BIOLOGY

MOLECULAR BIOLOGY: DNA AND PROTEIN SYNTHESIS

DNA Structure and Function

A. DNA Structure and Function

1. Double-helix structure
2. DNA composition (purine and pyrimidine bases, deoxyribose, phosphate)
3. Base-pairing specificity, concept of complementarity
4. Function in transmission of genetic information

B. DNA Replication

1. Mechanism of replication (separation of strands, specific coupling of free nucleic acids, enzymes required)
2. Semiconservative nature of replication

C. Repair of DNA

1. Repair during replication
2. Repair of mutations

D. Recombinant DNA Techniques

1. Restriction enzymes
2. Hybridization
3. Gene cloning
4. PCR

Protein Synthesis

A. Genetic Code

1. Typical information flow (DNA → RNA → protein)
2. Codon–anticodon relationship, degenerate code
3. Missense and nonsense codons
4. Initiation and termination codons (function, codon sequences)

B. Transcription

1. mRNA composition and structure (RNA nucleotides, 5′ cap, poly-A tail)
2. tRNA and rRNA composition and structure (e.g., RNA nucleotides)
3. Mechanism of transcription (RNA polymerase, promoters)

C. Translation

1. Roles of mRNA, tRNA, and rRNA; RNA base-pairing specificity
2. Structure and role of ribosomes

MOLECULAR BIOLOGY: EUKARYOTES

A. Eukaryotic Chromosome Organization

1. Chromosomal proteins
2. Telomeres, centromeres
3. Diseases resulting from abnormal chromosome number

B. Control of Gene Expression in Eukaryotes

1. Transcription regulation
2. DNA binding proteins, transcription factors
3. Cancer as a failure of normal cellular controls, oncogenes, tumor suppressor genes
4. Posttranscriptional control, basic concept of splicing (introns, exons)

ENZYMES AND METABOLISM

A. Enzyme Structure and Function

1. Function of enzymes in catalyzing biological reactions
2. Reduction of activation energy
3. Substrates and enzyme specificity
4. Control of enzyme activity

B. Basic Metabolism

1. Glycolysis (anaerobic and aerobic, substrates and products)
2. Krebs cycle (substrates and products, general features of the pathway)
3. Electron transport chain and oxidative phosphorylation (substrates and products, general features of the pathway)
4. Metabolism of fats and proteins

GENETICS

A. Mendelian Concepts

1. Phenotype and genotype (definitions, probability calculations, pedigree analysis)
2. Meaning of terms: gene, locus, allele (single, multiple)
3. Homozygosity and heterozygosity
4. Recessiveness
5. Complete dominance
6. Codominance
7. Incomplete dominance, penetrance,

B. Meiosis and Genetic Variability

1. Significance of meiosis
2. Important differences between meiosis and mitosis
3. Segregation of genes - crossovers
4. Sex-linked characteristics
    a. sex determination
    c. mitochondrial inheritance
5. Mutation
    a. general concept of mutation
    b. types of mutations (random, translation error, transcription error, base substitution, insertion, deletion, frameshift)
    c. chromosomal rearrangements (inversion, translocation)
    d. advantageous versus deleterious mutation
    e. inborn errors of metabolism
    f. relationship of mutagens to carcinogens

MICROBIOLOGY

A. Virus Structure
B. Viral life cycle
C. Human diseases caused by viruses
D. Prokaryotic Cell: differences between prokaryotic and eukaryotic cells
E. Bacteria: structure, growth and physiology, genetics
F. Human diseases caused by bacteria
G. Antibiotics mode of action
H. Human diseases caused by parasites (malaria, worms, flukes, ectoparasites)
I. Life cycles of most common parasites

EUKARYOTIC CELL

A. Plasma membrane
B. Membrane-bound organelles
C. Enzyme contents of lysosomes
D. Functions of Golgi apparatus
E. Differences between rough and smooth reticulum
F. Cell nucleus and nucleoli
G. The cytoskeleton
H. Cell cycle and mitosis
I. Cell junctions
J. Active vs. passive transport through membranes
K. Exocytosis and endocytosis
L. Cell death (apoptosis vs. necrosis)

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SPECIALIZED EUKARYOTIC CELLS AND TISSUES

A. Neural

1. Nerve cell structure (axon, dendrites, myelin sheath, oligodendrocytes, Schwann cells, nodes of Ranvier)
2. Synapse (synaptic activity, transmitter molecules)
3. Resting potential (electrochemical gradient, ions involved)
4. Action potential (threshold, all-or-none rule, sodium–potassium pump)
5. Excitatory and inhibitory nerve fibers (importance of summation, firing frequency)

B. Muscle Cell

1. Structural characteristics of skeletal, smooth, and cardiac muscle; striated versus nonstriated
2. Sarcomeres (general structure - “I” and “A” bands, “M” and “Z” lines, “H” zone)
3. Organization of contractile elements (thin/thick actin and myosin filaments, cross bridges, sliding filament model)
4. Calcium regulation of contraction, sarcoplasmic reticulum, role of troponin and tropomyosin
5. Nervous control (motor neurons, neuromuscular junctions, motor end plates, voluntary and involuntary muscles)

C. Skeletal System

1. Skeletal structure (names of major bones, specialization of bone types, joint structure)
2. Cartilage (structure, function)
3. Ligaments, tendons
4. Bone structure (osteoblasts, osteoclasts, protein matrix, calcium)

D. Other Specialized Cell Types

1. Epithelial cells (simple epithelium, stratified epithelium, localization in various organs)
2. Endothelial cells
3. Connective tissue cells (major tissues and cell types, fiber types, loose versus dense, extracellular matrix)

NERVOUS AND ENDOCRINE SYSTEMS

A. Endocrine System: Hormones

1. Definition of an endocrine gland, hormone
2. Function of the endocrine system (terms: autocrine, paracrine, and endocrine control, concept of negative feedback loop regulation)
3. Major endocrine glands (names, locations, products – full names and their abbreviations)
4. Major types of hormones, their chemical structure
5. Hypothalamus-pituitary gland- peripheral gland axis
6. Transport of hormones, their specificity
7. Cellular localization of hormone receptors depending on their structure
8. Cellular mechanisms of hormone action
9. Hormones regulating calcium homeostasis
10. Diseases resulting from inappropriate hormone levels

C. Nervous System: Structure and Function

1. Organization of vertebrate nervous system
2. Sensor and effector neurons
3. Cerebral cortex (cortical representation of sensory and motor functions)
4. Reflexes (feedback loop, reflex arc, effects on flexor and extensor muscles, roles of spinal cord, brain)
5. Sympathetic and parasympathetic nervous systems (functions, neurotransmitters used, antagonistic control)

D. Sensory Reception and Processing

1. Skin, proprioceptive and somatic sensors
2. Olfaction, taste
3. Hearing (ear structure, mechanism of hearing)
4. Vision (eye structure, light receptors, visual image processing)

CIRCULATORY, LYMPHATIC, AND IMMUNE SYSTEMS

A. Circulatory System

1. Functions of the cardiovascular system
2. Four-chambered heart (structure, function)
3. Pacemaker cells, impulse conduction system
4. Systolic and diastolic pressure (pressure in the left ventricle and aorta, closing and opening of valves)
5. Pulmonary and systemic circulation
6. Arterial and venous systems (arteries, arterioles, venules, veins)
7. Capillary beds (mechanisms of gas and solute exchange)
8. Composition of blood
    a. erythrocyte production and destruction (spleen, bone marrow)
    b. hematocrit and erythropoietin
    c. coagulation, clotting mechanisms, role of the liver in clotting factors production
9. Oxygen and carbon dioxide transport by blood
    a. hemoglobin, biochemical characteristics of hemoglobin, details of oxygen transport
10. Origin and composition of lymph

B. Immune System: Innate and Adaptive Systems

1. White blood cells, their structure and basic functions
    a. characteristics of T and B lymphocytes (cellular vs. humoral immunity)
    b. other cells of the immune system (macrophages, mast cells, dendritic cells)
2. Central an peripheral lymphatic tissues (bone marrow, thymus, spleen, lymph nodes)
3. Basic aspects of innate immunity and inflammatory response
4. Concepts of antigen and antibody
5. Structure of antibody molecule
6. Mechanism of stimulation by antigen, use of vaccination

DIGESTIVE AND EXCRETORY SYSTEMS

A. Digestive System

1. Saliva as source of enzymes
2. Stomach: structure (gross), production of digestive enzymes, gastric juice, protection against self-destruction
3. Liver: structure (gross), role in nutrient metabolism, blood glucose level regulation, production of bile
4. Bile composition and function
5. Pancreas: structure (gross), enzymes produced
6. Small intestine: structure (anatomic subdivisions), function and structure of villi, production of enzymes, absorption of food molecules
7. Large intestine: structure (gross)
8. Muscular control: peristalsis, sphincter muscles

B. Excretory System

1. Roles in homeostasis: blood pressure, osmoregulation, acid–base balance, forms of soluble nitrogenous waste excreted
2. Kidney structure
3. Nephron structure (glomerulus, Bowman's capsule, proximal tubule, loop of Henle, distal tubule, collecting duct)
4. Formation of urine (glomerular filtration, secretion and reabsorption of solutes, concentration of urine, countercurrent multiplier mechanism)
5. Urine storage and elimination (micturition reflex)

RESPIRATORY SYSTEM

A. Respiratory System

1. General structure and function
    a. gas exchange, partial pressures of oxygen and carbon dioxide
    b. protection against disease, particulate matter
2. Breathing mechanisms
    a. diaphragm, rib cage, pleural pressure

SKIN SYSTEM

A. Skin System

1. Structure (layer differentiation, cell types, tissue types (epithelial, connective)
2. Functions in homeostasis (vasoconstriction and vasodilation in surface capillaries)
3. Nails and hair

REPRODUCTIVE SYSTEM AND DEVELOPMENT

A. Reproductive System

1. Male and female reproductive structures and their functions (gonads, genitalia, differences between male and female structures)
2. Gametogenesis by meiosis
3. Ovum and sperm (differences in formation, morphology)
4. Reproductive sequence (fertilization, implantation, development, birth)

B. Embryogenesis

1. Stages of early development (order and general features of each: fertilization, cleavage, blastula formation, gastrulation)
2. Formation of primary germ layers (endoderm, mesoderm, ectoderm)
3. Neurulation
4. Major structures arising out of primary germ layers

C. Developmental Mechanisms

1. Cell specialization

c. tissue types

2. Programmed cell death

Recommended international textbook – respective chapters of ***Biology*** *by E.P. Solomon, Ch Martin, D.W. Martin L.R. Berg, 10th ed. 2014, Cengage Learning* ISBN-10**:** 1285423585