

Course name: ANALYSIS I - FOUNDATIONS OF ANALYSIS

Number of ECTS credits: 6

Content:

- The natural numbers. Rational numbers. Real numbers. Complex numbers.
- The sequence of real numbers. Limits and accumulation points. Cauchy condition. Upper and lower limit. Monotone sequences. Bolzano-Weierstrass theorem.
- Series. The convergence criteria. Absolutely and conditionally convergent series.
- Functions of real variables, even and odd functions, periodicity. Limits of functions, left and right limits. Continuity. Continuous functions on closed intervals limited. Bisection method for finding zeros.
- The elementary functions. Cyclometric functions.

Course name: ALGEBRA I - MATRIX CALCULUS

Number of ECTS credits: 6

Content:

- Vectors, analytic geometry in space.
- Matrices. Types of matrices and basic operations with matrices. Rank of a matrix. Inverse. Systems of linear equations. Matrix interpretation and theorem of solvability. Elementary matrices, Gauss method. Determinants. Cramer's rule.

Course name: PROGRAMMING I - INTRODUCTION TO PROGRAMMING

Number of ECTS credits: 6

Content:

Basic building blocks of a computer program (using the syntax of the programming language Java):

- Variables, types and expressions. Basic I/O operations. Decision statements. Control structures. Functions and parameters. Programs. Structural decomposition.

Basic data structures:

- Simple types. Arrays. Records. Characters and strings. Data representation in computer memory. Memory allocation. Linked structures. Stack. Queue. List. Tree.

Algorithms and problem solving:

- What is an algorithm? Problem solving strategies. The role of algorithms in problem solving. Algorithm implementation strategies. Debugging. Recursion - recursive functions, divide-and-conquer principle, backtracking, implementation of recursion.

Programming languages overview:

- Types of programming languages. Flow control. Functions. Subprograms. Namespaces.

Declarations and types:

- Types. Declarations of types. Safe typing. Type checking. Subtypes. Classes. Polymorphism.

Abstraction mechanisms:

- Data abstractions. Simple types. Composite types. Flow abstractions. Subprograms and functions. Abstract data types. Objects and classes. Patterns. Modules.

Course name: THEORETICAL COMPUTER SCIENCE

Number of ECTS credits: 6

Content:

- Introduction to mathematical theory, logic, truth tables, mathematical logic.
- Formal Languages.
- Basic concepts of mathematical logic.
- Methods of recording the sets. The basic relations between sets, the basic operations on sets or families of sets. Power set. Relations. Graphs. Equivalence relations. Partial and linear ordering. Lattices and Boolean algebra. Well ordering. Function. Special types of functions. Category.
- Finite and infinite, countable and uncountable sets.
- Cardinal and ordinal numbers. Peano arithmetic, mathematical induction.
- The system of axioms of set theory NBG and ZFC. Axiom of choice. Zorn's lemma.
- Introduction to symbolic computation (Mathematica).

Course name: COMPUTER PRACTICUM

Number of ECTS credits: 6

Content:

The faculty network and basic usage rules:

- Description of the faculty computer network, login methods, password changing procedure, e-mail and mailing list usage, access to e-materials.
- OS Linux basics:
- Description of the Linux OS and its Slovenian version - Pingo Linux. BASH shell usage basics.
- Programming language C:
- The syntax of the C programming language. Usage of programming language C to solve example problems.

Course name: ANALYSIS II - INFINITESIMAL CALCULUS

Number of ECTS credits: 6

Content:

- Derivative. Mean value theorems. Differentiation of monotone functions. L'Hopital's rule. Higher derivatives. Taylor's formula. Local extrema. Convex and concave functions. Inflection points. Tangent method of finding the zeros.
- The indefinite integral. Definite Integrals. Darboux and Riemann sums. Leibniz-Newton formula. Mean value theorems. Integration methods. Applications of the definite integral in geometry. Improper integral. Numerical integration.
- The logarithm, the number e, and the definition of exponentiation with the real exponent.
- Drawing planar curves.
- Sequences and function series. Power series. Taylor series. Elementary
- complex functions.

Course name: DATA PROGRAMMING

Number of ECTS credits: 6

Content:

1. Introduction to data programming.

Programming languages for data programming, basic data structures and operations, applications.

2. Introduction to Python.

Interpreter environment, syntax, numbers, strings, lists, files, sequential control, loop control, functions, lambda expressions, higher-order functions, functional programming.

3. Data structures in Python.

Lists, products, sequences, sets, dictionaries, loops for data structures.

4. Modules and classes in Python.

Syntax of modules, module environment, standard modules, syntax of classes, classes as objects, instances, methods, inheritance, iterators, generators.

5. Numeric Python (numpy).

N-dimensional arrays, indexes and array slicing, operations, data processing, data cleaning, data transformations, aggregations, grouping, timeseries, structured arrays.

6. Basics of R programming language.

History of R. Characteristics of R programming language, usage, graphical user interfaces for R, R studio - how it looks like and how it works, basic usage of command-line interface (practical example), numbers, vectors, R commands, functions and definitions, objects, attributes, matrices, lists, factors, data frames.

7. Reading and writing in R.

Reading of objects, vectors and matrices, reading data frames, reading from files, data generating, writing R objects, writing own simple functions in R.

8. Data managing in R.

databases, statistical models in R, graphical procedures, practical example of statistical model and graphic display usage.

9. Example of application in R.

Bioconductor, practical example of R usage in research.

Course name: ORGANIC CHEMISTRY AND BIOCHEMISTRY

Number of ECTS credits: 6

Content:

Students in the course acquainted with the basics of organic chemistry. They gain knowledge of the structure, property and the role of specific organic compounds and their reactivity. Students deepen their knowledge of various types of organic compounds, their structure, reactivity and the possibility of transformation of one organic compounds in the other with focusing on the functionalization of organic compounds. Gain a basic knowledge in the field of organic chemistry, which will serve as the basis for the acquisition of new science knowledge especially in biochemistry. Students learn about the structure, function, biosynthesis and degradation of the major life biomolecules, especially proteins and enzymes. Are able to identify, isolate and quantify biomolecules. Proficient in many techniques, methods and apparatus which are necessary for this. At the same time get insight into the dynamic process of metabolism, the key metabolites in individual metabolic cycles and their interconnection in regulatory mechanisms that maintain cells in a steady state.

If the balance in the cell breaks down for various reasons, it may be a variety of metabolic diseases.

Course name: ALGEBRA II - LINEAR ALGEBRA

Number of ECTS credits: 6

Content:

- Groups, rings, fields. Ring of polynomials.
- Vector space. Subspaces, linear operators. Linear independence. Basis and dimension of vector space.
- Eigenvalues. The characteristic and minimal polynomial.
- Inner product. Orthogonal systems. Gram-Schmidt process of orthogonalization. Norm. Norm of the matrix and the operator. Normal and related operators.
- Convexity in the vector space.
- Normalized vector spaces as metric spaces. Isometries of R^2 and R^3 .

Course name: GENETICS

Number of ECTS credits: 6

- Fundamentals of transmission genetics: laws of inheritance, pedigree analysis of inheritance of dominant and recessive genes, molecular basics of dominant and recessive mutations.
 - Autosomal and sex-linked inheritance.
 - Cytoplasmic inheritance.
 - Basic laboratory methods in molecular genetics: restriction enzymes, separation of DNA fragments, cloning DNA vectors, DNA recombinant techniques, methods for sequencing DNA, understanding and importance of genomic projects
 - Analysis of genes, reverse genetics, methods for analysis of expressed sequences
 - Morphology and structure elements of Eukaryote chromosome: telomere, centromere, role, replication model of telomere, organization of DNA on the chromosome, construction of chromatin, heterochromatin
 - Evolution of genomes
 - Organization of Eukaryote genome
 - Genes and organization of genes
 - Organellar genomes, evolution and properties
 - The pathway from DNA to protein
 - Synthesis and processing of RNA
 - Expression of genes
 - Modification of genetic material; mutations on the chromosome, gene, genome. The causes of mutations, the impact on the organism and the importance in the evolution
 - Repair mechanisms
 - Recombinations
 - Mobile genetic elements and their role
 - Forensic genetics, applications
 - Application of genomics
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Course name: DATA STRUCTURES AND ALGORITHMS

Number of ECTS credits: 6

Content:

- The basic mathematical tool
- Basic data structures
- The basic abstract types and their performance
- Sorting and finding:
- Basic algorithmic techniques
- Algorithms on graphs and networks

- Selected algorithms

Course name: INTRODUCTION TO DATABASE SYSTEMS

Number of ECTS credits: 6

Content:

- Introduction
- Logical data models: Entity-Relationship model, relational model, translation of ER into relational model, relational algebra, relational calculus, SQL, SQL3, QBE.
- DBMS implementation: Disks, files, index files, indexes, ISAM, B+ trees, hash indexes, evaluation of relational operations, query optimization, query evaluation, transactions, concurrency control, crash recovery.
- Database design: Logical database design, functional dependencies, normal forms, physical database design, denormalization, index selection.
- Application level: DBMS applications, embedded SQL, dynamic SQL, Internet databases.

Course name: BASIC PHYSICS WITH BIOPHYSICS

Number of ECTS credits: 6

Content:

The subject presents a comprehensive basis of physics and biophysics both in its theoretical and practical aspects. We introduce the basic physical concepts, which are the basis for understanding processes in living beings. The importance of these concepts is further fortified with explanations and with real examples. Students learn about the rich and additive physical quantities and operating procedures for measuring these quantities, forms of energy, material, electrical and thermal currents, conservation laws, oscillations and waves. They accurately understand biophysical applications such as biomechanics, pressure and concentration differences as a cause for material flows, temperature differences as a cause for heat flow, potential difference as the cause for electrical currents, vocal chords as sound transmitter and biophysical structure of ears as a sound receiver, optical instruments and basics of molecular biophysics. Physics and biophysics are an essential part of the study and understanding of physical phenomena in chemistry, biology and medicine, as in ecology. Students are acquainted with the understanding of theoretical and practical problems that they will encounter in laboratory research work, or in industry.

Course name: SYSTEMS II - OPERATING SYSTEMS AND COMPUTER NETWORKS

Number of ECTS credits: 6

Content:

- Introduction: what is operating system, history of operating systems, computer hardware overview, concepts of operating systems, system calls, operating system structure.
- Processes and threads: processes, threads, inter-process communication, critical conditions, critical region, classical IPC problems, scheduling.
- Deadlocks: resources, representation of processes and resources, deadlock modeling, Osterich algorithm, deadlock detection and recovery, deadlock avoidance, deadlock prevention.
- Memory: basic operations, swapping, virtual memory, page replacement algorithms, modeling page replacement algorithms, page management system, segmentation, Multics, Pentium.

- Input/output: principles of I/O hardware, principles of I/O software, software levels of I/O, disk, clock, character terminals, graphical interfaces, network terminals, other I/O equipment.
 - File systems: files, directories, file system implementation, examples of file systems - Unix, Windows.
 - Multimedia: multimedia files, video compression, JPEG, MPEG, scheduling multimedia processes, multimedia file systems, storing multimedia files, disk scheduling.
 - Multi-processor systems: multi-computer systems, distributed systems, architectures and examples.
 - Security: security environment, introduction to cryptography, user authentication, attacks from inside, attacks from outside, protection mechanisms, trusted systems.
- Unix-Linux: history of UNIX, overview of UNIX, UNIX processes and memory management, UNIX I/O and file system, UNIX security.

Course name: ALGORITHMS IN BIOINFORMATICS

Number of ECTS credits: 6

Content:

- Introduction to bioinformatics, basic bioinformatics problems in molecular biology, brief biological introduction.
- Algorithms for sequence analysis: based on pattern searching, sliding windows, matrices, classical statistical methods and graphical presentations.
- Comparison of two sequences: algorithms for exact matching.
- Comparison of two sequences: heuristics algorithms.
- Pattern matching and finding the best match.
- Suffix trees.
- Comparison of multiple sequences.
- Construction of evolutionary trees.
- Similarity search: problem definition, matrices, methods.
- Aligning two or more sequences: problem definition and methods, 2-approximation algorithm for multiple sequence alignment with respect to sum-of-squares distance function.
- Phylogenetic analysis: distance calculation, parsimony methods, maximum likelihood methods, bootstrapping, perfect phylogeny and extensions, Gusfield's algorithm for binary matrices. Modeling of the perfect phylogeny problem with chordal graphs.

Course name: STATISTICS

Number of ECTS credits: 6

Content:

- Introduction. What is statistics? Examples of applications of statistical methods in natural sciences. Population. Sample.
- Random variables. Continuous and discrete random variables. Examples of random variables. Probability function, probability density function, cumulative distribution function.
- Descriptive statistics. Frequency distribution. Measures of central tendency. Quantiles. Measures of variability.
- Sampling. Introductory examples. Random sampling. Sampling distribution. Standard error. Confidence intervals.

- Graphical methods of data representation. Histogram. Scatter plots. Box and whisker plot. QQ- diagram.
 - Hypothesis testing. Null hypothesis, alternative hypothesis. Errors in hypothesis testing. Examples: t-tests (mean of single sample, means of two independent/dependent samples, ANOVA)
 - Correlation and dependence. Regression. Linear regression. Measures of linear dependence. Correlation coefficients. Non-linear dependencies. Association, contingency tables.
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Course name: MATHEMATICAL CHEMISTRY

Number of ECTS credits: 6

A. Theoretical basis

- Basics of classical combinatorics
- Basics of formal languages
- Basics of graph theory
- Matrices, eigenvalues, eigenvectors
- Maps on surfaces, Euler formula
- Graph algorithms in Sage and Python

B. Families of molecular graphs, Applications in chemistry and biology

- Molecules and chemical graphs
- DNA, RNA as strings
- Proteins as strings of aminoacids
- Trees, molecular trees, alkanes
- Benzenoids and their generalizations
- Fullerenes and fullerene-like structures
- Cubical and subcubical graphs
- Generating graphs using tools such as CaGe
- House of Graphs and similar databases

C. Problems on graphs with applications

- Spectral graph theory (Hückel theory, HOMO-LUMO)
- Matching theory (Kekulé structures)
- Hamilton cycles
- Graph coloring (Vertices correspond to atoms)
- Euler circuits (polyhedral self-assembly)

D. Representation of graphs, graph drawing, molecular mechanics

- Graph drawing using eigenvectors
- Force-field methods
- Rotagraphs and other polycriculants

E. Graph invariants and topological indices

- Wiener index
- Szeged index
- HL index
- etc.

Each chapter is supported by programs in Sage.

Course name: SYSTEMS BIOLOGY APPROACH IN HUMAN DISEASE STUDY

Number of ECTS credits: 6

In this course students will familiarize with critical parameters in modern experimental medical research.

Students will learn about developing good research questions and hypothesis, clinical studies and experimental design, variables and confounders, statistical analysis and data interpretation and presentation. The students will practice the selection of variables, consider the influence of co-variables, testing multiple hypothesis and the effect of sample size and power analysis. They will be introduced to basics of epidemiology and why it is important for human disease research, evidence based medicine and meta-analyses.

The seminar lectures will include the basics of molecular biology methods with an emphasis on presentation of data about genes, epigenetics, transcripts, proteins and metabolites and their functions and interactions. Students will practically use programs for analysis and graphical data presentation of data and learn on examples how to write a scientific paper or research thesis and how to make an oral research presentation. Students will learn how to answer concrete research questions in human disease. Seminar lectures will present methods on real-world data from studies of molecular mechanisms and diseases, such as immune response and metabolic syndrome.

Major themes

- Formulating experimental question and testing hypothesis (variables- dependent, independent, co-variables, confounding; drawing conclusions-deduction, induction, comparison; validity, reliability of results-errors (type I, II, confidence interval, bootstrapping), population effect size and power analysis
- Study design, *in vitro/in vivo* experiments, types of pre-clinical, clinical studies; sampling, sample size, replication, randomization; error and bias of sample, experiment performance and study design
- Conducting multiple comparisons (post hoc tests, Bonferroni, Tukey..), ANCOVA, practical use of regression, basics of epidemiology
- Biostatistic of diagnostic test and method comparison (analytical, diagnostic specificity, sensitivity, predictive value)
- Systems medicine, 4P medicine, precision medicine
- Systems medicine in research and development of new drugs
- Ethical issues, informed consent, personal information privacy
- Overview of -omic data methods and methods for their further confirmation in medical studies with emphasis on transcriptomics, proteomics and metabolomics; overview of databases and freely available tools for their analysis with cases from different diseases

Practical approaches in solving modern medical research questions

- Each seminar lecture will focus on one of human diseases and the data gathered about it (eg rheumatoid arthritis, atherosclerosis etc)
- Experimental data obtained from genomics, epigenetics, proteomics, metabolomics will be used and their advantages/disadvantages discussed
- Using online deposited data and data bases
- Data visualization, tables and graphs for research paper/thesis and oral presentation -using program for data presentation and statistical analysis
- Students will practice study conduct to compare two study populations and think of what variables could affect the treatment outcome or disease outcome and propose possible way of obtaining those information's from study population (i.e. digital biomarkers, increased use of wearable devices provide unique opportunities to develop innovative therapeutic strategies)