

LIST OF ENTRANCE EXAM QUESTIONS

FOR THE INTERNATIONAL MASTER'S DEGREE PROGRAM

ITMO

BIOINFORMATICS AND SYSTEMS BIOLOGY

Please note: At the entrance exam an applicant chooses **one track** and gets two questions (one biological and one computational) from the corresponding question list.

Track 1. Data Analysis in Biology

(suitable for applicants with biological, medical or related backgrounds)

1. Biology

1. General features of prokaryotic and eukaryotic cells structure and functioning.
2. Catalysis and biosynthesis. Catabolic and anabolic pathways in the cell's metabolism. Energy metabolism. ATP. Photosynthesis.
3. Structure and function of DNA. Chromosomal DNA and its packaging. Global structure of chromosomes.
4. Human genome. Genome sequencing projects. Population genetics.
5. Epigenetics. Mechanism of epigenetic regulation.
6. DNA replication in prokaryotes and eukaryotes. DNA polymerases.
7. Transcription in prokaryotes and eukaryotes. Types of prokaryotic and eukaryotic RNA polymerases. Transcription factors.
8. RNA processing in eukaryotes. Splicing, alternative splicing. Trans-splicing, self-splicing introns.
9. Translation in prokaryotes and eukaryotes. Ribosome. Translation factors. Folding and chaperons. Post-translational modifications of proteins.
10. The eukaryotic cell cycle. Mitosis and meiosis.
11. Cell membrane. Composition of the membrane. Membrane proteins. Principles of membrane transport. Carrier proteins and active membrane transport. Ion channels.
12. Molecular technologies. Polymerase chain reaction. Restriction enzymes. Genome editing.
13. General principles of cell signaling. Main signaling pathways and molecules.
14. The immune systems: innate and adaptive. Organs and cells of the immune system. Antibodies. Vaccines.
15. DNA repair. Cell cycle checkpoints. Programmed cell death (apoptosis).

2. Mathematics and Programming in Python

1. Prime and composite numbers. Divisibility. Infinitude of primes. Fundamental theorem of arithmetics. Greatest common denominator and lowest common multiple.
2. Degree with a rational exponent. Exponential function. Logarithm. Its definition and properties.
3. Trigonometric functions. Their definitions and properties. Vector and scalar product in two-dimensional and three-dimensional space.
4. Principle of mathematical induction. Bernoulli inequality. Arithmetical and geometrical progressions, general term formula and sum formula.
5. Polynomials in one variable. Vieta's formulas. Number of roots of a polynomial.
6. Python Interpreter. Using Python interactively. Running Python programs.
7. Numbers in Python. Operations with integers. Operations with real numbers. Comparison operations.
8. Strings in Python. Subsetting. Searching for substrings. Lists.
9. Conditional operator in Python. Logical operations. Loops.
10. Functions in Python. Defining and calling functions. Recursive functions. Example

RECOMMENDED READING

1. Biology

1. Alberts B, et al. Molecular Biology of the Cell. Garland Sciences, ed.V or higher.
2. Krebs JE, et al. Lewin's Genes. Jones & Bartlett Learning; ed.X or higher.
3. Pollard TD, et al. Cell Biology.
4. Klug W, et al. Concepts of Genetics.
5. Nelson DL, Cox MM. Lehninger Principles of Biochemistry. W. H. Freeman Publishing, ed.V or higher.

2. Mathematics and Python

1. [Math | Khan Academy](#)
2. [The Python Tutorial](#)
2. [Learn Python 2](#)

Track 2. Algorithmic Bioinformatics

(suitable for applicants with informatics, mathematics or other technical backgrounds)

1. Biology

1. Biology foundations. Important molecules for biology. Water and life. pH, acids and bases.
2. Cell structure and function. Prokaryotic and eukaryotic cells.
3. Energy and Metabolism. The flow of energy in living systems. Enzymes.
4. Cell division, cell cycle and control of the cell cycle.
5. Mitosis and meiosis.
6. Chromosome structure and numbers. Levels of chromatin structure.
7. Mendel's experiments, Mendel's laws, dominant and recessive alleles. Mendelian inheritance, deviations from mendelian inheritance. Sex linkage.
8. DNA structure and replication.
9. Overview of transcription in prokaryotic and eukaryotic cells.
10. Translating genetic information.
11. Human genome. Genome sequencing projects (1k human genomes, VGP).
12. Biological classification, binary nomenclature. Phylogenetic classification. Three-domain system of life.
13. Evolution and natural selection. Evidence of evolution. Phylogeny. Artificial selection.
14. Plant cells and differences from animal cells. Plant body structure. Photosynthesis.
15. The innate and adaptive immune systems. Organs and cells of the immune system. Antibodies. Vaccines.

2. Mathematics and programming

Each question contains a theoretical and practical part. The practical part consists of writing a small program in a compiled programming language (preferably, C++ or Java) that reads some input from a file, carries out the specified actions, and prints the required output to a file. The applicants should **demonstrate the program running on their PC** and are expected to answer the questions about the implementation, in particular about the algorithm asymptotic complexity.

1. Prime and composite numbers. Divisibility. Infinitude of primes. Fundamental theorem of arithmetics. Greatest common denominator and lowest common multiple.
2. Degree with a rational exponent. Exponential function. Logarithm. Its definition and properties.
3. Trigonometric functions. Their definitions and properties. Vector and scalar product in two-dimensional and three-dimensional space.

4. Principle of mathematical induction. Bernoulli inequality. Arithmetical and geometrical progressions, general term formula and sum formula.
5. Polynomials in one variable. Vieta's formulas. Number of roots of a polynomial.
6. Python Interpreter. Using Python interactively. Running Python programs.
7. Numbers in Python. Operations with integers. Operations with real numbers. Comparison operations.
8. Strings in Python. Subsetting. Searching for substrings. Lists.
9. Conditional operator in Python. Logical operations. Loops.
10. Functions in Python. Defining and calling functions. Recursive functions. Example

RECOMMENDED READING

1. Biology

1. [High School Biology](#)
2. [Introduction to Biology](#)
3. [Biology for Physicists](#) (in Rus)
4. [Molecular Biology and Genetics](#) (in Rus)

2. Mathematics and Python

1. Graham R, et al. Concrete Mathematics: A Foundation for Computer Science.
2. Diez DM, et al. OpenIntro Statistics. 4th edition. OpenIntro, 2019.
3. [Problems in Mathematical Analysis](#)