Entrance Exam Questions 2020

01.04.02 Applied Mathematics and Informatics

Master's Program "Bioinformatics and Systems Biology"

ITMO University

*At the entrance exam a student chooses <u>one of the two specializations</u> and gets two questions (one biological and one computational) from the corresponding question list.

<u>Specialization 1. Data Analysis in Biology and Medicine</u>

Biology

1. General features of the prokaryotic and eukaryotic cells structure and functioning.
2. Catabolism and biosynthesis. Their coordination.
3. The structure and function of DNA. Chromosomal DNA and its packaging. The global structure of chromosomes.
4. DNA replication in prokaryotes and eukaryotes. DNA-polymerases.
5. Transcription in prokaryotes and eukaryotes. Types of eukaryotic RNA-polymerases. Transcription factors.
6. Translation in prokaryotes and eukaryotes. Ribosome. Translation factors.
7. m-RNA maturation. Splicing.
8. Cell membrane. Composition of the membrane. Membrane proteins.
9. Principles of membrane transport. Carrier proteins and active membrane transport. Ion channels.
10. Genetic engineering tools. Restriction enzymes.
11. General principles of cell signaling. The main signaling pathways and molecules.
12. The cellular basis of immunity. The functional properties of antibodies. The fine structure of antibodies.
13. Components of the cell-cycle control system. Intracellular control of cell-cycle events. Programmed cell death (apoptosis).
14. The Mechanics of Cell Division. Mitosis. Cytokinesis.

Recommended reading:

- Alberts B., Johnson A., Lewis J., Raff M., Roberts K., Walter P. Molecular Biology of the Cell. Garland Sciences; edition V or higher. (or Alberts B., Bray D., Hopkins K., Johnson A., Lewis J., Raff M., Roberts K., Walter P. Essential Cell Biology. Garland Sciences; edition III or higher).
- Krebs J.E., Goldstein E.S., Kilpatrick S.T. Lewin's Genes. Jones & Bartlett Learning; edition X or higher.
- Nelson D.L., Cox M.M. Lehninger's Principles of Biochemistry. W.H. Freeman Publishing, edition V or higher.
- Thomas D. Pollard Cell biology.

Mathematics

1. Prime and composite numbers. Divisibility. Infinitude of primes. The fundamental theorem of arithmetics. Greatest common denominator and lowest common multiple.
2. Degree with a rational exponent. Exponent 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. The principle of mathematical induction. Bernoulli inequality. Arithmetical and geometrical progressions, general term formula and sum formula.
5. Polynomials in one variable. Vieta's formulas. The number of roots of a polynomial.

Recommended reading:

- https://www.khanacademy.org/math

Programming in Python

1. Python Interpreter. Using Python interactively. Running Python programs.
2. Numbers. Operations with integers. Operations with real numbers. Comparison operations
3. Strings. Subsetting. Searching for substrings. Lists.
4. Conditional operator. Logical operations. Loops.
5. Functions. Defining and calling functions. Recursive functions. Examples.

Recommended reading:

- https://docs.python.org/3/tutorial/
- https://developers.google.com/edu/python/
- https://www.codecademy.com/learn/learn-python/

Linux platform

1. Running executable files from the terminal. Input/output. Input/output redirection.
2. Navigating file system. List files in directory, changing directories, creating directories.
3. Working with file from the terminal. Copying, moving, deleting files. Displaying contents with cat, less, head, tail.
4. File search. Examples of using find and grep tools.
5. Remote access with ssh. Running commands remotely. Copying files to and from remote server. Scp command.

Recommended reading:

- https://www.digitalocean.com/community/tutorials/an-introduction-to-linux-basics
- https://www.digitalocean.com/community/tutorials/an-introduction-to-the-linux-terminal
- https://www.codecademy.com/learn/learn-the-command-line
- Sander van Vugt, Beginning the Linux Command Line

Specialization 2. Algorithmic Bioinformatics

Biology

1. Biology foundations. Important molecules for biology. Water and life. pH, acids and bases.
2. Cells. Basic cell structures. The cell membrane. Eukaryotic cell structures. Prokaryotes and eukaryotes. Plant and animal cells.
3. Energy and transport. Metabolism. Enzymes. Passive and active transport. Osmosis and tonicity. Photosynthesis. Cellular respiration.
4. Reproduction and cell division. Types of reproduction. Chromosome structure and numbers. The cell cycle and mitosis. Meiosis. Fertilization and development.

5. Classical genetics. Mendel's experiments, Mendel's laws, dominant and recessive alleles. Mendelian inheritance, deviations from mendelian inheritance. Sex linkage.
6. Molecular genetics. DNA structure and replication. RNA and protein synthesis. Biotechnology.
7. Evolution and natural selection. Evidence of evolution. Phylogeny.
8. Biological classification, binary nomenclature. Phylogenetic classification. Three-domain system of life.
9. Body structure and homeostasis. Organ systems.

Recommended reading:

- https://www.khanacademy.org/science/high-school-biology
- https://ocw.mit.edu/courses/biology/7-012-introduction-to-biology-fall-2004/video-lectures/

Algorithms

1. Asymptotic notations. O-notation. Common mathematical functions in asymptotic notations.
2. Sorting. Mergesort. Quicksort. Heapsort.
3. Stacks and queues.
4. Hash tables and collisions.
5. Binary search tree. Querying, insertion and deletion.
6. Dynamic programming. Matrix multiplication, longest common subsequence problems.
7. Greedy algorithms. Huffman codes.
8. Graph, Tree. DAG. Definitions and properties.
9. Breadth-first search.
10. Depth-first search. Topological sort.
11. Minimum spanning tree. Kruskal's algorithm.
12. Minimum spanning tree. Prim's algorithm.
13. Single-source shortest paths. Dijkstra's algorithm
14. String matching. The Rabin-Karp algorithm.
15. String matching. The Knuth-Morris-Pratt algorithm.

Recommended reading:

- Cormen TH, Leiserson CE, Rivest RL and Stein C. Introduction to Algorithms. Third Edition. MIT Press, 2009.
- https://www.coursera.org/learn/algorithms-part1
- https://www.coursera.org/learn/algorithms-part2

Mathematics (probability theory and statistics)

1. Sample space, sigma algebra. Axioms of probability theory. Conditional probability, independent events. Bayes theorem.
2. Definition of a random variable. Discrete and continuous random variables. Probability mass function. Cumulative distribution function. Probability density function.
3. Bernoulli trials and related distributions, Poisson distribution, Uniform distribution.
4. Discrete bivariate distributions, continuous bivariate distributions. Covariance and correlation.
5. Mean, median, mode. Variance, standard deviation.
6. Hypothesis testing: significance level and power, Neyman-Pearson lemma, Likelihood ratio tests.

Recommended reading:

- https://www.coursera.org/specializations/statistics
- Diez DM, Cetinkaya-Rundel M, and Barr CD. OpenIntro Statistics. 4th Ed. OpenIntro, 2019.