

KEY CONCEPTS IN BIOLOGY



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Medical College

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BIOLOGY

1. Bricks of life – DNA composition

- 1.1. Mechanism of replication and control of DNA quality;
- 1.2. Principles of complementarity;
- 1.3. Functional structure of eukaryotic DNA;
- 1.4. DNA topology: from double helix to chromosome;

2. RNAs diversity

- 2.1. Polymerases as complex enzymes recognizing different types of genes;
- 2.2. Transcription as a dynamic process – initiation, elongation and termination;
- 2.3. Mechanisms of transcription control;
- 2.4. mRNA – structure and its modification;
- 2.5. Alternative splicing – the way to get more!;
- 2.6. Types of introns;
- 2.7. tRNA – structure, specificity;
- 2.8. rRNA – scaffold of ribosomes;
- 2.9. small RNAs – key players in the regulation of replication and transcription (snRNA, Y-RNA, siRNA, shRNA);

3. Gene expression – “from blueprints to the active structure”

- 3.1. Eukaryotic gene structure and its regulatory elements;
- 3.2. Systems of DNA repair;

- 3.3. Understanding of genetic code – how genome is read;
- 3.4. Translation – interplay of RNAs and enzymes;
- 3.5. Protein structures – role of Heat Shock Proteins in acquiring native conformation;
- 3.6. Posttranslational modification and its importance in protein function;
- 3.7. Cellular and secretory proteins;
- 3.8. Protein degradation;

4. Enzymes – cellular machines

- 4.1. Role of enzymes in catalyzing of biological reaction;
- 4.2. Regulation of enzyme activity;
- 4.3. Reaction center and its specificity to substrates;
- 4.4. General types of enzymes;

5. Cell life – circular or linear

- 5.1. Cell as an open thermodynamic system;
- 5.2. Structure and role of biological membranes;
- 5.3. Functional differentiation of membrane proteins;
- 5.4. Cytoskeleton and its role in intercellular connections, cell movement and tissue organization;
- 5.5. Cell junction – interplay of cytoskeleton and extracellular matrix;

- 5.6. *Endoplasmic reticulum – its role in the cell;*
- 5.7. *Golgi apparatus – its functional structure;*
- 5.8. *Golgi network and lysosomes;*
- 5.9. *Native or alien – mitochondria (structure and function);*
- 5.10. *Endocytosis, exocytosis and vesicular transport;*
- 5.11. *Nucleus – its topology and structure;*
- 5.12. *Nucleoli – organization and structure;*
- 6. Metabolism – how the cell obtains energy**
 - 6.1. *Glycolysis – what is it for? (Anaerobic and aerobic – substrates and products);*
 - 6.2. *Krebs cycle – role in the cell and general features;*
 - 6.3. *The respiratory chain and ATP synthesis;*
 - 6.4. *Metabolism of fat;*
 - 6.5. *Metabolism of proteins;*
- 7. Cell communication and signaling**
 - 7.1. *Receptors and signaling cascades – general principles;*
 - 7.2. *Different ligands – different types of communication;*
 - 7.3. *G-protein linked cell surface receptors;*
 - 7.4. *Enzyme linked cell surface receptors;*
 - 7.5. *Ion channels;*
 - 7.6. *Intracellular receptors;*
- 8. Cell division**
 - 8.1. *Meiosis;*
 - 8.2. *Mitosis;*
 - 8.3. *Crossing over;*
 - 8.4. *Recombination;*
 - 8.5. *Basics of inheritance – genetic and biochemical sex determination;*
 - 8.6. *Mitochondrial inheritance;*
- 9. Cancer**
 - 9.1. *Mutagen, clastogen, teratogen and carcinogen – role in carcinogenesis;*
 - 9.2. *Mutation as a source of genetic instability;*
 - 9.3. *Proto-oncogenes and oncogenes;*
 - 9.4. *Origin of cancer – single abnormal somatic cell vs. altered stem cell;*
 - 9.5. *Evolution of cancer – cancer stem cells;*
 - 9.6. *Involvement of immune system in cancer cells spread;*
- 10. Microbiology**
 - 10.1. *Virus structure;*
 - 10.2. *Viral life cycle;*
 - 10.3. *Human diseases caused by viruses;*
 - 10.4. *Prokaryotic cell: differences between prokaryotic and eukaryotic cells;*
 - 10.5. *Bacteria: structure, growth and physiology, genetics;*
 - 10.6. *Human diseases caused by bacteria;*
 - 10.7. *Antibiotics mode of action;*
 - 10.8. *Human diseases caused by parasites (malaria, worms, flukes, ectoparasites);*
- 11. Specialized eukaryotic cells/tissues/organs/systems**
 - 11.1. Nerve cell structure (axon, dendrites, myelin sheath, oligodendrocytes, Schwann cells, nodes of Ranvier)**
 - 11.1.1. *Synapse (synaptic activity, transmitter molecules);*
 - 11.1.2. *Resting potential (electrochemical gradient, ions involved);*
 - 11.1.3. *Action potential (threshold, all-or-none rule, sodium–potassium pump);*
 - 11.2. Nervous System – organization of vertebrate nervous system**
 - 11.2.1. *Sensor and effector neurons;*

- 11.2.2. *Cerebral cortex (cortical representation of sensory and motor functions);*
- 11.2.3. *Reflexes (feedback loop, reflex arc, effects on flexor and extensor muscles, roles of spinal cord, brain);*
- 11.2.4. *Sympathetic and parasympathetic nervous systems (functions, neurotransmitters used, antagonistic control);*
- 11.3. Muscle cell structure (skeletal, smooth, and cardiac muscle; striated versus non-striated)**
- 11.3.1. *Sarcomeres (general structure – “I” and “A” bands, “M” and “Z” lines, “H” zone);*
- 11.3.2. *Organization of contractile elements (thin/thick actin and myosin filaments, cross bridges, sliding filament model);*
- 11.3.3. *Calcium regulation of contraction, sarcoplasmic reticulum, role of troponin and tropomyosin;*
- 11.3.4. *Nervous control (motor neurons, neuromuscular junctions, motor end plates, voluntary and involuntary muscles);*
- 11.4. Skeletal structure (names of major bones, specialization of bone types, joint structure)**
- 11.4.1. *Cartilage (structure, function);*
- 11.4.2. *Ligaments, tendons;*
- 11.4.3. *Bone structure (osteoblasts, osteoclasts, protein matrix, calcium);*
- 11.5. Epithelial cells (simple epithelium, stratified epithelium, localization in various organs)**
- 11.6. Endothelial cells**
- 11.7. Connective tissue cells (major tissues and cell types, fiber types, loose versus dense, extracellular matrix)**
- 11.8. Endocrine system – definition of an endocrine gland, hormone**
- 11.8.1. *Function of the endocrine system (terms: autocrine, paracrine, and endocrine control, concept of negative feedback loop regulation);*
- 11.8.2. *Major endocrine glands (names, locations, products – full names and their abbreviations);*
- 11.8.3. *Major types of hormones, their chemical structures;*
- 11.8.4. *Transport of hormones, their specificity;*
- 11.8.5. *Cellular localization of hormone receptors depending on their structure;*
- 11.8.6. *Cellular mechanisms of hormone action;*
- 11.8.7. *Hypothalamus-pituitary gland-peripheral gland axis;*
- 11.8.8. *Hormones regulating calcium homeostasis;*
- 11.8.9. *Diseases resulting from inappropriate hormone levels;*
- 11.9. Sensory reception and processing**
- 11.9.1. *Skin, proprioceptive and somatic sensors;*
- 11.9.2. *Olfaction, taste;*
- 11.9.3. *Hearing (ear structure, mechanism of hearing);*
- 11.9.4. *Vision (eye structure, light receptors, visual image processing);*
- 11.10. Circulatory system – functions of the cardiovascular system**
- 11.10.1. *Four-chambered heart (structure, function);*
- 11.10.2. *Pacemaker cells, impulse conduction system;*

- 11.10.3. *Systolic and diastolic pressure (pressure in the left ventricle and aorta, closing and opening of valves);*
- 11.10.4. *Pulmonary and systemic circulation;*
- 11.10.5. *Arterial and venous systems (arteries, arterioles, venules, veins);*
- 11.10.6. *Capillary beds (mechanisms of gas and solute exchange);*
- 11.11. **Blood – composition**
- 11.11.1. *Erythrocyte production and destruction (spleen, bone marrow), hematocrit and erythropoietin;*
- 11.11.2. *Hemoglobin, biochemical characteristics of hemoglobin, details of oxygen/carbon dioxide transport;*
- 11.11.3. *Coagulation, clotting mechanisms, role of the liver in clotting factors production;*
- 11.11.4. *Origin and composition of lymph;*
- 11.12. **Immune system – innate and adaptive systems**
- 11.12.1. *White blood cells, their structure and basic functions;*
- 11.12.2. *T and B lymphocytes (cellular vs. humoral immunity);*
- 11.12.3. *Other cells of the immune system (macrophages, mast cells, dendritic cells);*
- 11.12.4. *Central and peripheral lymphatic tissues (bone marrow, thymus, spleen, lymph nodes);*
- 11.12.5. *Basic aspects of innate immunity and inflammatory response;*
- 11.12.6. *Concepts of antigen and antibody;*
- 11.12.7. *Structure of antibody molecule;*
- 11.12.8. *Mechanism of stimulation by antigen, use of vaccination;*
- 11.13. **Digestive system – general organization and function**
- 11.13.1. *Saliva as source of enzymes;*
- 11.13.2. *Stomach: structure (gross), production of digestive enzymes, gastric juice, protection against self-destruction;*
- 11.13.3. *Liver: structure (gross), role in nutrient metabolism, blood glucose level regulation, production of bile;*
- 11.13.4. *Bile composition and function;*
- 11.13.5. *Pancreas: structure (gross), enzymes produced;*
- 11.13.6. *Small intestine: structure (anatomic subdivisions), function and structure of villi, production of enzymes, absorption of food molecules;*
- 11.13.7. *Large intestine: structure (gross);*
- 11.13.8. *Muscular control: peristalsis, sphincter muscles;*
- 11.14. **Excretory system – kidney structure, nephron structure (glomerulus, Bowman’s capsule, proximal tubule, loop of Henle, distal tubule, collecting duct)**
- 11.14.1. *Formation of urine (glomerular filtration, secretion and reabsorption of solutes, concentration of urine, countercurrent multiplier mechanism);*
- 11.14.2. *Roles of kidneys in homeostasis: blood pressure, osmoregulation, acid–base balance, forms of soluble nitrogenous waste excreted;*
- 11.14.3. *Urine storage and elimination (micturition reflex);*
- 11.15. **Respiratory system – general structure and function**
- 11.15.1. *Gas exchange, partial pressures of oxygen and carbon dioxide;*
- 11.15.2. *Protection against disease, particulate matter;*

11.15.3. *Breathing mechanisms (diaphragm, rib cage, pleural pressure);*

11.16. **Skin system – structure (layer differentiation, cell types, tissue types [epithelial, connective]and functions in homeostasis (vasoconstriction and vasodilation in surface capillaries)**

11.16.1. *Nails and hair;*

11.17. **Reproductive system – male and female reproductive structures and their functions (gonads, genitalia, differences between male and female structures)**

11.17.1. *Gametogenesis by meiosis;*

11.17.2. *Ovum and sperm (differences in formation, morphology);*

11.17.3. *Reproductive sequence (fertilization, implantation, development, birth);*

12. Embryogenesis

12.1. *Stages of early development (order and general features of each: fertilization, cleavage, blastula formation, gastrulation);*

12.2. *Formation of primary germ layers (endoderm, mesoderm, ectoderm);*

12.3. *Neurulation;*

12.4. *Major structures arising out of primary germ layers.*

RECOMMENDED TEXTBOOKS

BIOLOGY

*Recommended international textbooks –
respective chapters from:*

1. **Biology: A Global Approach, by N.A. Campbell et al.** Global Edition (English), Prentice Hall; 11th edition (2017), ISBN-10: 9781292170435
2. **Molecular biology of the cell, B. Alberts et al.** Norton & Company; 6th Revised edition (2014); ISBN-10: 0815344643