## BIOINFORMATICS, UNDERGRADUATE STUDY PROGRAMME, FIRST BOLOGNA CYCLE

# COURSE DESCRIPTIONS

## COMPULSORY COURSES

Course name: **BIOLOGY**
Number of ECTS credits: **6**

**Content:**
The course addresses the basic topics in the biological sciences, forming the basis for understanding other, more specific biologically-oriented subjects (e.g., genetics), as well as for non-biological courses that require knowledge of biology, such as various bioinformatics courses. Students will become acquainted with basic principles of biology, and get insights in the laboratory work through lab practice. They will be informed about the functioning of light microscope and stereolupe and learn how to use the microscope.
Covered topics include the basics of biology, cell biology, genetics, evolution, botany and zoology. In cell biology, students recognize the cell as the basic unit of life and learn about their structure and function. Students will get acquainted with the basics of genetics and mechanisms of genetic inheritance, as a basis for understanding the evolution and speciation. A review of kingdoms of life will give them knowledge about the diversity of life forms. Students will learn about the structure and function of plants and animals, their adaptations to different living environments, as well as about various animal and plant tissues, organs, organ systems and their 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: **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: **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: **DISCRETE MATHEMATICS II - COMBINATORICS**
Number of ECTS credits: **6**

**Content:**
- The principle of the sum, product. Counting pairs. Elementary combinatorics. Assignment. Assignment within the set. The existence of a 1-factor. Assignment between two sets, Hall's theorem. König's theorem, applications. Recursion. Generating functions. Linear recursion with constant coefficients. Applications of combinatorics. Inclusion-exclusion principle. Rook polynomial. Möbius inversion. Partially ordered sets and the Möbius function. Theorem on the inversion. Designs. Finite projective planes. Correction code. Steiner systems. Kirkman schoolgirl problem. Ramsey theorem, proof and application. Polya Theory. Burnside's lemma. Polya's theorem.
- Graphs, examples of graphs. Trees. Basic properties, enumeration of trees. The cheapest tree. Operations on graphs. Product of graphs. Deck graphs and voltage graphs. Graphs and groups. Graph automorphism group. Cayley graphs and Frucht theorem. Symmetric graphs. Planarity and duality. Criterion of planarity. Graph embeddings in other plots. Duality and Euler's theorem. Graph coloring. Coloring vertices. Coloring edges. Chromatic polynomial. Directed graphs. Eulerian digraphs. Tournaments. Markov chains. Connectivity. Menger's and Hall's theorem. Different versions of Menger's theorem and Ford-Fulkerson's theorem. Matroid theory. Definitions. Matroids and graphs. Examples of matroids and applications

Course name: **ANALYSIS III - FUNCTIONS OF MANY VARIABLES**
Number of ECTS credits: **6**

**Content:**
- Metric spaces. Cauchy-Schwarz inequality. Open and closed sets.
- Compactness and connectedness. Sequences in metric spaces. Cauchy sequences and complete metric spaces. Continuity and uniform continuity. Properties of continuous mappings.
- Functions of several variables. Continuity, partial differentiability. Differential mapping from Rn to Rm. Jacobian matrix. Chain rule of differentiation.
- Higher order partial derivatives. Taylor's formula. Theorem on the locally inverse function and on implicit functions. Local extremal problems, constrained extremal problems.
- Double and multiple integrals. Properties. The conditions on the existence. The introduction of new variables.
- Calculation and application.
- Proper and generalized integrals with parameter. Beta and Gamma functions. Stirling formula.

Course name: **STATISTICS**
Number of ECTS credits: **6**

**Content:**
Statistics is one of the most widely used fields of mathematics. The course will start out with simple questions about sampling which, however, lead to fundamental concepts of statistics like estimator, sampling distribution, standard error and confidence interval. This in turn leads to more abstract questions about statistical models, the role of parameters and the question of estimating such parameters. The course will treat methods of parameter estimation and examine the quality of estimators. The chapter on hypothesis testing follows along with the conceptual questions arising from it. The central result here is Wilks's theorem which makes it possible to construct statistical tests.
Linear regression is one of the most widely used models in statistics. The course will state the basic assumptions underlying the model, deal with the question of estimating parameters, Gauss-Markov theorem and generalizations of regression such as logit and probit models.

Course name: **PROBABILTY**
Number of ECTS credits: **6**

**Content:**
- Basics of combinatorics
- Fundamental Theorem of combinatorics.
- Variations and variations with repetition.
- Combinations and combinations with repetition.
- Permutations and permutations with repetition.
- The binomial formula and generalizations.
- Outcomes and Events
- The sample space, events, definition of probability.
- Calculations with the events.
- Conditional probability and independence.
- Random Variables
- Random variables and their distributions.
- Overview of some discrete distributions.
- Mathematical expectation and variance.
- Continuous random variables.
- Multidimensional distribution
- Definition of multi-dimensional discrete distribution.
- The independence of random variables.
- covariance, the sum of random variables.
- Conditional distributions and conditional mathematical expectation.
- Multidimensional continuous distributions.
- Generating functions
- Definition and examples.
- The process of diversification.
- Aproximations of distributions
- Convergence of random variables in the distribution.
- The normal distribution approximation of sums of random variables.
- Poisson approximation.

Course name: **STOCHASTIC PROCESSES I**
Number of ECTS credits: **6**

**Content:**
Stochastic processes are a field of probability important for applications in numerous fields. The starting point for the understanding is the treatment of Markov chains in discrete time. The students will become familiar with concepts like strong Markov property, ergodic properties of Markov chains, reversibility and other. With the introduction of sojourn times we pass on to Markov chains in continuous time which is a step in the direction of continuous time stochastic processes.
Martingales are a central concept in modern probability theory. Examples of martingales will be presented first followed by the two fundamental theorems on optional stopping and the convergence theorem. These two results in turn lead to many results like martingale inequalities, convergence theorems for random sums and similar.
Brownian motion is a fundamental object in stochastic processes in continuous time. The construction question will be treated, path properties examined, the strong Markov property will be presented along with the reflection principle. In the end we will look at a few continuous time martingales related to Brownian motion.

Course name: **BIOINFORMATICS**
Number of ECTS credits: **6**

**Content:**
The main goal of the course is to bridge molecular biology and computer science. Expertise in the former and understanding algorithmic approaches to complex problem solving will enable students to conduct research in genomics, proteomics and other "omics", with the emphasis on data acquisition and analysis. By understanding "omics" research technology, students will be able to perform high-throughput data analysis and connect the results with molecular mechanisms in the cell and potential organism's pathology. Implementation of the gained knowledge includes basic and applicative research in the fields of biochemistry, biotechnology, medicine, pharmacy, veterinary, forensics, ecology, energetics, etc.
Introductory part of the subject will cover basics about languages, structures and functions of biological macromolecules, including techniques for their analysis. Bioinformatics databases and tools supporting studies of macromolecules will be introduced. "Omics" studies will be presented together with high-throughput technologies, i.e., DNA microarrays and next-generation sequencing.
The main part of the subject will be dedicated to algorithmic principles, which represent bases for many bioinformatics tools for biological sequence analysis. Different text search algorithms and related data structures will be covered, together with numerous examples of dynamic programming algorithms. Methods for nucleotide and protein sequence analysis and alignment, sequence reconstruction and construction of evolutionary trees will be presented, and corresponding software tools discussed.
The third part of the subject will be dedicated to DNA microarray bioinformatics. Students will get familiar with high-throughput experimental design and gene expression data analysis through illustrative examples of transcriptome studies using DNA microarrays. Statistical and machine learning approaches will be presented together with software tools for analysis of DNA microarray data and its management.

Course name: **BIOLOGICAL TOPICS IN ENGLISH**
Number of ECTS credits: **6**

**Content:**
The concepts in different fields of Biological Sciences will be introduced and discussed throughout the lectures. The focus of the first part will be on cellular and molecular biology, human physiology/pathophysiology and neuropathology from the systems biology and bioinformatics points of view. Students will first learn about macromolecules with focus on DNA, proteins and their

functions. Next, prokaryotic & eukaryotic cells will be discussed, with emphasis on chromatin and the regulation of gene expression, biotechnology and cloning. Critical cellular processes in cells will be addressed, such as transport across membranes, cell cycle and signaling. The development of cancer on one hand and a neurological disease on the other, will serve as case study examples of dysregulated cellular processes.
The second part of lectures will cover evolution, with special emphasis on the concepts leading up to Darwin's way of thinking. The ecological part of lectures will include the web of life, biodiversity and living fossils. The final lectures will emphasize marine biology and the conservation of nature.
The seminar part of the course will cover practical issues such as article reading, writing and presentations in science.

Course name: **PHYSICAL CHEMISTRY**
Number of ECTS credits: **6**

**Content:**
Physical Chemistry is trying to elucidate the fundamental principles of all chemical and biochemical processes. The subject builds its knowledge on the basis of laws of Physics with the help of mathematical formalisms. The students will develop a deep understanding of all four laws of Chemical Thermodynamics and of the principles of Chemical Kinetics and Electrochemistry. This fundamental knowledge will be applied to the study of phase and chemical equilibria.

The subject will try to answer two important questions: which is the spontaneous direction of all chemical or biochemical processes and what their rate is. It will help the students to master the abilities of logical thinking as well as of mathematical description of natural phenomena. The subject will provide fundamental knowledge of Physical Chemistry which is indispensable for true understanding of the nature of the World and its processes.

Course name: **BASIC POPULATION GENETICS**
Number of ECTS credits: **6**

**Content:**
The purpose of this course is to familiarize students with basic aspects of population genetics and of molecular tools in the study of populations of plants and animals. Various ways of measuring the diversity of populations (heterozygosity, distribution and allele frequencies, genotypes) and the factors affecting the diversity of populations (selection, genetic drift, mutations, gene flow) will be discussed. Students are also acquainted with the formation of populations and their structure in space. Particular emphasis will be on the use of population genetics in the conservation of species.

Some of the content will be devoted to molecular population genetics, in which we will discuss nucleotide sequence divergence, amino acid substitution, nucleotide substitutions, molecular clock, within species polymorphism and non-coding sequences.

The practical aspect of population genetics, will be presented in the tutorial, which will demonstrate the use of specific statistical methods in order to solve simple qunatitative genetic problems. Students will gain additional skills with the preparation and presentation of seminars from the scientific literature in this field.

Course name: **STRUCTURES OF BIOLOGICAL MOLECULES**
Number of ECTS credits: **6**

**Content:**
The main intent of the course is to introduce students to the biological molecules from which we are built, such as carbohydrates, fats, nucleic acids and proteins and their structures, as well as

molecules important in energy metabolism (kot so ATP, GTP). The course will begin with the characterization of organic compounds, isomers, enantiomers, functional groups of atoms and their characteristics (such as polarity). Students will learn about the different ways of building polymers and degrading them based on enzyme reations. The structures of starch, cellulose, glycogen, chitin and glycoproteins will be covered, as well as an overview of fats made on examples of triglycerides, phospholipids, carotenoids, steroids and waxes. Cholesterol and omega-3 fatty acids will be emphasized, as well as trans-fatty acids, which are all important in our daily lives. The different groups of amino acids will be studied with examples. The bonds within proteins (such as H bonds, disulfide and ionic bonds) will be addressed, as well as the bonds responsible for the quarternary structures of proteins (such as van der Waal and hydrophobic bonds). The determination of protein structures using X-ray crystallography, NMR, electron microscopy (scanning SEM and transmitting TEM) and crystallization of proteins will be addressed. The structures of nucleic acids will be presented. At the end, students will be able to recognize all the different groups of molecules based on their structures, functional groups and other characteristics, and link them to their detection methods and functions in organisms.

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 quantified 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: **INTRODUCTION TO GENETICS AND GENOMICS**
Number of ECTS credits: **6**

**Content:**
In this course students gain knowledge to understand the basics of genetics and principles of analytical techniques to solve genetic problems. The course provides the basics of formal-, molecular, -population-, quantitative, and evolutionary genetics. Students will understand the logic of genetic experiments, to develop a genetic approach for solving problems and acquire a critical judgment of interaction between genotype and phenotype. By analyzing the opportunities offered by genetics, skills for the application of this knowledge in practice will be developed. Proper selection of methods to achieve the objective will be encouraged. Students will be able to identify targets and seek appropriate solutions with options offered by the knowledge and technology. Laboratory exercises give students the opportunity to learn and implement the basic techniques used in genetics and also to consolidate the theoretical principles presented in lectures.

Course name: **EVOLUTIONARY GENETICS**
Number of ECTS credits: **6**

**Content:**
The aim of this course is to introduce students to the basic concepts of evolutionary genetics and deepen their knowledge about the usefulness of molecular tools determining evolutionary history of species. Students will acquire more detailed insight into the molecular basis of variability of living things, patterns and mechanisms of change of biological macromolecules, molecular phylogenetics, and gene evolution. Other acquired competences relate to a synoptic knowledge of evolutionary theory and mathematical representation of basic microevolutionary events. Students will be able to understand specifics of molecular evolution and application of bioinformatics into molecular evolution and phylogenetics. Lectures will provide theoretical knowledge, which will be upgraded in the tutorials with practical computational exercises and case-studies. By addressing key problems in the course the students will learn different research methods and techniques that will allow them to acquire new skills and develop critical thinking.

Course name: **GENERAL AND INORGANIC CHEMISTRY**
Number of ECTS credits: **6**

**Content:**
The course presents the basic chemical laws. Students learn the basics of quantitative characteristics and structure of matter, chemical processes and electronic configuration of atom, types of chemical bonds, chemical reactions, chemical equilibrium and energy changes in chemical reactions.
The first part is made from brief summary of the substance and material changes and chemical laws; second part is upgraded with explanation of basic chemical concepts: atom, molecule, ion, element, compound, substance, mixture, formulas, etc. Students are introduced to the computational exercises. Scope of atomic and chemical bonds is focused on the importance of the chemical bonds within atoms and molecules and on the structure of periodic table of elements. A basic overview of the dispersants systems and chemical equilibrium within the reactions. Review of inorganic compounds is given according to the periodic table of elements and review of organic compounds is with functional groups. Students acquire the basic chemical education which is key to every naturalist, and his effect on the labor market. At the same time, students learn to use critical analysis and development, practical application of theories in solving practical problems in the field of chemistry. The subject is the basis for other chemical objects in the program, and serves as a balancing of chemical knowledge, which the students bring from high school. Students upgrade theoretical knowledge acquired by lectures, with practical examples in the context of computational and laboratory exercises.

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: **THEORETICAL COMPUTER SCIENCE I**
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. Latices 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: **PROGRAMMING I**
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 algoirithms 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: **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: **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 frineds:
- 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: **SYSTEMS III – INFORMATION SYSTEMS**
Number of ECTS credits: **6**

**Content:**

- Information systems

Basic definitions from the field of information systems. Introduction to business analysis. Analysis and design of business processes. Analysis and design of data. Database tools. Software development tools. Web technology. Definition of information system requirements. Definition of information system architecture.
Implementation of information systems. Documenting information system.

- Data systems

Database management systems (DBMS). Architecture of DBMS. SQL language. Database design. Data modeling, Database modeling tools. Information system development tools.

## ELECTIVE COURSES

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. Gramm-Schmidt process of ortogonalization. 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 R2 and R3.

Course name: **GAME THEORY**
Number of ECTS credits: **6**

**Content:**

- The decision problems in strategic situations.
- Basic concepts of game theory: players, moves, income, matrix game with two players.
- Games in normal form: dominating moves, the best answer, Nash balance.
- Important examples of games in normal form: prisoners' dilemma, game of coordination, partnership struggle, Coin game.
- Random decisions: mixed moves, the existence of Nash balance.
- Dynamic games, games in the branched form: strategies, Nash balance, reversible induction, undergames, perfect balance of undergames.
- Important examples of games in a branched form: centipede game, ultimatum game, the game of negotiations, repeated prisoners' dilemma.
- Comparison of decision theory and human decision making: experiments.

Course name: **ALGEBRA III - ABSTRACT ALGEBRA**
Number of ECTS credits: **6**

**Content:**

- Introduction to number theory, Euclidean algorithm, congruences.
- Polynomials o in single variable. Euclidean algorithm. Zeros of polynomials. Solving algebraic equations. Polynomials in several variables. Symmetric polynomials. Fundamental theorem of algebra.
- Grupoids, semigroups and groups. Homomorphisms of groups. Normal subgroups and factor groups. Families of groups. Groups given by generators and relations. Sylow theorems.

Course name: **MATHEMATICAL MODELLING**
Number of ECTS credits: **6**

**Content:**

- Optimization (Minima, maxima, saddle points. Taylor's formula for scalar fields. Types of critical points. Finding optima under constraints. Discrete catenary. Newton's method. Method of continuation. Stability of trusses.
- Calculus of variations (Standard problem of variation calculus. Isoperimetric problems. Truss oscillations. Rotating axes.)
- Torsion (Navier equations. Torsion load. Torsion.)
- Statistics ($\chi 2$ test. Unbiased estimation. Statistical simulations.)
- Combinatorial optimization (Optimization problems. The matching problem. The transport problem. The shorest path on a graph. The maximal flow problem. The traveling salesman problem. Combinatorial optimization.)
- Linear programming (Linear program. Non-standard forms of linear programs. Terminology. Combinatorial nature of linear programming. The simplex method. The revised simplex algorithm).
- Sawing (Formulation of the problem. Algorithm. Avoinding the inverse matrix. The rucksack problem).
- Duality (Definition. Duality theorem. Optimality of simplex method.)

- Algebraic graph theory (The concept of a graph. Transitive envelope. Network. Cycles and co-cycles. Dimensions of subspaces in C and K. Basis in K. Solving Ax=χ. Basis in C.)
- Out of Kilter (The problem. Reduction. Duality. Minty's theorem.)

Course name: **INTRODUCTION TO NUMERICAL CALCULATIONS**
Number of ECTS credits: **6**

**Content:**
- Fundamentals of numerical computing. The floating point and rounding errors. Calculations in floating points. Stable computational processes and the problem sensitivity. The total error.
- Non-linear equations. Bisection. Tangent method: derivatives, implicit functions, systems
- nonlinear equations. Secant method. Algebraic equations.
- Systems of linear equations. LU decomposition and Cholesky decomposition. Gaussian elimination. Diagonally dominant and tridiagonal matrices. Problem sensitivity. Aposteriori error estimation. Neumann series and iteratively improvement of the accuracy.
- Eigenvalues. Power method, Inverse power method. Schur and Gershogorin theorem.
- Function approximation. Polynomial interpolation. Divided difference. Hermite interpolation.
- Numerical integration. Integration with polynomial interpolation. Composite rules. Gaussian quadrature formulas. Euler-Maclaurin formula
- Numerical solution of ordinary differential equations. Solving differential equations of the first order. The Taylor series method of obtaining solution. Simple methods, the order of the method. Methods of type Runge-Kutta.
- A linear programming. Convexity and linear inequalities. Simplex algorithm.

Course name: **BIODIVERSITY OF CULTURAL PLANTS**
Number of ECTS credits: **6**

**Content:**
Students get familiar with basic environmental requirements for each fruit species and with the role of various organs of fruit plants. Developmental stages of fruit trees, phenology, bases of bud differentiations and climatic factors that affect these processes are presented. During the vineyard work, students get acquainted with wine as an agricultural industry in the USA and the EU with its strengths and limitations. Students learn about the basic climate conditions that are necessary for successful cultivation of vine. From a technological perspective they evaluate the viability of vine cultivation in Mediterranean region. During the horticultural part of the subject the students get familiar with different types of vegetables with an emphasis on morphological and selection objectives for each species and their environmental growing requirements. In practical exercises the student is informed primarily by organography of fruit plants and vines. Students learn about different rootstock and basics of pruning. They get acquainted with the morphological differences and types of vegetables and their production technology.

Course name: **CONSERVATION BIOLOGY**
Number of ECTS credits: **6**

**Content:**
Conservation biology was developed in response to the rapid extinction of species. This is a new branch of biology that studies the biodiversity and its sustainable use. Its aim is to preserve biodiversity and provide opportunities for further evolutionary change. The course introduces the biodiversity crisis, its extent and causes. This crisis is widely recognized as one of the main threats to the long-term existence of human civilization. The students are presented the limitations of classical nature conservation on one hand, and insight into conservation of small populations and dynamic ecology on the other. The aim is to identify a set of factors (environmental, demographic, genetic, population, etc.), that affect viable population size and trigger extinctions. Students get insight into a set of interdependent processes that operate at different levels, and in the interaction reduce

biodiversity. Understanding of processes in small populations allows them to identify main sources of threat to target populations.

Course name: **ANATOMY AND HISTOLOGY**
Number of ECTS credits: **6**

**Content:**
This course is designed to address the organizational diversity of vertebrates by comparing organ systems of lower and higher vertebrates. Students will learn about the morphology of organs in relation to their function. They will learn about the structural development of organ systems, during the embryonic differentiation, and the close association of their function with the ecological conditions that accompanies the development history of vertebrates. In this course students will deal with the structure of vertebrates, functional significance of variations in the structure and the functions of the structures in the geological past. The course aims to provide knowledge of anatomy, physiology and histology to the extent that is sufficient for basic understanding of the structure and function of the human body in comparison with the bodies of other vertebrates. Students can upgrade the knowledge gained in this class in related courses, which relate to histology, anatomy and physiology.

Course name: **SYSTEMATIC BOTANY AND GEOBOTANY**
Number of ECTS credits: **6**

**Content:**
The aim of the course is to aknowledge the students with principles of systematic botany, plant evolution and geobotany. The Slovenian vegetation and flora is stressed, which provides the basics for understanding the biodiversity patterns in Slovenia as well as abroad. Slovenia (especially its SW part) with its high biodiversity is a country where the elements of different regions meet is a great place for studying the floral biodiversity and vegetation. The course also provides the addition to the General botany course from the 1st grade. The course gives the inmportant knowledge of domestic flora and vegetion, two important elements of national natural heritage.

Course name: **ENVIRONMENTAL MONITORING**
Number of ECTS credits: **6**

**Content:**
The course aims to acquaint students with the basic principles of chemical analysis. Course apply knowledge of the design, manufacture and application of modern measurement techniques and instruments in environmental monitoring.
Students deepen the knowledge of fundamental chemical principles and learn the basic analytical techniques used in determining the status of environment. At lectures students acquire theoretical knowledge, which can be upgraded to professional practice in the context of computational and laboratory exercises. Emphasis is placed on the correct analysis of the samples, their preparation for the measurement (solution or direct analysis of solid samples), and statistical processing of the results by checking the accuracy.
By addressing key problems in the course, students become familiar with various research methods and techniques that will allow them to deepen and acquire new knowledge, develop critical thinking and the ability to synthesise and apply acquired knowledge and skills in practice.

Course name: **GIS AND INTRODUCTION TO THEMATIC CARTOGRAPHY**
Number of ECTS credits: **6**

**Content:**
This course acquaint students with methods to solve geographic problems by using geographic information systems (further GIS) and the visualization of results. The introduction of organization of GIS has also been upgraded with more specific approaches to the spatial analysis. Major emphasis is given to the nature, capturing, processing and accuracy of spatial data, because the knowledge on their structures is of the utmost importance for the correct approach to solving the set of problems. For the students to be able to properly present the results of geographical research to other users is very important that they become familiar with the general laws of production of the thematic maps. In addition to the mathematical elements of maps and cartographic generalization, students will learn about appropriate ways of the cartographic design expressions.

Course name: **MARINE BIODIVERSITY**
Number of ECTS credits: **6**

**Content:**
The course provides students with knowledge on biodiversity of world wide oceans and seas and explanation of factors that influence on biodiversity. Students get familiar with benthic bionomy of the Medditerranean Sea, with stress upon the Adriatic Sea. The course also provides the basic characteristics and specialities of the Medditeranean and Adriatic fauna and flora. Recent changes in sea biodiversity that are consequence of global oceanographic and climate changes, and the antopogenic influence (bioinvasion, mariculture, epibiosis).

Course name: **MANAGEMENT OF PROTECTED AREAS AND SUSTAINABLE USE**
Number of ECTS credits: **6**

**Content:**
Protected areas are the most important instrument of protection of biodiversity and can significantly contribute to the socio-economically developing regions. Protected areas can achieve their objectives only if they are linked in a comprehensive and effective system. Such a system must be adequately supported by legal and sectoral basis, guaranteed and should be in the proper management of protected areas and sustainable funding.
Students are acquainted with the subject of the historical origins of protected areas in the world and Slovenia, they learn about the international categorization of protected areas. To understand the importance of their management they become familiar with different methods and approaches to the management of protected areas and legal issues and the situation in Slovenia, including the procedures for the designation of protected areas.

Course name: **SYSTEMATISATION, STANDARDISATION OF QUALITY AND PATENT LAW**
Number of ECTS credits: **6**

**Content:**
The course is dedicated to the presentation of systems of patent protection, with emphasis on the protection of inventions, biological material and genetic resources, which, with the development of modern technologies such as biotechnology and modern biotechnology in particular, is becoming increasingly important topic a in relation to decisions on the patentability of inventions. The goal of this course is a comprehensive presentation of the scope of patent protection, with the emphasis on the protection of biological material and genetic resources. Students will be in this course acquainted with the national and international system of patent protection, knowledge of which is crucial for understanding and enforcement of patent rights in different areas. They will be presented with the aspect of the use of patent literature, the use of various databases and other resources that are important for determining the state of technique, which is one of the key criteria for the granting

of rights. Knowledge on how to prepare a patent application and when an idea can become an invention, students will gain by the preparation of seminars and by using interactive approaches to specific cases in order to increase innovation among students.

Course name: **STATISTICAL METHODS IN GIS**
Number of ECTS credits: **6**

**Content:**
Students will learn the basics of spatial statistics, its evolution, strengths and weaknesses, the difference between it and the usual statistics and the use of its basic methods and computer programs, which are used for its application. They will learn about the inevitability of the use of quantitative methods in geography. In addition to basic principles they will acquire the knowledge about advanced static methods, with greater emphasis on the point and continuous events in the sampling. The acquired knowledge will allow them to do quantitative analysis of mass phenomena, which are the starting point for many, especially the socio-geographic researches. Students will put this knowledge to good use at work in many other courses, but they will also come in handy in the analyses carried out for seminar and master thesis.

Course name: **BIOGEOGRAPHY**
Number of ECTS credits: **6**

**Content:**
During lectures of the subject Biogeography students learn basic principles of distribution of diversity of life on earth surface and about processes and the historical and current ecological conditions that affect the distribution of species and communities. Students are acquainted about some of the leading hypotheses, which permit them to create separate hypotheses of observed phenomena. Students are also introduced to the fundamental principles of research work in biogeography, from descriptive to experimental, such as a various molecular techniques and the use of geographic information systems, allowing independent work while monitoring relevant scientific literature. During field courses students learn the characteristics of the Mediterranean biogeographical region and of the Balkan Peninsula.

Course name: **LIMNOLOGY**
Number of ECTS credits: **6**

**Content:**
In the lectures of the course of Limnology students learn the basic characteristics of water as a substance and its global distribution and circulation, and various forms of freshwater ecosystems. In following lectures they gain knowledge of the lighting and thermal conditions in inland waters: permeation and absorption of light in water, heat distribution in the rivers and lakes. They are presented with the annual dynamics of water circulation in lakes and water movement in rivers.
Students also learn about food chains in freshwater ecosystems and the links between their articles. Here, students focus on the chemical characteristics of inland waters and on the different distribution of dissolved oxygen in the running and standing waters in oligotrophic and eutrophic lakes, the salinity of inland waters. Students understand the concept of carbonate equilibrium and learn about the circulation of the main elements in rivers and lakes. They acquaint with plankton communities and their interactions, and interactions between land and water. Students learn about the composition of the sediments, organisms and processes conducted there. It also presents the benthic and fish communities. In the final part of the course are presented in ontogeny of inland water ecosystems and briefly paleolimnology and its importance.

Course name: **ECOTOXICOLOGY**
Number of ECTS credits: **6**

**Content:**
The course is devoted to the presentation of ecotoxicology and methods which provide high quality environmental risk assessment of chemicals. Ecotoxicology is presented in the narrow sense as a science that studies the harmful effects of chemicals on ecosystems, unlike toxicology, which pays full attention to studying the effects of individual substances in humans.
The aim of this course is to present the impact of chemicals on various ecosystems, the determination of the damage and ways to improve the situation and the prevention of further injury. Knowledge gain in the course enables students to understand the dynamics and biological balance of natural and artificially induced changes in the nature / environment, resulting from the impact of human activity in the use of chemicals. Attention is directed to find and common sense principles and methods in both science and the specificity of each of them. The topic ecology provides students with the basics of ecology knowledge. The emphasis is on understanding the importance of communities, population dynamics and genetics of populations in the evaluation of potential environmental effects of chemicals. Knowledge of toxicology is limited to the basic principles and methods. Students are also presented with inport of chemicals into the organism, the receipt and distribution of substances in various tissues in the body, metabolism and excretion from the organism.

Course name: **CELL AND MOLECULAR BIOLOGY**
Number of ECTS credits: **6**

**Content:**
In the course of Molecular and cell biology students will learn and understand the structure of different cell types and based on their structure, the basic operations of each cell type. The student will be also able to critically evaluate the obtained theoretical and practical knowledge of molecular and cell biology and use it in the work environment as well as in research and user environment. Students will acquire the ability to understand other subjects in this area and use the basic vocabulary of the subject matter as a scientific discipline in Slovenian and foreign language (English).

Course name: **GENERAL BOTANY**
Number of ECTS credits: **6**

**Content:**
The students are introduced to the general concepts of general botany, which represents the basis of other basic and applied fields of botany as well as the broader field of the sciences of life. Students learn and understand the basic structure of plant organisms on the level of macromolecules, subcellular microstructures, cells, tissues and whole organism. Emphasis is given to the adjustment of plant life in different environments both at cellular, anatomical and morphological level. Students learn the basic principles and forms of reproduction. Theoretical knowledge that students acquire during lectures is enhanced during laboratory work.

Course name: **GENERAL ZOOLOGY**
Number of ECTS credits: **6**

**Content:**
General zoology provides basics of zooological science that is important for understanding zoological objects (i.e. basic and aplicative zoological objects) through further study years. The objectives of general zoology are animal structure (morphology, anatomy), function, and basics of biodiversity (i.e. the processes that enable life and its continuation). It also provides the basics of Darwin's evolution and theories of origin of life. The knowledge on structure is given through different levels: citology histology, organography. Furthermore, the phylogenetic classification is explained, including the history of its development, its principles and rules of zoological nomenclature with cladistics. The systematics is represented as different hypotheses, not facts. Students can therefore also aknowledge the limits in the interpretation of fossil data and in construction of taxonomical and phylogentic systems. The object also gives the theoretical basics of species definitions in zoology.

Course name: **BIODIVERSITY AND ECOLOGY IN THE MEDITERRANEAN**
Number of ECTS credits: **6**

**Content:**
In the of course Mediterranean Biodiversity and ecology students discover the physical characteristics of Mediterranean area and the biodiversity in which it occurs. On the basis of acquired knowledge students can recognize the specificity of the Mediterranean area in Europe and beyond and can understand the importance of space as a major generator of biodiversity in Europe and elsewhere in the world. Students learn about different forms of the Mediterranean landscape and the importance of human performance on its image today's time and past. They learn about the basic factors of land degradation and desertification of the Mediterranean landscape and its impact on biodiversity. They cognizance of certain environmental remediation degraded Mediterranean landscape. Students gain a holistic integration of content look at this complex area, because of pronounced multidisciplinary of course, which links some basic knowledge of biology geography, geology, climatology and history. In the context of the course are introduced to different approaches and research methods that will allow them the ability to synthesise and in particular the development of critical thought.

Course name: **EVOLUTION BIOLOGY**
Number of ECTS credits: **6**

**Content:**
Students will be acquainted with the fundamentals of evolutionary biology as a universal concept on which is based the biological science. Throughout the history of the development of evolutionary thought come to the Darwinian evolution, which was later accompanied by the development of modern neo - Darwinists. During the tense confrontations between evolutionism - creationism students can understand the importance of evolution for the modern biology, due to the role it plays in the formulation of hypotheses and their testing. The course is aimed at understanding the foundations of Darwinian evolution (spontaneous variation - selection), participants are introduced to the basic hypothesis of the creation of life. The course introduces the basic concept of connectivity of modern biology, in the light of evolutionary biology. This course will allow the students the understanding of fundamental mechanisms of change and adaptation of the living world. The relatively high proportion of independent work is aimed at promoting and developing critical diverse biological interpretations of the facts in the light of evolution biology, which can be achieved by self-studying and presenting and defending the conclusions in the form of seminars.

Course name: **STOCHASTIC PROCESSES II**
Number of ECTS credits: **6**

**Content:**

- Discrete-time Markov chains, classification of states, strong Markov property, hitting probabilities, ergodic properties.
- Continuous time Markov chains: definitions, strong Markov property, left and right equations, birth and death processes, branching processes, ergodic properties, applications.
- Martingales, optional stopping times, convergence theorems, applications.
- Brownian motion: construction of Brownian motion, properties of trajectories, Markov property, the reflection principle, martingales connected with Brownian motion
- Poisson processes: abstract definitions, transformations of Poisson process, excursion theory.

Course name: **THEORETICAL COMPUTER SCIENCE II – FORMAL LANGUAGES AND COMPUTABILITY**
Number of ECTS credits: **6**

**Content:**
Finite automata and regular expressions:

- Computation model, finite automaton – DFA and NFA
- Alphabet, language, regular expression/language
- The relation between DFA, NFA and regular expressions
- Using FA to solve problems
- RE pumping lemma, non-regular languages

Grammars, context (non)free languages and stack automata

- Grammar, derivation tree, attribute grammar
- Context-dependent and context-free languages, stack automaton
- Grammar normal forms: Greibach, Chomsky (CNF)
- Transforming grammars into CNF
- CYK algorithm
- Pumping lemma for CFG
- Operations on languages (intersection, union ...)

Turing machines and their languages:

- Turing machine and its derivations, RAM
- Church-Turing thesis
- Recursively enumerable languages, Chomsky hierarchy
- Unsolvable and undecidable problems, the stopping problem, Rice theorem and PCP

Introduction to the theory of complexity:

- P and NP – relation between them
- Problem translation, NP completeness

NP complete problems

Course name: **THEORETICAL COMPUTER SCIENCE III – INFORMATION THEORY**
Number of ECTS credits: **6**

**Content:**
**Introduction to information theory**
What is information and coding

**Mathematical foundations of information theory**
Calculus: exponential and logarithmic functions, limits, convergence, convexity
Probability:
Random variables, Inference, Expectations
Jensen's and Gigbbs inequality

**Discrete entropy**
Entropy,
Joint Entropy,
Conditional Entropy,
Relative entropy,
Mutual Information,
Stochastic Process and Markov Chains,
Asymptotic Equipartition Property Theorem (AEP)

**Data Compression**
Examples of codes
Kraft inequality,
Optimal Codes
Shannon-Fano coding
Huffman codes
Arithmetic coding

**Channel Capacity**
Examples of Channel Capacity:
Noiseless Binary Channel, Noisy Channel with Nonoverlapping Outputs, Noisy Typewriter, Binary Symmetric Channel
Channel Coding Theorem
Hamming Codes
Linear-Block Codes

**Differential Entropy**
Differential Entropy
Relation of Differential Entropy to Discrete Entropy
Joint and Conditional Differential Entropy
Relative Entropy and Mutual Information

**Gaussian Channel**
Definitions
Shannon-Nyquist sampling theorem,
Converse to the Coding Theorem for Gaussian Channels, Channel capacity,
Bandlimited Channels

Course name: **PROGRAMMING III – CONCURRENT PROGRAMMING**
Number of ECTS credits: **6**

**Content:**

- Concurrent programming concepts; Techniques for parallelizing programs
- Synchronization, atomic actions.
- Critical sections: locks
- Parallel programming: barriers, barrier synchronization, bag of tasks paradigm
- Semaphores: basic concepts and uses, the method of passing the baton
- Introduction to Pthreads library
- Monitors and conditional variables: basic concepts, synchronization techniques, programming
- Distributed memory programming:
  message passing, remote procedure call, remote method invocation
- Introduction to MPI
- Examples of multithreaded, parallel and distributed programming.

Course name: **PROGRAMMING II – CONCEPTS OF PROGRAMMING LANGUAGES**
Number of ECTS credits: **6**

**Content:**

- Introduction
- Lambda calculus
- Syntax
- Basic structures
- Functional languages
- Imperative languages
- Types
- Modules
- Objects and classes

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, threads, inter-process communication, critical conditions, critical regions, 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, sftware levels of I/O, disk, clock, character terminals, graphical interfaces, network terminals, other I/O equipment.
- File systems, 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: **SYSTEMS I - HARDWARE**
Number of ECTS credits: **6**

**Content:**

- Introduction to information theory and coding.
- Computer arithmetic. Arithmetic in fixed and floating point. Basic operations: addition, subtraction, multiplication, division. Carry over. Booth's procedure.
- Switching functions and circuits.
- History of computer systems and an introduction to machine computing.
- Instructions. Basic properties of instructions. Instruction formats. The composition of instructions according to the addressing modes, the number of explicit operands, storage methods of operands in CPU, type of operations and type and length of operands. RISC and CISC computers.
- Central processing unit.
- Memory and cache.
- Virtual Memory
- Input and output: Operation of I/O devices. Connecting of I/O devices. Direct memory access and I/O processors.
- Parallel computer systems and advanced processor architectures.

Course name: **COMPUTER NETWORKS**
Number of ECTS credits: **6**

**Content:**

- Basic definitions and classification of computer networks
- The reference models ISO OSI and TCP/IP.
    - The physical layer (signal tramsmission)
    - The data-link layer (error detection and correction, medium access, flow control)
    - The network layer (datagrams, routing, congestion control algorithms)
    - The transport layer (connection oriented and connection-less service, protocols, multiplexing)
    - The presentation layer (coding and security)
    - The application layer (sample Internet applications)
- Communication technology integration (wired, wireless and mobile), modern information services (server/client model, P2P), web services.

Course name: **PLANT BIOTECHNOLOGY**
Number of ECTS credits: **6**

**Content:**

The course informs students with the opportunities in research and with the practical knowledge to solve important problems in plant biotechnology and molecular breeding. The program informs the students with a detailed knowledge of molecular biology and genetic manipulation of plants. For familiarization with the current concepts and methodologies, the model plant systems, which are used in modern plant biotechnology laboratories, are presented to the students and on the other hand, how these technologies can be used to modify and improve the economically important crops.The emphasis is on practical applications involving the use of molecular and bioinformatic methods that are used for the study of plant genomes, to evaluate, use and to conserve genetic

diversity, for the identification and protection of plant cultivars and for the determination of plant pathogens. Case studies demonstrate the commercial application of the products that have been developed through plant biotechnology. Students will be also informed about the ethical issues that arise in the application of biotechnology, together with the treatment of bio-safety and release of genetically modified crops into the environment.

Course name: **PLANT MOLECULAR DIAGNOSTIC**
Number of ECTS credits: **6**

**Content:**
The course informs students with the latest knowledge from the fields of molecular diagnostics with emphasis on the methods and applications used on plants. Students are informed with the applications and usefulness of modern molecular methods (PCR, PCR in real time, types of electrophoresis, Southern blot hybridization, detection of fluorescently labeled DNA fragments, detection with antibodies) used in the identification of agricultural plants for the purpose of improving it (marker assisted selection) or for the management of gene banks, the diagnosis of plant pathogens, the determination of genetically modified plants (GMP) and for the determining of genetically modified organisms (GMOs) that are added to the foods.