Biology MSc 2022

A- Questions: General Topics

1. Basic structural and functional units of living organisms.
Key points: General properties and hierarchical levels of organization in living systems. The evolution of the pro- and eukaryotic cells; general and specific components, and their functional roles (cell wall, membranes and compartments, transport processes, cytoskeleton and cell movements). The development of multicellular organisms, and unique characteristics of different groups.

2. Molecular carriers of inheritance. The eukaryotic cell cycle and its regulation. The reproductive life cycle.
Key points: Structural and functional properties of the hereditary material (DNA, genes). Cell cycle phases, checkpoints, and regulation. Determination, differentiation, totipotency, pluripotency, stem cells. Sexual, asexual, and parasexual modes of reproduction. Vegetative and generative stages in plant life.

3. Development of the gene concept. Basic concepts and laws of viral, bacterial and eukaryotic genome organization.
Key points: The concept and structure of the gene. Relationship between genotype and phenotype. Mutations and repair mechanisms. The concept and organization of the genome. Relationships (contradictions) between genome sizes, and the number of chromosomes and genes at different phylogenetic levels of living organism. Modes, rate, direction, and evolutionary significance of genome changes. The selfish gene, and group selection.

4. Regulation of pro- and eukaryotic gene functions.
Key points: The operon model (activators, repressors, regulatory sequences, the principle of positive and negative regulation). Multilevel regulation of eukaryotic gene functions (chromatin rearrangement, nucleosome structure, cis- and trans-elements). “Normal” and “alternative” pathways of mRNA maturation.

5. The flow of biological information.
Key points: The molecular basis and regulation (post-transcription and post-translational) of information storage (the genetic code) and information flow (the central dogma). Gene silencing. Molecular messengers in communication between living organisms, forms of cell-to-cell communication, plant and animal hormones, neurons and glial cells, levels of neural tissue organization, synapses, molecular receptors, action potential, organization of intracellular signalling systems.

6. Biological membranes.
Key points: Compartmentalization, membrane models, membrane functions, channels and transport systems, biological properties of endomembranes, membrane potentials and changes, ligand- and voltage-gated ion channels. Various membrane transport processes (regulated, transmembrane, vesicular) in cells and their physiological roles.

7. Signalling pathways.
Key points: Signalling systems in animal and plant cells, membrane-bound and independent signalling, molecular receptors, G-proteins, enzyme-linked receptors, cyclic nucleotides and their role in signalling, protein phosphorylation cascades, Ca^{2+} ions as signal molecules.

8. Structural skeletal elements in the living world - the dynamic cytoskeleton.
Key points: Outer and inner skeleton, skeletal components, organization of microbes (bacteria and fungi) and plant skeletal elements, tissue specificity and organization of animal structural proteins, skeletal proteins, structured water, constant and variable skeletal elements, cell skeletal changes during cell division. Evolutionary origin of the cytoskeleton.

9. Biological rhythms.
Key points: Light as a regulator of the living world, classification of biological rhythms, short rhythms, circadian rhythms, sexual cycles, the regulation of flowering, annual rhythms, hormonal regulation of rhythms, clock genes. Conserved mechanisms of biological time perception. Cycles and rhythms in the ecophysiological functions of plants, daily and seasonal changes and their regulatory mechanisms. Senescence and programmed cell death.

10. The circulation of matter and energy in living organisms and the living world.
Key points: Closed and open systems. Autotrophic and heterotrophic organisms. Characteristics of substance uptake, transport and release. Aerobic and anaerobic respiration. The cycle of biogenic elements. Adaptation of living organisms to extreme living conditions. Acclimatization and adaptation aspects of plant carbon-, water- and nutrient-cycling, resource utilization, functional types and their adaptive values.

11. Aims and tools of biotechnology, genetically modified organisms.
Key points: Milestones in the development of biotechnology and the interdisciplinary connections among fields (green, red, white, gray). The aims and tasks of traditional recombinant DNA technology. System-biology approach in biotechnology, the genomic approach. Creation and use of transgenic organisms (microbes, plants and animals), and their importance in fundamental research and in biotechnology. Safety, legal and ethical questions associated with genetically modified organisms (GMOs).

12. Levels of biological hierarchy.
Key points: The levels of the supraindividual organization (individual, population, community, assemblage, association, biocoenosis, ecosystem); synbiological research fields related to each level, and their key questions; environmental and nature protection at each level.

13. Interactions of organisms and their anthropogenic environment.
Key points: Pollutants and sources, impacts, treatment, prevention, alternative energy sources (technical background, potential, capacity, environmental load); outstanding international conventions for the protection of water and air quality. Relevance of on Botanical, zoological, nature conservation and community organization aspects of environmental protection. Ecological economics and biodiversity (guiding principles, axioms, sustainable development).

14. Biodiversity and regulatory factors, nature conservation strategies.
Key points: Biodiversity (levels, measurement and monitoring, indicators, diversity crisis, global distributions, species richness). Natural and human disturbance, fragmentation, species, population, nature conservation at community and habitat levels, area-based biodiversity protection (types of protected areas, conservation management, restoration, rehabilitation, recultivation). Legal aspects of nature conservation, international conventions.

15. Evolutionary, ecological and biogeographical causes of the spread of organisms.
Key points: Areas, area systems, dispersion, dispersal, fluctuation, expansion, regression, vicariance. Endemic, autochthonous, and relict species. The effects of continental drift, ice ages and climate change, the relationship between climate and vegetation, natural and anthropogenic climate change. The role of climate in the distribution of flora (climate diagrams, climate types, vegetation zones). Research methods and main results of historical biogeography.

B- Questions: Molecular Biology Specialization

1. The most important milestones in virological research from the beginning to the present day. The general structure of viruses, nomenclature, basic groups.
Key points: Describe the main milestones in virological research and how our knowledge of viruses has evolved. Describe how viruses are structured, their morphology and symmetry; what their most important components are. Characterize and group the viruses according to their nucleic acids.

2. Description of viral replication mechanisms, principles of Baltimore grouping, and characterization of groups.
Key points: Describe the Baltimore classification, describe the replication schemes within the groups, characterize the replication mechanisms of viruses according to their genetic material type.

3. The role of bioinformatics in biological and medical sciences
Key points: Bioinformatic data and databases, interoperability of databases and their applications, nucleic acid-based research possibilities - the benefits of sequence-based analysis, the development and significance of genomic tools and artificial intelligence in bioinformatics.

4. Mutagenesis. Mutations and repair
Key points: Mutagenesis and the use of mutations in the field of modern genetics. Forward and reverse genetics, mutagenesis, and genetic analysis. Model systems in genetics.

5. Developmental pattern formation, body plan, morphogenesis, epigenetics.
Key points: Development and evolution. Homeosis. The genetic toolkit. Model systems in developmental biology and evolution.

6. Biofilms. Microbial Interactions
Key points: Genetics and mechanism of bacterial and fungal interactions. Conjugation. Mycotoxins, antibiotics, and their interactions.

7. The 'omics' -sciences. Transcriptomics, Proteomics, Metabolomics
Key points: RNA analysis, Non-coding RNAs, DNA-Chip, Protein analysis, Mass spectrometry, HPLC. Interactions of components of biological systems, multigenic interactions, biological resistance (gene to gene hypothesis).

8. Evolution of the immune system and innate immunity
Key points: Development of the immune system through model organisms. Cellular and humoral components of innate immunity. Receptors, grouping, and signalling pathways of innate immunity. The process of inflammation.

9. Acquired immunity, genetics of immunity.
Key points: Relationships between the humoral and cellular immune responses. The structure, function, and genetics of the immunoglobulin light and heavy chains. The role of "junctional diversity" and hypermutability. Immunostimulators. Antibody type switching, allele exclusion, MHC structure, and role. T-cell receptors and B-cell receptors. Main features of immune regulatory processes. Allergy. Vaccines.

10. Immunobiological techniques
Key points: Antigens, Structure, and Production of Antibodies, Use of Antigen-Antibody Interactions in modern Life Sciences, Western Blot, ELISA, Immunohistochemistry, Immunofluorescence labelling, Flow Cytometry.