (ESR) 273
- O<sub>2</sub> and CO<sub>2</sub> Transport in the Blood 274
  - = Hemoglobin Transport of O<sub>2</sub> 274
  - = CO<sub>2</sub> Transport 274
  - = Hemoglobin and Carbon Monoxide 276
  - = Hemoglobin Concentration (Hb) 276
- The Anemias 277
- The Regulation of Erythrocyte Generation 278
- Hemostasis and Coagulation of the Blood 279
  - = Hemostasis 280
  - = Coagulation of the Blood 280
  - = Fibrinolysis 280
  - = The Regulation of Blood Clotting 281
- The Immune System 282**
  - Nonspecific Immunity 282
    - = Cellular Immunity 282
    - = Humoral Immunity 283
  - Specific Immunity 283
    - = Antigen Presentation by Macrophages 283
    - = T Lymphocytes (Cellular Immunity) 285
    - = B Lymphocytes (Humoral and Cellular Immunity) 286
    - = Memory Cells 287
- The Lymphoid Organs (Immune Organs) 287**
  - The Thymus 290
  - The Lymph Nodes 291
  - The Spleen (Splen, Lien) 293
  - Lymphoid Tissues of the Mucous Membranes 295

## **7 The Endocrine System 307**

### **Hormones 309**

Mechanisms of Hormonal Action 309

Major Sites of Hormone Formation 312

Regulation of Hormone Secretion 313

### **Hypothalamic-Hypophyseal Axis 313**

#### **Pituitary Gland (Hypophysis) 314**

Neurohypophysis (Posterior Lobe of the Pituitary Gland) 315

- Posterior Pituitary Deficiency 315

- Overactivity of the Posterior Pituitary Gland 315

Adenohypophysis (Anterior Lobe of the Pituitary Gland) 315

- Anterior Pituitary Insufficiency 316

- Overactivity of the Pituitary Gland 317

## **Pineal Gland (Pineal Body, Epiphysis Cerebri) 317**

- Pineal Insufficiency 318

### **Thyroid Gland 318**

- Overactivity of the Thyroid Gland 320

- Thyroid Insufficiency 320

The C Cells of the Thyroid Gland 320

Parathyroid Glands (Epithelial Bodies) 320

- Overactivity of the Parathyroid Glands 321

- Parathyroid Insufficiency 321

### **Adrenal Glands (Suprarenal Glands) 321**

Adrenal Cortex 321

- Adrenal Insufficiency 323

- Adrenal Overactivity 324

Adrenal Medulla 324

### **Islet Apparatus of the Pancreas 325**

- Pancreatic Islet Insufficiency 325

### **The Gonads 327**

### **Other Tissues and Single Cells Secreting Hormones 328**

## **8 The Respiratory System 333**

### **The Path of Oxygen to the Cell: External and Internal Respiration 334**

#### **Organs of the Air Passages 335**

Nasal Cavity and Paranasal Sinuses 335

Pharynx 339

Larynx 339

- Laryngeal Skeleton 339

- Laryngeal Muscles 341

- Laryngeal Mucosa 341

- Voice Production 344

The Windpipe and Bronchial Tree 344

- Windpipe (Trachea) 344

- Bronchial Tree 344

- Mucous Membrane 348

### **Serous Cavities and Membranes of the Chest and Abdomen 348**

#### **Lungs (Pulmones) 348**

Visceral and Parietal Pleura 350

External Structure of the Lung 350

- Hilus of the Lung 350

Internal Structure of the Lung 350

- Pulmonary Vessels 351

- Nerves and Lymph Vessels 352

#### **Ventilation of the Lungs 353**

The Lung and Respiratory Volumes 354

Minute Volume and Respiratory Frequency 354

Alveolar and Dead Space Ventilation 356

#### **Gas Exchange and the Blood-Air Barrier 357**

Gas Exchange in the Lung 357

- = Partial Pressures of the Respiratory Gases. 357

- = Composition of Alveolar Air 358

- = Diffusion of Respiratory Gases 359

~~The Blood–Air Barrier (Alveolocapillary Membrane) 361~~

~~Oxygen Deficiency (Hypoxia, Anoxia) 362~~

~~Artificial Respiration 363~~

~~**The Regulation of Breathing** 363~~

~~Central Regulation of Breathing 363~~

~~Chemical Regulation of Breathing 364~~

~~Nonspecific Respiratory Stimuli 365~~

~~**The Mechanics of Breathing** 365~~

~~Intrapulmonary Pressure 365~~

~~Inspiration 367~~

~~Expiration 367~~

~~Resistance to Breathing 368~~

~~The Work of Breathing 368~~

~~Pulmonary Function Tests 369~~

## **9 The Digestive System 377**

~~**Metabolism, Energy Requirements and Nutrients** 378~~

~~Metabolism 378~~

~~Energy Requirements 379~~

~~– Energy Content of Nutrients 379~~

~~– Energy Requirements at Rest (Basal Metabolism, Basal Metabolic Rate, BMR) 380~~

~~– Energy Requirements during Physical Activity (Excess Metabolism of Exercise) 381~~

~~– Determination of Energy Metabolism 381~~

~~Nutrients 382~~

~~– Proteins 382~~

~~– Fats (Lipids) 382~~

~~– Carbohydrates 383~~

~~– Vitamins 384~~

~~– Minerals (Macrominerals and Trace Minerals) 385~~

~~Antioxidants (Free Radical Scavengers) 386~~

~~Active Substances in Plants 387~~

~~Fiber 389~~

~~**The Digestive Organs** 389~~

~~The Oral Cavity 389~~

~~– The Tongue 391~~

~~– The Teeth (Dentes) 394~~

~~– The Salivary Glands 398~~

~~The Throat (Pharynx) 400~~

~~– The Act of Swallowing (Deglutition) 401~~

~~The Gullet (Esophagus) 402~~

~~The Stomach (Ventriculus, Gaster) 404~~

~~– Function 404~~

~~– Shape and Position 405~~

~~– Mucosa and Muscular Layers 407~~

~~The Small Bowel (Intestinum Tenue, Enteron) 407~~

~~– Function 407~~

~~– Shape and position 409~~

~~– Movements of the Small Intestine 409~~

~~– Mucous Membrane of the Small Bowel 409~~

~~– Gut-associated Lymphatic Tissue (GALT) 413~~

~~The Large Bowel (Intestinum Crassum) 414~~

~~– Function 414~~

~~– Shape and Position 414~~

~~– Mucosa of the Large Intestine 416~~

~~– Movements of the Large Bowel 417~~

~~– Closure of the Anus 418~~

~~Relations of the Peritoneum and Mesenteries of the Abdominal Organs 418~~

~~The Pancreas 421~~

~~– Function 421~~

~~– Shape and Position 422~~

~~– The Pancreatic Islets 423~~

~~The Liver 423~~

~~– Function 423~~

~~– Shape and Position 423~~

~~– Fine Structure of the Liver 426~~

~~The Gallbladder (Vesica Biliaris) and Bile Duct 426~~

~~**Overview of the Digestive Processes** 428~~

~~Fat Digestion 428~~

~~Carbohydrate Digestion 430~~

~~Protein Digestion 431~~

## **10 The Kidneys and Urinary Tract 441**

~~**Role of the Kidneys** 442~~

~~**Overview of Structure and Function of the Kidneys** 442~~

~~**The Kidney (Ren, Nephros)** 443~~

~~Shape and Position 443~~

~~Renal Cortex and Renal Medulla 446~~

~~The Renal Vessels 448~~

~~The Renal Corpuscles and the Glomerular Filter 448~~

~~– Properties of the Glomerular Filter 450~~

~~Glomerular Filtration 450~~

~~– Glomerular Filtration Rate 450~~

~~– Effective Filtration Pressure 451~~

~~– Autoregulation of Renal Blood Flow 452~~

~~Renal Tubules and Collecting Ducts 452~~

~~– Transport Processes in the Renal Tubules 452~~

~~– The Na<sup>+</sup>–K<sup>+</sup> pump (Na<sup>+</sup>, K<sup>+</sup>-ATPase) 454~~

~~– Renin–Angiotensin–Aldosterone Mechanism 455~~

~~– Concentration and Dilution of the Urine 456~~

~~– Concentration of Urine in the Collecting Ducts 456~~

~~– Diuretics 457~~

~~Composition of Urine 457~~

~~**Urinary Tract** 457~~

~~Renal Pelvis 458~~

~~Ureter 458~~

~~Urinary Bladder (Vesica Urinaria) 459~~

~~– Bladder Muscle and Internal Surface 461~~

~~– Muscles of the Ureteral Orifices 462~~

~~– Muscles of the Urethral Orifice 462~~

Urethra 463

- The Male Urethra 463
- The Female Urethra 465

## **11 The Reproductive Organs 471**

### **Function and Structure of the Reproductive Organs 472**

#### **Male Reproductive Organs 472**

Overview 472

Testis (Orchis) 474

- Testosterone Production 474
- Development of Sperm Cells (Spermatogenesis) 475
- Spermatozoa 476

Epididymis 477

Vas Deferens 478

Seminal Vesicles (Vesiculae Seminales) or Seminal Glands (Glandulae Seminales) 478

Prostate Gland 479

Cowper's Glands (Bulbourethral Glands) 481

~~Composition of the Ejaculate 481~~

~~Gastration and Sterilization 481~~

External Male Sex Organs 481

- Scrotal Sac (Scrotum) 482
- Penis (Male Member) 482

~~Erection 484~~

~~Ejaculation 484~~

#### **Female Reproductive Organs 485**

Overview 485

Ovaries 486

- Structure of the Ovary 486
- Development of the Ovum (Oogenesis) and Follicle Maturation 487
- Ovulation 489
- Corpus Luteum 490

The Menstrual Cycle 492

- Fallopian Tube (Uterine Tube, Salpinx) 493

Uterus 494

Vagina 495

External Female Sex Organs (Vulva) 496

- Vestibule (Vestibulum Vaginae), Labia Majora and Minora, and Clitoris 496

The Female Breast (Mamma) and Mammary Gland 497

**Summary 499**

## **12 Reproduction, Development, and Birth 505**

**Germ Cells 506**

**Fertilization 506**

- Sex Determination 509

**Transport through the Uterine Tube and Segmentation 511**

**Implantation and Development of the Placenta (Afterbirth) 513**

Structure of the Placenta 514

Umbilical Cord (Funiculus Umbilicalis) 516

**Development of the Embryo 516**

Derivatives of the Germ Layers 518

Evolution of the Body 519

~~**Development of the Fetus 520**~~

~~Signs of Maturity 522~~

~~Duration of Gestation and Calculation of the Date of Delivery 522~~

~~**Birth 523**~~

~~**Postnatal Development 525**~~

~~Body Length 526~~

~~Body Weight 526~~

~~Physical Proportions 527~~

~~Growth of the Skeleton 528~~

## **13 The Central and Peripheral Nervous Systems 533**

**Classification of the Nervous System 534**

**Role of the Nervous System 534**

**Development of the Nervous System 535**

**Central Nervous System 536**

Development and Organization 536

The Brain (Encephalon) 538

- Cerebrum or Forebrain (Telencephalon) 538

~~= Diencephalon 548~~

~~= Midbrain (Mesencephalon) 550~~

~~= Pons (Bridge) and Cerebellum 550~~

~~= Medulla Oblongata 553~~

~~= Brainstem 555~~

~~= The Electroencephalogram (EEG) 556~~

~~= Sleep and Wakefulness 556~~

Spinal Cord (Medulla Spinalis) 557

- Spinal Nerves 558

- Gray and White Matter of the Spinal Cord 561

~~= Ascending and Descending Tracts of the Spinal Cord 563~~

~~Voluntary Motor Tracts (Pyramidal Tracts) 564~~

~~= Voluntary Motor Tracts of the Head 566~~

~~= Voluntary Motor Tracts of the Trunk and Extremities 566~~

~~= Somatotopic Organization of the Motor Area 567~~

~~Extrapyramidal Motor System 568~~

~~Lesions of the Lower Motoneuron (Flaccid Paralysis) 569~~

~~Lesions of the Upper Motoneuron (Spastic Paralysis) 569~~

~~Spinal Reflexes 570~~

~~= Reflex Arc 570~~

~~= Proprioceptive or Stretch Reflex 570~~

~~= Sensorimotor or Skin Reflexes 572~~

~~= Pathological Reflexes 572~~

Membranes of the Brain and Spinal Cord 573

- Membranes of the Brain 573

- Membranes of the Spinal Cord 574

Cerebrospinal Fluid (CSF) and the Ventricular System 576

- CSF Drainage 578
- Lumbar Puncture 578

Blood Supply of the Brain 578

**Peripheral Nervous System 584**

Peripheral Nerves 584

Ganglia 584

Spinal Nerves 585

Networks of Nerves (Plexus or Plexuses) 585

- Cervical Plexus 586
- Brachial Plexus 586
- Lumbar Plexus 589
- Sacral Plexus 589

Cranial Nerves 589

**14 The Autonomic Nervous System 605**

**Function and Components 606**

**Outline of the System 608**

**Sympathetic Nervous System 609**

Function 609

Structure 610

- Chemical Neurotransmitters 612

Postsynaptic Receptors on Effector Organs 613

**Parasympathetic Nervous System 613**

Function 613

Structure 614

- Chemical Neurotransmitters 614

Cranial Parasympathetic System 614

- Cranial Nerve III (Oculomotor Nerve) 614
- Cranial Nerve VII (Facial Nerve) 615
- Cranial Nerve IX (Glossopharyngeal Nerve) 616
- Cranial Nerve X (Vagus Nerve) 616

Sacral Parasympathetic Outflow 616

**Nervous System of the Intestinal Wall 616**

**15 Sense Organs 623**

**Receptors and Sensory Cells 624**

**The Eye 625**

The Eyeball (Globe, Bulbus Oculi) 625

- Location of the Globe and Structure of its Wall 625
- Anterior Part of the Globe 626

Anterior and Posterior Chamber of the Eye 627

Intraocular (inside the eye) Pressure 628

Lens and the Process of Accommodation 628

Iris and Pupillary Reflexes 629

Cornea 630

- Posterior Part of the Globe 630

Sclera 630

Vascular Tunic (Uvea) 631

Retina 631

Rods and Cones 633

Optic Disk (Discus Nervi Optici) 633

Macula Lutea (Yellow Spot) 634

Eye Ground (Fundus) 635

~~The Optic System 635~~

- ~~Power of Refraction 635~~
- ~~Errors of Refraction 636~~

~~Nearsightedness 636~~

~~Farsightedness 636~~

~~Astigmatism 637~~

~~Visual Acuity 638~~

~~The Visual Pathway 639~~

~~Visual Field Defects 639~~

~~Accessory Structures 641~~

- ~~Eyelids (Palpebrae) 641~~
- ~~Lacrimal Apparatus 641~~
- ~~Extraocular Muscles 642~~

**The Ear 644**

The Organ of Hearing 645

- External Ear 645
- Middle Ear 645
- Inner Ear 648

- ~~Auditory Pathway 648~~
- ~~Mechanism of Hearing 650~~

Hearing Problems 651

The Organ of Equilibrium 651

- ~~Macula of Utricle and Sacculae 651~~
- ~~Acoustic Crest (Crista Ampularis) 652~~

**The Sense of Taste 654**

**The Sense of Smell 655**

**16 The Skin and Its Appendages 663**

**Skin (Cutis) and Subcutaneous Tissue (Tela Subcutanea) 664**

Layers of the Skin 664

- Epidermis 664
- Dermis 666
- Subcutaneous Tissue 667

Sensory Organs of the Skin 667

Tasks of the Skin 667

**Skin Appendages 668**

Glands of the Skin 668

Hair 669

Nails 670