BIOENGINEERING ENTRANCE TEST PROGRAM FOR APPLICANTS TO THE MASTER'S DEGREE IN CONTEST GROUPS OF PHYSTECH SCHOOL OF BIOLOGICAL AND MEDICAL PHYSICS

The entrance exam will be held orally with preliminary preparation of answers on the following topics (1 question from each block). During the interview with the examiner, you will be able to talk about your achievements in fields of molecular biology, bioinformatics, etc. It’s better to prepare your own portfolio. Depending on the specialization you are interested in, you may be given additional questions. These can be simple tasks in biochemistry. You can find examples in the list of questions in block 2. Questions related to the subject of bioinformatics during admission to this specialty may include simple tasks: to write a short program or find an error in the code. You can use different programming languages.

Unit 1. Bioinformatics

1. Theory of probability: Conditional probabilities. Definition of conditional probability, total probability formula, Bayes formula. Independence of events.

2. Theory of probability: random variable, distribution function. Mathematical expectation, variance, correlation, covariances, their properties.

3. Theory of probability: Basic theorems of probability. Chebyshev's inequality. The law of large numbers. Central limit theorem.

4. Theory of probability: Distributions. Standard discrete and continuous distributions, their mathematical expectations, variances and properties (binomial, uniform, normal, Poisson, exponential, geometric).

5. Theory of probability: The concept of the Markov chain. Stationary state.

6. Programming, algorithms and data analysis. The simplest programming language constructs. Loops, branches, recursion.

7. Basic UNIX commands.

8. Programming and algorithms: Binary search and search trees. Hash tables.

9. Programming and algorithms: Graphs, graph traversal in breadth and depth.

10. Programming and algorithms: Sortings, average and worst complexity of algorithms.

11. Programming and algorithms: Regular expressions

12. Statistics and data analysis: Sampling, likelihood.

13. Statistics and data analysis: Estimation of distribution parameters, maximum likelihood method.

14. Statistics and data analysis: Confidence intervals.

15. Statistics and data analysis: Basic concepts of machine learning. Delayed sampling, its disadvantages. Cross validation. Leave-one-out analysis. Overtraining.

16. Statistics and data analysis: Clustering. Algorithm K-Means. Estimates of the quality of clustering

Unit 2. Molecular biology and biochemistry

1. Molecular Biology: the central dogma of molecular biology.

2. Structure of DNA and mechanism for heredity. Non-canonical DNA structures. Hyperchromicity. Supercoiling of circular genomes and plasmids. DNA, chromosomes and the cell cycle. DNA packaging into a chromatic fiber in eukaryotes. The structure of the nucleosome. Histone code.

3. DNA replication. Polymerases involved in replication, their enzymatic activity. Replication fork and its components. Topological challenges to replication of circular and linear genomes.

4. Classification of DNA damage and their correction mechanisms. DNA repair-deficiency disorders. The application of DNA-damaging agents in medicine. Cell response to double-strand breaks in DNA. TUNEL assay.

5. Homologous recombination of DNA and its biological functions. Conservative site-specific recombination. The main classes of mobile genetic elements. Repeats. Peculiarities of recombination in the formation of immunoglobulin genes and T-cell receptors.

6. Application of DNA repair mechanisms in genome editing. Restriction-modification system, the purpose of its existence in bacteria and its application in genetic engineering.

7. Genome editing technologies: zinc fingers, TALEN, CRISPR. The purpose of the CRISPR/Cas system in bacteria

8. DNA transcription, DNA supercoils and nucleosomes. Structure of RNA polymerase. Stages of the transcription cycle and principles of regulation. Transcription attenuation. Common similarities and differences in transcription between bacteria and eukaryotes.

9. Main mechanisms of mRNA processing: capping, polyadenylation, intron splicing. Modern concepts of splicing mechanisms.

10. Modern ideas about the structure, function and evolutionary history of eukaryotes.

11. Genetic code. Reading frames. Structure and function of tRNA.

12. Translation initiation: common mechanisms and features in prokaryotes and eukaryotes. RNA structures that regulate the efficiency of translation. Elongation cycle. Translation termination.

13. Basic principles of regulation of translation. Protein folding and processing. Post-translational modification of proteins. Peptide bond. Primary, secondary, tertiary protein structure.

14. Basic ideas about the eukaryotic cell structure. Purpose of cell organelles. Mitosis and its phases. Cell cycle, stages of the cell cycle. Cell differentiation.

15. Regulatory regions in the genome: promoter, TATA box, enhancer, silencer, insulator.

16. Diversity and functions of short non-coding RNAs. RNA interference. The biological role of RNA interference. siRNA. Applied use of RNAi

17. The principle of the polymerase chain reaction. A real-time PCR. Reverse transcription PCR.

18. DNA sequencing methods. Sanger sequencing. Next generation sequencing.

19. Molecular biology: genome, gene, CG composition, genetic code, its degeneracy and universality, ribosome, nucleotides, amino acids, tRNA, complementarity, ribosome binding site, reading frame, RNA secondary structure.

20. - Biochemistry: calculation of the pH value of a 6 nM hydrochloric acid solution.

21. Biochemistry: indicate the possible number of isomeric tripeptides that can be obtained by the condensation of three amino acids - leucine, arginine and glycine.

22. Biochemistry: Starch and cellulose are made up of the same monomer - glucose. Explain the possible reasons for the differences in the physicochemical properties of these polysaccharides.

23. Biochemistry: membrane phospholipids carry a significant charge. What does this charge mean? What ions can compensate for this charge?

24. Biochemistry: Enzymatic reaction substrate concentration is 4 Michaelis constants. What will be the ratio of the rate of this reaction?

25. Biochemistry: fats are divided into saturated (solid) and unsaturated (liquid) according to the composition of higher fatty acids. Which fats will have the highest energy content per gram of substance? Explain your answer.

26. Biochemistry: Some types of RNA (tRNA, rRNA, etc.) form stable secondary structures (hairpins). How can their boundaries be determined from the primary RNA sequence?

27. Biochemistry: what parameters of amino acids should be taken into account when predicting the transmembrane regions of proteins?

References

1. Alberts B. et al. Molecular Biology of the Cell in Cell 4th. – 2002.

2. Murray R. K. et al. Harper’s illustrated biochemistry. – Mcgraw-hill, 2014.

3. "Introduction to bioinformatics algorithms" Jones, Pevzner

4. “Bioinformatics - From Genome to Therapies” - Lengauer et al (2007)