At the entrance exam an applicant chooses <u>one track</u> 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. The structure of DNA and the proof of DNA as the genetic material.
3. Genetic information organization in prokaryotes and eukaryotes. The structure of chromosomes.
4. Epigenetics. Epigenetic regulation of gene expression.
5. DNA replication in prokaryotes and eukaryotes. DNA polymerases.
6. Transcription in prokaryotes and eukaryotes. Types of prokaryotic and eukaryotic RNA polymerases. Transcription factors.
7. RNA processing in eukaryotes. Splicing, alternative splicing, introns.
8. Translation in prokaryotes and eukaryotes. Ribosome. Translation factors. Folding and chaperons. Post-translational modifications of proteins.
9. The cell cycle. Mitosis. Control of cell cycle and checkpoints. Meiosis.
10. Mendelian genetics: experiments and laws. Extensions to Mendel's rules.
11. The chromosomal theory of inheritance. Inheritance patterns. Sex linkage.
12. Population genetics.
13. Molecular technologies. Polymerase chain reaction. Restriction enzymes. Genome editing.
14. General principles of cell signaling. Main signaling pathways and molecules.
15. Mutations and DNA repair mechanisms.

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. (Python) Numbers. Operations with integers. Operations with real numbers. Comparison operations.
8. (Python) Strings. Subsetting. Searching for substrings. Lists.
9. (Python) Conditional operator. Logical operations. Loops.
10. (Python) Functions. Defining and calling functions. Recursive functions. Examples.

Recommended materials:

Biology:

○ Molecular Biology of the Cell. Alberts B, et al. Garland Sciences (ed.V or higher)
○ Concepts of Genetics. Klug W, et al.
○ Lewin's Genes. Krebs J, et al. Jones & Bartlett Learning (ed.X or higher)
○ Cell Biology. Pollard T, et al.
○ Lehninger Principles of Biochemistry. Nelson D, Cox M. Freeman Publishing (ed.V or higher)

Mathematics and Python:

○ Math. Khan Academy
○ Super Course in Mathematics: Coordinate Geometry and Vector Algebra. Trishna Knowledge Systems
○ Super Course in Mathematics: Algebra I and II. Trishna Knowledge Systems
○ Introduction to Algebra: The Art of Problem Solving. Rusczyk R
○ Linear Algebra: Step by Step. Singh K
○ Pure Mathematics for Beginners: A Rigorous Introduction to Logic, Set Theory, Abstract Algebra, Number Theory, Real Analysis. Warner S
○ The Python Tutorial
○ Learn Python 2
○ "Python Generation": A Course for Beginners (in Rus)
○ Python (in Rus)
○ Python Books for Beginners

Track 2. Algorithmic Bioinformatics

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

1. Biology

1. The chemical blocks of life: DNA, RNA, and proteins.
2. Cell structure and function. Prokaryotic and eukaryotic cells.
3. The flow of energy in living systems. ATP. Photosynthesis.
4. The cell division and cell cycle.
5. Mitosis.
6. Meiosis.
7. Chromosome structure and numbers. Levels of chromatin structure.
8. Mendel's experiments and laws.
9. DNA structure and replication.
10. Transcription. Key distinctions in the transcription process between prokaryotic and eukaryotic cells.
11. Translation: difference in prokaryotic and eukaryotic cells.
12. Human genome. Genome sequencing projects.
13. Levels of biological organization. Three-domain system of life.
14. The genetic code and its properties.
15. Mutations: types and consequences.

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++, Java, Python). The applicant should **demonstrate the program running** and is expected to answer the questions about the implementation, in particular about the algorithm asymptotic complexity)*

1. Elementary functions of one variable. Continuity and differentiability. Graphs of functions, extrema, convexity, etc.
   - Practical task: Root of a function.
2. Single variable integrals and derivatives: definitions, properties, main techniques.
   - Practical task: Area under a curve.
3. Linear operators and matrices. Eigenvectors and eigenvalues.
   - Practical task: Matrix exponentiation.

4. The principle of mathematical induction. Series (arithmetic progression, geometric progression, square pyramidal numbers, etc). Recurrence relations (Fibonacci numbers, binomial coefficients, etc).
   - Practical task: Bubble sort.
5. Probability space. Independent events, conditional probability, Bayes theorem. Definition of a random variable. Discrete and continuous random variables. Probability mass function. Cumulative distribution function. Probability density function.
   - Practical task: Merge sort.
6. Continuous and discrete probability distributions. Examples of discrete distribution. Bernoulli trials and related distributions, Poisson distribution, Uniform distribution, Gaussian distribution. Central limit theorem. Mean, median, mode. Variance, standard deviation.
   - Practical task: Distribution moments.

Practical tasks on Stepik:

https://stepik.org/invitation/60e26fcc76f3a57c50cbda1359460270cc9fb826/

Recommended materials:

Biology:

- High School Biology
- Introduction to Biology
- Biology for Physicists (in Rus)
- Molecular Biology (in Rus)
- Molecular Biology and Genetics (in Rus)
- Molecular Cell Biology (in Rus)
- Campbell Biology. Urry L, Cain M, et al.
- Color Atlas of Genetics. Passarge E
- Color Atlas of Biochemistry. Koolman J, Rohm K

Mathematics and programming:

- Discrete Mathematics and Its Applications. Rosen K (https://github.com/ccy05327/DM)
- Discrete Mathematics with Applications. Epp S
- Concrete Mathematics: A Foundation for Computer Science. Graham R, et al.
- OpenIntro Statistics, 4th Ed. Diez DM, et al. OpenIntro, 2019.
- Problems in Mathematical Analysis
- Probability Theory. Borovkov A (in Rus)
- Mathematical Statistics. Borovkov A (in Rus)