SCOPE OF THE QUALIFICATION EXAM - BIOLOGICAL SCIENCES

Doctoral School of Exact and Natural Sciences

The scope of the qualification exam will be related to the candidate's master's thesis topic and future doctoral project. The candidate will receive 3 questions and must answer 2 of them.

SYSTEMATICS AND EVOLUTION

1. Endosymbiosis in evolution (hypotheses, evidence, evolutionary role of endosymbiosis).
2. Characteristic features of prokaryotes.
3. Characteristics of eukaryotic microorganisms.
4. Horizontal gene transfer and its role in evolution.
5. Major stages of plant evolution.
6. Major stages of animal evolution.
7. Reproductive strategies and adaptations of fungi.
8. Analogous and homologous traits – definitions and examples.
9. Coevolution – significance and examples.
10. Mass extinctions in Earth's history – causes and consequences.
11. Systematic position of *Homo sapiens* and major stages of anthropogenesis.
12. Theory of evolution: Mendelian and non-Mendelian inheritance, adaptive radiation with examples.
13. Types of natural selection with examples.
14. Mechanisms of evolution: mutations, non-random mating, gene flow, genetic drift, and natural selection.
15. Speciation and species concepts.

ORGANISMAL ECOLOGY

1. Population dynamics models – analysis of mathematical models (e.g., Lotka-Volterra, metapopulation models) in ecological studies.
2. Mechanisms of ecological succession – comparison of primary and secondary succession and the influence of keystone species on ecosystem changes.
3. Phenotypic plasticity and ecological adaptations – the role of plasticity in organismal adaptation to changing environments.
4. Fate and transformation of pollutants in ecosystems – bioaccumulation, biomagnification, and degradation of toxic substances in aquatic and terrestrial environments.
5. Trophic efficiency and trophic pyramids – functioning principles and energy efficiency.
6. Ecosystem functioning in the Anthropocene – impact of climate change and habitat fragmentation on ecosystem structure.
7. Population genetics in conservation ecology – importance of genetic diversity in endangered species protection.
8. Microbiome and organismal ecology – impact of symbiosis with microorganisms on organisms, populations, and ecosystems.
9. Impact of invasive species on ecosystems – mechanisms of spread and control methods.
10. Urban ecosystems as new habitats – adaptations of flora and fauna to urban conditions.

11. Ecology of interspecies interactions – antagonistic and non-antagonistic interactions with examples.
12. Concept of sustainable development – definition, goals, and challenges.
13. Levels of biodiversity: alpha, beta, and gamma – definitions, significance, and influencing processes.
14. Role of vegetation in biogeochemical cycles – impact of vegetation cover changes on carbon and nitrogen cycles.
15. Limiting factors in the environment and the concept of ecological niche – biotic and abiotic factors, competitive exclusion principle.

CELL BIOLOGY

1. Nucleus: chromatin and nuclear envelope structure, types of nuclear membrane transport.
2. Mitochondria: structural and molecular organization and functions.
3. Intracellular and extracellular protein transport – mechanisms and biological significance.
4. Plastids: structural and molecular organization and functions.
5. Cytoskeleton – structure, regulation, and functions.
6. Biological membranes: structure, functions, and membrane transport.
7. Phases and regulatory mechanisms of the cell cycle.
8. Meiosis and gametogenesis in animals and plants.
9. Embryonic and induced stem cells: derivation and applications.
10. Phases and regulatory mechanisms of mitosis.
11. Programmed cell death – molecular mechanisms and biological significance.
12. Cytokinesis in various cell types.
13. Cell communication – signaling pathways, types of junctions, extracellular matrix.
14. Animal and plant tissues – types, structure, and biological roles.

BIOCHEMISTRY AND BASIC TECHNIQUES

1. Phosphorylation and its types with process examples.
2. Proteins – structural levels, modifications, and functions.
3. Enzymes – classification, structure, and function.
4. Structure and function of nucleic acids: DNA and RNA.
5. Genetic mapping.
6. Genetic analysis of metabolic pathways.
7. Lipids – types and biological functions.
8. Liquid chromatography and collision-induced dissociation mass spectrometry (LC-MS-MS/MS).
9. Methods for identifying proteins and peptides and differential protein expression analysis.
10. Cellular respiration and its types.
11. Photosynthesis – stages, modifications, and biological significance.
12. Structure of cell walls in Gram-positive and Gram-negative bacteria.
13. Metabolism – basic concepts and examples.
14. Chemical structure and types of viruses.

GENETICS AND BASIC TECHNIQUES

1. Mendelian inheritance (Mendel's laws) and deviations from them.
2. Epigenetic modifications – definition, types, and biological significance.
3. Complementation in diploid organisms (*D. melanogaster*) and haploid organisms (*S. cerevisiae*).

4. Human genetics: trait determination, genetic diseases, pedigree analysis.
5. Gene structure in prokaryotes and eukaryotes.
6. Mutations as a source of genetic variation – types of mutations.
7. Inheritance of linked genes – types and examples.
8. Genetic code and codon-anticodon interaction rules.
9. Mutation repair mechanisms.
10. Suppression and reversion of mutations.
11. Horizontal gene transfer.
12. Regulation of gene expression in bacteria – examples of the lac and trp operons in *E. coli*.
13. Replication, transcription, and translation – stages, enzymes, biological significance.
14. Molecular analysis techniques of RNA (e.g., primer extension, RNA-oligonucleotide duplex cleavage by RNase H).
15. Methods for determining biochemical activity of RNA-degrading enzymes, 3' end analysis.

BASIC METHODS IN BIOLOGICAL RESEARCH

1. Principles of nucleic acid sequencing techniques: Sanger method and NGS (Illumina, PacBio, nanopore sequencing).
2. "Omics" analyses – types, applications, limitations.
3. Basic reporter genes.
4. Gene conjugation into plasmid vectors using ligation and alternative methods (e.g., SLIC, GATEWAY).
5. PCR and qPCR reactions and their applications in molecular biology.
6. Reverse transcription.
7. Cytogenetic methods and molecular diagnostics of human genetic diseases.
8. Yeast and bacterial transformation methods.
9. Southern and Northern blot techniques.
10. Example protein analysis methods – immunocytochemistry and Western blot.
11. Genome modification methods using CRISPR/Cas.
12. Integrative transformation methods (DNA delivery into cells) such as biolistic bombardment, electroporation, PEG, lipofection, *Agrobacterium* use, microinjection, glass beads, etc.
13. Principles and types of light microscopy (including fluorescence microscopy).
14. Principles of electron microscopy.
15. Plasmids in molecular biology/biotechnology – structure and applications.
16. Cell line and organism culture in the laboratory – methods, purposes, media components.
17. Gene cloning in bacteria – plasmid and vector structure.
18. Nucleic acid modifying enzymes and their applications.
19. Restriction enzymes and their applications.
20. Vaccine development methods.
21. Biological methods of wastewater treatment.
22. Methods of heterologous gene expression and recombinant protein purification (affinity chromatography, immunoprecipitation).
23. Methods for studying protein-protein interactions.
24. Phylogenetic reconstruction methods.
25. Modern methods in ecological research (e.g., Geographic Information Systems (GIS), telemetry).
26. Methods for estimating biodiversity.
27. Methods of biodiversity conservation.
28. Methods of biodiversity monitoring in *in situ* research.
29. Principles of experimental design in environmental studies, with a focus on long-term experiments.