A: Biotechnology and Bioanalytics

Bioorganic Chemistry

11-BCH-0701 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
- Gain knowledge and understanding of bioorganic synthesis, analytical methods and their applications; - Learn to perform bioorganic synthesis methods

Content
- Molecular characterisation of bioorganic molecules, especially biopolymers, including peptides, proteins, nucleic acids and carbohydrates, synthesis methods and strategies for peptides, carbohydrates, and nucleic acids - Chemical modifications of peptides and proteins - Introduction of fluorescent dyes, radioligands, biotin and their applications - Molecular probes for biological purposes and their selective introduction - Drug development based on peptides, proteins, nucleic acids and carbohydrates - Combinatorial synthesis strategies, their applications and assay methods (HTS screening) in the pharmaceutical industry - Analyses to characterize peptides, proteins, carbohydrates and nucleic acids The courses can be accompanied by tutorials

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation (20 min) 1 Practical Course Protocol	Oral Exam, 30 min

Physiology of the intestinal microbiome

11-BCH-0725 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	30	-	60
Self-study [h]	40	90	-	50

Objectives

Successful graduates of the module will have gained a basic understanding of the microbiome and several disciplinary topics in microbiome research.
This includes in particular:
- Knowledge of the human microbiome in health and disease, the interplay between the microbiome and the immune response
- Knowledge of interactions of bacteria, viruses and fungi with the human microbiome
- Knowledge of the bidirectional interactions between the gut microbiome and the brain
- Knowledge of the influence of nutrition on the microbiota
- Insights into the chemical-microbiome interaction
- Overview of molecular biological methods in microbiome research

Content

Lecture: Investigation of the human microbiota, Microbiome composition, Gut microbiota and its metabolites: possible effects on the host, Oral microbiota, Skin microbiota, Gastrointestinal microbiota, The microbiota-gut-brain axis: focus on basic communication pathways, Chemical-microbiome interaction, Intervention, prevention and the brain: prebiotics, probiotics and fecal transplants

Seminar: Molecular biological methods of microbiomes, statistical analysis of microbiome data with R, literature seminar

Practical course: Fundamentals and principles of microbiome analysis (16S amplicon sequencing, metaproteomics, metabolomics)

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Written Exam, 60 min

Stereoselective Synthesis in Organic Chemistry

13-BCH-0712 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
Learning about stereoselective C-C, C-O and C-N linkage reactions in theory and practice

Content
The lecture will discuss aspects of chemo-, regio- and stereoselectivity of organic reactions as well as the control of absolute stereochemistry by using chiral auxiliaries and catalysts. This includes in particular oxidation and reduction reactions, C-C linking reactions, transition metal catalyzed reactions and pericyclic reactions. In the accompanying practical course, preparations are synthesized which are fully characterized by NMR, IR and mass spectroscopy. The courses can be accompanied by tutorials.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
-	Written Exam, 90 min

Protein crystallography

13-BCH-0705 – compulsory elective – 1st semester

Workload				
300 hrs				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15		75
Self-study [h]	50	65		65

Objectives
Understanding of the basics of protein structure determination using X-ray crystallography and competence in the interpretation and use of structures in the protein database

Content
Using the method of X-ray crystallography, the spatial structures of organic molecules, inorganic solids and biological macromolecules can be determined at atomic resolution. In the lecture, the basics of these methods relevant to natural scientists are taught in a practical way. The following topics are covered. The focus is on biocrystallography. Crystallization, crystals, symmetry and space groups, X-ray sources and detectors, data collection, diffraction of X-rays, phasing, model construction and structure visualization, structure refinement, validation and interpretation, comparison with structure determination using NMR and CryoEM.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
none	Module examination: written exam 90 min., with weighting: 3; practical course (report), weighting 1

Molecular biology, biotechnology and ecophysiology of plants

11-BIO-203 – compulsory elective – 1st semester

Workload				
300 hrs				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	30	45	-	105

Objectives

- Knowledge of biotechnological applications of plants and of current genetic methods for their improvement
- Insights into the acclimation of photosynthetic organisms to changing environmental conditions and into experimental methods for investigating this acclimation
- Insights into current research questions

Content

- Introduction to biotechnological applications of plants and algae
- Molecular-genetic methods for plants and algae (methods for transformation and mutagenesis, mutant libraries, CRISPR etc.)
- Plant secondary metabolism and production of bioactive compounds, metabolic engineering
- Carbon allocation and determination of a physiological fingerprint using Fourier-transform infrared spectrometry (FTIR)
- In the laboratory practical course, students have the opportunity to work on a current research project in the Plant Physiology group.
- In the seminar, students present the projects of the practical course and the results achieved.

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol 1 Seminar Presentation 20 min (weighting: 1)	Written Exam 60 min (weighting 3)

Molecular Modelling

11-BCH-0703 – elective – 1st semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	-	-	90
Self-study [h]	90	-	-	90

Objectives
Learning the most important methods of molecular modelling and their application to solve biochemical problems.

Content
Fundamentals of methods for calculating molecular structures and molecular properties (quantum chemistry, molecular mechanics, molecular dynamics, docking, etc.); acquisition of practical skills in the use of the most important software packages for molecular modelling. The courses can be accompanied by tutorials.

Participation Requirements
None

Pre-Examination Requirements	**Examination**
1 practical course protocol	Exam 90 min, with weighting: 1

Electrobiotechnology

11-BCH-0723 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	30	-	60
Self-study [h]	80	50	-	50

Objectives

When successfully finishing the module, one will master the basics of microbial electrochemistry and have in-depth knowledge of electrobiotechnology.
This includes in particular:
- In-depth knowledge of natural bioelectrochemical processes in cells as well as the bioelectrochemistry of enzymes and microorganisms;
- Carrying out thermodynamic analysis of microbial systems;
- The selection and application of methods of microbial electrochemistry/electrobiotechnology;
- Knowledge on microbial electrosynthesis and electroorganic synthesis for electrobiorefineries.

Content

Lecture: Physical-chemical fundamentals of electrochemistry, microbial electrochemistry, methods in microbial electrochemistry, microbial electrochemical kinetics, applications in electrobiotechnology, electrosynthesis, selected aspects of electroorganic chemistry in aqueous systems, fundamentals of electrobiorefineries

Seminar: Basics of microbial thermodynamics and kinetics, thermodynamic growth models of microbial systems and their application, thermodynamics and modeling of electroactive microorganisms, literature seminar

Practical course: Basics of cyclic voltammetry, protein film voltammetry, electroorganic synthesis, basics and principles of bioelectrochemical cultivation

Participation Requirements

Basic knowledge of physical chemistry, analytical chemistry, biochemistry, microbiology, molecular biology, mathematics

Pre-Examination Requirements	**Examination**
1 oral presentation (20 min.) in the seminar, 1 protocol for the practical course	Written exam, 90 minutes

Molecular Biotechnology I

11-BCH-0721– compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	35	30	65

Objectives

Successful graduates of the module can describe the regulation and genetic organization of natural and artificial metabolic pathways for the production of low and high molecular weight products, balance biosyntheses and evaluate their economic efficiency and sustainability. They can design genes *in silico*, construct them in the laboratory and use them functionally in microorganisms to produce valuable substances. They are familiar with the molecular basis for this and can use genetic and metabolic engineering to specifically modify microbial cells and adapt them to technical requirements.

Content

Genetic engineering, systems biotechnology, microbial physiology (metabolic and energy metabolism), sequencing, various microbes as host organisms for production processes.

Current developments in the field of molecular biotechnology

Gene design and gene synthesis, genetic engineering, metabolic engineering, engineering of genetic functional modules, delivery of gene constructs. Practical work with E. coli. Biocatalysis. Sustainability.

In the seminar, each student must give a 20-minute presentation on a given topic and then discuss it in the group.

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Seminar presentation 1 Practical Course Protocol	Written Exam, 90 min

Sequence Analysis and Genomics

10-202-2207– compulsory elective – 1st semester

Workload				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	-	15	60
Self-study [h]	84	-	28	68

Objectives

After active participation in the module “Bioinformatics of RNA and Protein Structures”, students will be able to
- interpret sequence data in a biological context,
- understand the basic algorithms for sequence comparison in sufficient depth to select the appropriate tools for specific applications,
- apply the basic algorithms for sequence comparison and modify them in a simple way,
- work independently on simple tasks from comparative genomics and
- - present and critically discuss the results of their practical work.

Content

Lecture “Sequence Analysis and Genomics”:
- Exact and approximate search in sequence data
- Local and global alignment of sequences
- Phylogenetic reconstruction in theory and practice

A special lecture is offered on one of the following topics:
- “Evolutionary Algorithms”: Combinatorial Optimization Problems; Simulated Annealing; Value Landscapes; Genetic Algorithms; Genetic Programming
- “Hidden Markov Models in Bioinformatics”: Basics of HMMs: Baum-Welch and Viterbi algorithms; parameter estimation; pairwise alignments with HMMs; profile HMMs for sequence families; multiple alignments with learning from profile HMMs.
- “Prebiotic evolution”: Astrophysical basics; Prebiotic chemistry; Chemical reaction networks; The RNA world and alternative scenarios; Mathematical models: Quasispecies, hypercycle, and co; The genetic code
- “Population Genetics”: Introduction to the theoretical foundations and tools of population genetics and population genomics.
- “Epigenetics”: Types of epigenetic modifications; definition of epigenetics; introduction to experimental techniques with a focus on their evaluation; mapping of sequencing data; peak calling methods;

- “High-throughput sequencing”: bioinformatic definition of genome and gene; generation and analysis of omics data such as genomes, transcriptomes and proteomes; algorithms for the analysis of large amounts of data from high-throughput sequencing, including high-speed alignment algorithms based on suffix arrays and the Burrows Wheeler transformation such as “BWA” and “BOWTIE”; algorithms for the reconstruction of genomes based on De Bruijn graphs.

A practical course is offered in one of the following subject areas:
- “Nucleic Acids”: practical use of standard programs (including “blast”, “clustal” and “muscle”) for genome-wide search and sequence comparison; search for structured information, such as protein-coding regions, non-coding RNAs or regulatory elements in genomes with the aid of current tools and methods (e.g. “Proteinortho”, “RNAz” or “Augustus”); use of data sources such as the “UCSC Genome Browser”.
- “Phylogenetic reconstruction”: Reconstruction of phylogenies with standard tools such as “phylip”, “MEGA” or “NeighborNet”; problem-oriented selection of a method (maximum parsimony, maximum likelihood or distance-based); visual representation of events and changes on evolutionary time scales (e.g. with “TreeViewer” or “iTOL”)
- “High-throughput sequencing”: databases and standard file formats of sequencing data; basic evaluation and quality control of data from sequencing experiments; practical introduction to basic evaluation programs such as “samtools”, “bedtools” or other evaluation methods made available online; graphical representation of results.

- “Population genetics”: Methods for analyzing data on genetic polymorphisms and genomic diversity as well as mathematical models for modeling population genetic effects (such as mutation, drift and selection) in evolution. In the practical courses, students are encouraged to work independently; the focus is not on the results, but on creating and refining solution approaches. The implementation takes place in a 2-week block practical course. An exercise accompanies the lecture in which presented algorithms are implemented and deepened and presented programs are applied. - Language of instruction: English or German - Examination language: English or German

Participation Requirements
None.

Pre-Examination Requirements	**Examination**
Completed final report in course project (15 minutes)	Oral exam, 30 min

Biotechnology and Cell Culture Techniques

11-BCH-0704 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
Knowledge and understanding of methods for cell and tissue cultivation as well as tissue engineering. Implementation of methods for the generation of 3D *in vitro* reaggregates and tissue equivalents and their use for cell biology issues. Application of classical methods for the characterization of 2D and 3D tissue cultures (microscopy, immunocytochemistry / expression analysis of markers) as well as modern bioelectronic real-time monitoring techniques for the analysis of cellular properties such as migration behaviour.

Content
Fundamentals of eukaryotic cell culture, use of cells, biomaterials and complex scaffold structures for tissue engineering. Organ-specific development and cultivation of 2D, 3D and complex tissue models for *in vitro* and therapeutic applications. Functional real-time monitoring of cell culture conditions and cell functions with microsensors. The courses can be accompanied by tutorials. In the seminar, each student must give a 15-20 minute presentation on a given topic and then discuss it together.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral Exam, 30 min

Bioengineering: Biofabrication of Organ-on-Chip Technologies

11-BCH-0823 – compulsory elective– 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15		75
Self-study [h]	50	65		65

Objectives

Based on the lecture, students can apply and critically reflect on the essential principles of biofabrication in the field of biomicrofluidics and biosensor technology to practical, chemical-biological problems. In the practical course, students learn how to create chip designs independently using CAD programs and, based on this, how to manufacture biochips using various microsystem techniques. After active participation in the module, students will be able to plan and carry out the analysis of tissue cultures using specific optical and bioelectronic methods. In the accompanying seminar, students will independently develop research questions in the field of current biofabrication and present them using all available media.

Content

Basic strategies and methods of micro- and biofabrication as well as the analysis of organ-on-chip systems for biotechnological applications. Design, assembly technology and material science for the production of biochips using additive (3D printing) and photolithographic (clean room) processes. Integration of tissue models on microelectrode arrays and microfluidic chips. Teaching of analytical methods to characterize biochips and their integrated tissue cultures. Furthermore, current approaches on biochips in the field of analysis of cellular physiology, signalling pathways, organ replacement or high-throughput screening in the context of drug development and safety testing are discussed.
The courses can be accompanied by tutorials.

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral Exam, 15 min (Weighting 1) Seminar presentation 15 min (Weighting 1)

Biophysical Methods in Medicine and Biology

09-BIO-0808 - compulsory elective - 2nd semester

Workload 10 credits = 300 hours of work

Teaching units

	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	-	-	90
Self-study [h]	180	-	-	0

Objectives

- Background knowledge and theoretical handling of different biomedical relevant methods and processes
- Practical exercises in handling, advantages and assessment of methodological limits

Content

- **NMR**
  Basic knowledge of spectroscopy, protein structure analysis, 2D NMR experiments (COSY, TOCSY, HSQC), isotopic labelling of proteins
  Examples: structure of membrane proteins and amyloids
- **MRT**
  Basic knowledge of MR imaging in research and medicine, detection options in the human body,
  Examples: zebra fish as a model for alzheimer's disease
- **Fluorescence Methods (Confocal Microscopy) and Radiation based Methods (X-Ray, CT, Nuclearmedical Methods)**
  Basic knowledge of the methods, labelling of (multiple) fluorescence molecules, cell applications; from Ion Beam Methods (PIXE) up to CT, scintigraphy, PET
  Examples: drug delivery systems
- **Mass Spectroscopy**
  Basic knowledge and characteristics of different MS-approaches (EI, ESI, MALDI) desorption approaches for analysis of surfaces (MS imaging)
  Examples: analysis of lipids
- **Molecular Dyanmics Simulations**
  Monitoring structure, function and dynamics of proteins with computer simulations

Participation Requirements

none

Pre-Examination Requirements	Examination
1 Practical Course Protocol	Oral Exam, 30 min

Bioinformatics of RNA- and Protein-Structures

10-202-2208 – compulsory elective – 2nd semester

Workload				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	-	15	60
Self-study [h]	84	-	28	68

Objectives

After actively participating in this module, students should be able to:

- describe RNA and protein folding using the underlying physical and chemical processes and laws,
- apply the relevant standard algorithms and modify them in a simple way,
- independently work on tasks from the field of structural biology and develop suitable work-flows, and
- present and critically discuss the results of such work

Content

Content of the main lecture "Bioinformatics of RNA and protein structures":

- "RNA secondary structures": thermodynamic folding, folding kinetics, phylogenetic structure reconstruction, protein threading
- "3D structures": molecular dynamics and molecular modelling, distance geometry protein folding, models from statistical mechanics, lattice models.

An exercise accompanies the lecture, in which the algorithms presented are implemented and deepened and the programs presented are applied.

Additionally, a special lecture is part of the module, and will treat one of the following subject areas:

- “Interaction and modification of biomolecules": representation, recognition and prediction of sequence motifs that occur in connection with the interactions of biomolecules (DNA, RNA, protein); functionality of specific HTS methods for measuring interactions, e.g. ChIP-seq, CLIP-seq, Y2H, and their computer-assisted evaluation; approaches for adapting folding algorithms for modeling interactions between RNA molecules; complexity and structure of protein-protein interaction networks.
- “Bioinformatics in Epigenetics": Variability and stability of DNA methylation and histone modification patterns; necessary steps and algorithms for the evaluation of large amounts of data from high-throughput sequencing in the field of epigenetics, including 3D organization of the nuclear genome, Hi-C-seq, abstraction and modeling of epigenetic processes and their dynamics, e.g. Gillespie algorithm; approaches of models for ‘epigenetic switches’ and ‘chromatin computation’.
- Translated with DeepL.com (free version)
- Translated with DeepL.com (free version)
- "Theory and application of dynamic programming": editing distance on sequences and trees, longest common subsequences and partial order, Bellman’s principle, algebraic dynamic programming.
- "Analysis of gene expression data": fundamentals of gene expression and micro-array technology; clustering algorithms and machine learning methods for gene expression data; expression databases.
- "Fitness landscapes and molecular dynamics": pathways of protein and RNA folding; simulated annealing; neutral networks; knowledge-based potentials.
- "Modelling of tissue organisation processes": Cellular automata for simulating growing cell aggregates; Stochastic description of growth of multi-part systems on a grid: master equations; Deterministic limit of the stochastic description; Stochastic description of colloid particles in the continuum: Langevin equations; From the colloid particle to the cell: adding cell growth and cell division; Cells as deformable, compressible objects: basic equations from continuum mechanics; Modelling of tumour growth *in vitro*: hybrid approach to combining single-cell representations with continuum equations for nutrients; Two-dimensional fluid and elastic membranes; Tissue layers: early embryogenesis and intestinal glands.

A course project is part of the module. The project will relate to one of the following subject areas:

- "RNA structures": Practical use of the "Vienna RNA package" and other tools for handling RNA structures
- "Protein structures": Practical aspects of protein structure prediction, including homology search and modeling (e.g. with Rosetta) and protein threading with "Critical Assessment of Techniques for Protein Structure Prediction" (CASP) as a basis.
- "From structure to function": Computer methods and software for the functional characterization of RNAs or proteins. (e.g. with the help of dN/dS tests, co-evolution analyses, ancestor reconstruction and annotation of protein domains)

Participation Requirements
None.

Pre-Examination Requirements	**Examination**
Completed final report in course project (15 minutes)	Oral exam, 30 min

Biochemistry of Receptors and Signal Transduction

11-BCH-0801 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
Knowledge and understanding of receptors, their ligands and signal transduction mechanisms, as well as their applications, learning how to carry out binding and signal transduction assays

Content
Basic mechanisms of signal transduction in cells Knowledge of the main receptor classes as well as their ligands and signal transduction mechanisms, activation and regulation of signalling in living cells In particular, steroid receptors, G protein-coupled receptors, tyrosine kinase-coupled receptors and ligand- and voltage-gated ion channels are discussed. Furthermore, down-stream effects, such as phosphorylation, ubiquitinylation, activation/deactivation of transcription factors, cell migration and cytoskeleton rearrangements are discussed. Apoptosis versus growth, proliferation and cell cycle responses are included. Further topics include knowledge of the function and mechanisms of transport proteins. The courses can be accompanied by tutorials.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation (20 min) 1 Practical Course Protocol	Oral Exam, 30 min

RNA Biochemistry

11-BCH-0804 – compulsory elective – 2nd semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	80	-	65

Objectives
Understanding of RNA functions in transcription and regulation of cellular processes in pro- and eukaryotes; natural and artificial ribozymes; molecular biological use and medical applications of microRNAs, antisense RNA, RNA interference and ribozymes; RNA viruses: influenza and SARS-CoV2; mRNA-based vaccines

Content
RNA functions; RNA world; RNA-based catalysis; in vitro evolution strategies for the development of new functions in RNA molecules: aptamers and ribozymes; riboswitches; preparation and handling of in vivo and in vitro RNA; characterization of RNA/RNA and RNA/protein interactions.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral exam, 30 min

Chemical Biology

13-BCH-0814 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45 h	15 h	-	75 h
Self-study [h]	60 h	30 h	-	75 h

Objectives

Methods for investigating protein functions using small organic molecules

Content

1. Introduction to chemical biology

2. Biochemical and cell-based assays for bioactivity analysis of chemical substances

3. Enzymes as target structures for organic substances: protein kinases and their inhibitors, activity-based proteomics

4. Protein-protein interactions as target structures for organic compounds: peptidic and non-peptidic inhibitors, approaches for the development of new antitumor drugs, small-molecule inhibitors of SH2 domains, syntheses of phenylphosphate mimetics, synthesis of prodrugs

5. Targeted protein degradation: hydrophobically-tagged small molecules, proteolysis-targeting chimera (PROTACs).

6. Bioorthogonal chemistry: Staudinger ligations, Cu(I)-catalyzed azide-alkyne cycloaddition (CuAAC), ring strain-mediated cycloadditions

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Written Exam, 90 min

Molecular Anthropology

31-BIO-0805 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
Understanding molecular evolution in terms of genome, transcriptome, and proteome evolution; using DNA sequences (ancient and modern) to study population history. Evolutionary processes and selection in the course of human evolution; analysis of ancient DNA; analysis of DNA sequencing data; understanding of evolutionary models in relation to DNA sequences; analysis of human migration and demographic processes; analysis of human-associated microbial communities and pathogens.

Content
Mechanisms of genome evolution; understanding of evolutionary mechanisms (drift, positive, negative and balancing selection; Preparation and analysis of RNA and DNA, especially ancient DNA; analysis methods for large data sets (e.g., whole genomes). The courses can be accompanied by tutorials**.**

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Oral Exam, 90 minutes, in groups of students

Molecular Biotechnology II

11-BCH-208 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	15	60
Self-study [h]	50	15	65	50

Objectives
Independent operation of bioreactors, quantitative description of material conversions in bioreactors. Acquisition of skills in the quantitative description of biological processes. Calculation of maximum possible yields in production systems by quantifying material flows. This lays the foundation for describing the sustainability of bioprocesses. Modelling approaches of systems biology and own (biological) data sets are used. Creation of models, processing of data, process simulation. Both stoichiometric and thermodynamic approaches are used to describe different processes in the fields of white and industrial biotechnology.

Content
Lecture: Molecular Biotechnology II lays the methodological foundation for modeling biological systems (quantitative physiology, material flow analyses, metabolic networks and interactions, thermodynamics). Examples from the field of industrial production using microorganisms are used to demonstrate potential applications. Exercise and seminar: Parallel to the lecture, an exercise will be held, which takes up the lecture examples and enables the participants to model and simulate the examples themselves and to develop a concept of predictive estimation, which then allows them to make theoretical predictions about bioprocesses. Literature examples. Practical course: Use of recombinant production strains (biocatalysts) in laboratory bioreactors for the production of a low molecular weight pharmaceutical synthon, product recovery & purification and quantitative process evaluation (economic, ecological, sustainability).

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar presentation 1 Practical Course Protocol	Written Exam, 90 min

Molecular Genetics

11-BCH-0813 – compulsory elective – 2nd semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15		75
Self-study [h]	50	65		65

Objectives
Knowledge of molecular genetic regulatory mechanisms in pro- and eukaryotes; learning and carrying out gene mapping and complementation studies on simple model organisms; mutational analysis

Content
Genetics of bacteriophages and mobile genetic elements; position-specific recombination and transposition; organelle genetics; methods of recombinant gene expression; methods for the identification of genetic elements (e.g. transposon tagging, enhancer trapping); molecular mechanisms of ageing; 1st, 2nd and 3rd generation DNA sequencing methods; artificial genomes and molecular circuits

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Oral exam, 30 min

Graphs and Biological Nets

10-202-2205 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	15	-	45
Self-study [h]	84	28	-	83

Objectives
After active participation in the module “Graphs and Biological Networks”, students will be able to - formulate and explain basic terms and concepts of graph theory, - model biological questions as graph-theoretical problems and solve them using suitable algorithmic approaches and - interpret and critically discuss the results in the context of the biological problem.

Content
Basic Lecture: - Basic properties of graphs: Context, planarity, circles, colorings - Random graphs Special lecture/seminar: current research topics, e.g. - Metabolic networks: flow analysis, organizations, network evolution - Gene regulatory networks: dynamics, stability, - Models of complex biological networks: growing networks, scale-free, self-similarity

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation (30 min) Practical Course Results	Oral Exam, 30 minutes

Working as a Scientist in the Lab and in the Office

11-BCH-0903 – compulsory – 3rd semester

Workload				
5 credits = 150 hours of work				
Teaching units				
	Lecture	Seminar	Colloquium	Practical course
Attendance time [h]	30	30	15	-
Self-study [h]	30	45	0	-

Objectives
Learning working methods and techniques in the scientific presentation of data, publication of results, data access, literature and patent research, learning methods of personnel management and responsibility as well as conflict resolution

Content
Methods for obtaining scientific data and their presentation (lecture, publication, literature and patent research), concepts of personnel management and responsibility, as well as conflict resolution, business management aspects in science Exemplary preparation of literature, personnel management and presentation in the seminar, as well as participation in current scientific colloquia The courses can be accompanied by tutorials.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
none	Scientific poster

Practical Laboratory Course

11-BCH-0904 – compulsory– 3rd semester

Workload				
15 credits = 450 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	-	15	-	180
Self-study [h]	-	35	-	220

Objectives
Learn techniques and methods that qualify students to write a Master's thesis

Content
Practical implementation of current methods in biochemistry that are required for the preparation of a Master's thesis. Learning special techniques to prepare for independent scientific work The courses can be accompanied by tutorials. In the seminar, each student must give a 30-minute presentation on a given topic and then discuss it together

Participation Requirements
6 completed compulsory elective modules of compulsory elective placeholders 1-6, 4 of which were passed

Pre-Examination Requirements	**Examination**
none	Written report

Entrepreneurship Management

11-BCH-0960 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	-	30	30	-
Self-study [h]	-	120	120	-

Objectives

After successfully participating in the module, students will be able to describe the fundamentals of entrepreneurship management. They will be capable of independently developing solutions for real-world problems in a team setting, thereby deepening their knowledge autonomously. Building on this, they will be able to independently derive, develop, and present corresponding business models and business plans from entrepreneurial ideas.

Content

Within a lecture series, fundamental knowledge and skills in the field of entrepreneurship management are imparted, providing insights into the practice of starting a business. This lecture series is designed to accompany students throughout the module and enable them to implement a semester project.

The content of the lecture series is aligned with the progression of a practical project, primarily covering the following topics:

- Business model
- Market research
- Marketing and sales in a startup
- Organization of a startup
- Financing of startups
- Team management

In an exercise session that alternates with the lectures, students are given topic-specific tasks to deepen the knowledge conveyed. The tasks, oriented around the project questions presented, are to be solved independently by the students.

Participation Requirements

Pre-Examination Requirements	**Examination**
	Project work: Presentation (10 minutes) with written report (12 weeks)

Methods and Approaches in Geomorphology, Applied Geoecology and Quaternary Science

12-GGR-PG01 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	-	60	-
Self-study [h]	105	-	140	-

Objectives
Expansion of knowledge of working methods in physical geography in the areas of basic research and practice-oriented applications; methods of data acquisition and interpretation, multiproxy approaches, model applications

Content
In the lectures, advanced methods and concepts of landscape-related environmental research are presented using selected examples of geomorphology, applied geoecology and Quaternary research. Within the exercises, exemplary insights into data acquisition and interpretation are given.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
-	Written Exam 90 min

English for Biosciences C1

30-BCH-0905 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]		90		
Self-study [h]		300		

Objectives

Speaking and comprehension skills in subject-, study- and work-related communication situations at level C1 of the Common European Framework of Reference for Languages.

Specific learning and communication strategies are addressed as well as awareness of English as an international academic and professional language.

In detail, participants should acquire the skills to
- understand longer conversations on abstract and complex scientific topics, even if they are not clearly structured and if the meaning is only implicit; recognise a wide range of technical and scientific language expressions and linguistic registers;
- understand in detail long, complex scientific texts;
- formulate clear, detailed descriptions and give presentations on complex topics;
- write clear, well-structured texts on various complex study and science-related topics, emphasising relevant central aspects, elaborating points of view in detail, supporting them with reasons and relevant examples and concluding with an appropriate conclusion;
- express themselves fluently, spontaneously and almost effortlessly orally; use a wide range of subject-related vocabulary flexibly; search for formulations that are barely recognisable;
- express themselves in written texts with clarity and precision, adapting flexibly and effectively to the addressees;
- convey the main ideas in long and complex texts clearly, fluently and in a structured manner, even to addressees outside the relevant subject area or outside the university.

Content

Students expand and deepen their application-related lexical, grammatical, and phonetic knowledge as well as text and discourse patterns in technical and scientific English for a wide range of complex situations in the life sciences, e.g. in order to understand and use longer, complex (specialised) texts on academic and professional topics related to their studies. Students will be able to give presentations in their subject area, participate effectively in a (seminar) discussion and adequately produce various long, complex texts related to higher education or their profession, e.g. present the results of a scientific study, write an abstract or a review. Students will deepen their knowledge of various aspects that may arise in the context of English-language subject-related communication in the professional and academic world.

Participation Requirements

Placement test or proof of English language skills at the level of a basic Abitur course completed with 'good' (level B2 of the Common European Framework of Reference for Languages)

Pre-Examination Requirements	**Examination**
None	Presentation, 20 min Written examination, 90 min

B: Biomedicine

Bioorganic Chemistry

11-BCH-0701 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
- Gain knowledge and understanding of bioorganic synthesis, analytical methods and their applications; - Learn to perform bioorganic synthesis methods

Content
- Molecular characterisation of bioorganic molecules, especially biopolymers, including peptides, proteins, nucleic acids and carbohydrates, synthesis methods and strategies for peptides, carbohydrates, and nucleic acids - Chemical modifications of peptides and proteins - Introduction of fluorescent dyes, radioligands, biotin and their applications - Molecular probes for biological purposes and their selective introduction - Drug development based on peptides, proteins, nucleic acids and carbohydrates - Combinatorial synthesis strategies, their applications and assay methods (HTS screening) in the pharmaceutical industry - Analyses to characterize peptides, proteins, carbohydrates and nucleic acids The courses can be accompanied by tutorials

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation (20 min) 1 Practical Course Protocol	Oral Exam, 30 min

Matrix Engineering

11-BCH-0718 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	40	45	-	95

Objectives
Understanding of structure and function of the extracellular matrices in human tissues and of the engineering of their mimics using synthetic and biohybrid materials for *in vitro* and *in vivo* applications in cell culture and tissue regeneration; Learning of methods for engineering of biohybrid 3D cell culture systems and their application in sterile cell culture; Learning of (microscopic) methods for *in vitro* investigations of cell behaviour in biohybrid materials; Learning of skill to develop and discuss a research plan on the topic in seminars

Content
Composition, structure as well as biophysical and biochemical properties of typical extracellular matrices; Functional interaction of the extracellular matrix with tissue cells including signal transduction of biophysical and biochemical signals with a focus on mechanotransduction; Synthesis and reconstitution of biomimetic matrices from synthetic, biohybrid and natural materials (polymers, biopolymers (proteins, sugars); Methods for the biophysical characterization of natural and artificial extracellular matrices as well as cell-matrix interactions; Elaboration and seminar discussion of a research plan for a given question in the subject area

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Oral Exam, 30 min

Physiology of the intestinal microbiome

11-BCH-0725 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	30	-	60
Self-study [h]	40	90	-	50

Objectives

Successful graduates of the module will have gained a basic understanding of the microbiome and several disciplinary topics in microbiome research.
This includes in particular:
- Knowledge of the human microbiome in health and disease, the interplay between the microbiome and the immune response
- Knowledge of interactions of bacteria, viruses and fungi with the human microbiome
- Knowledge of the bidirectional interactions between the gut microbiome and the brain
- Knowledge of the influence of nutrition on the microbiota
- Insights into the chemical-microbiome interaction
- Overview of molecular biological methods in microbiome research

Content

Lecture: Investigation of the human microbiota, Microbiome composition, Gut microbiota and its metabolites: possible effects on the host, Oral microbiota, Skin microbiota, Gastrointestinal microbiota, The microbiota-gut-brain axis: focus on basic communication pathways, Chemical-microbiome interaction, Intervention, prevention and the brain: prebiotics, probiotics and fecal transplants

Seminar: Molecular biological methods of microbiomes, statistical analysis of microbiome data with R, literature seminar

Practical course: Fundamentals and principles of microbiome analysis (16S amplicon sequencing, metaproteomics, metabolomics)

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Written Exam, 60 min

How the Brain Works

11-BCH-211 – compulsory elective – 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	-	90	-
Self-study [h]	60	-	120	-

Objectives
Acquisition of knowledge in the fields of cellular and systemic neurobiology, development of theoretical and practical skills using modern methods of systemic neurobiology (neuroimaging, electrophysiology, EEG, psychophysics), Acquisition of skills in scientific data analysis and presentation. Practice with scientific presentations and reports under guidance.

Content
Basics of information processing in nervous systems; advanced aspects of the structure and function of the mammalian central nervous system; biological and artificial neural networks; neurobiological techniques for studying brain processes; exercises in the computer pool with introduction to the Python programming language for simulating neurons and brain processes.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Exercise Protocol	Multiple Choice Exam, 90 min

Molecular Mechanisms of Neuronal Communication

11-BIO-215 – compulsory elective – 1rst semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	15	30	45	30
Self-study [h]	15	60	45	60

Objectives
To acquire an understanding of the concepts underlying neuronal communication; To develop theoretical and practical skills in conducting neurophysiological experiments using optogenetics, electrophysiology, and behavioural studies in *Drosophila melanogaster*; To learn data analysis and graphical documentation using software packages; To present scientific projects and write scientific reports.

Content
Modern neurophysiological methods; Physiology and anatomy of signal transmission between neurons; Analysis of neuronal communication pathways at different levels of biological organization: molecules, neurons, networks, behaviour; Modulation of neuronal communication.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Oral Exam, 20 min

Molecular Oncology and Immunology

09-BCH-0710 – compulsory elective– 1st semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	45	60	-	75

Objectives

Knowledge and understanding of the molecular foundations of cell division and immune regulation, as well as the pathogenesis of oncological and immunological diseases. This includes a particular focus on relevant cellular regulatory processes, their pathological alterations, and the genetic and environmental factors involved. Additionally, the course aims to impart knowledge of current therapeutic strategies and to teach important cell and molecular biology analysis techniques relevant to the field.
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Content

Changes in signal transduction, transcriptional control, and other general regulatory processes, as well as apoptosis and cell cycle control in cancer, autoimmune, and chronic inflammatory diseases. The exemplary significance and mode of action of oncogenes and tumor suppressor genes; mechanisms of tumor initiation, promotion, metastasis, and angiogenesis. Cellular changes in tumor development, carcinogens, and mutations. Coincidence/causality. Cell cycle regulation exemplified by Cyclin B through transcription, protein degradation, phosphorylation, and complex formation. Example regulators include p53, MDM2, RB/E2F, DREAM/MuvB, A/B-MYB, FOXM1, cyclin-dependent kinases, and phosphatases. Apoptosis regulation, including extrinsic and intrinsic pathways. Modern cancer therapies such as CDK inhibitors, PROTACs, recombinant antibodies, and the use of neoantigens.

Fundamentals of immunology: cells and signaling pathways of the innate and adaptive immune systems, as well as their interactions. Immunological foundations of malignant, autoimmune, and chronic inflammatory diseases. Molecular foundations of current therapeutic concepts, including gene therapy and immune-based strategies.

High-throughput analyses for investigating these diseases. Cell and molecular biological methods: apoptosis and cell cycle measurement, gene transfer techniques, fluorescence microscopic analysis of protein interactions in living cells, flow cytometry, immunological, and other methods.

The courses are accompanied by tutorials in small groups in the form of seminars. In the seminar, each student must give a 15-minute presentation on a given topic, followed by a group discussion.

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral Exam, 30 min

Sequence Analysis and Genomics

10-202-2207– compulsory elective – 1st semester

Workload				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	-	15	60
Self-study [h]	84	-	28	68

Objectives

After active participation in the module “Bioinformatics of RNA and Protein Structures”, students will be able to
- interpret sequence data in a biological context,
- understand the basic algorithms for sequence comparison in sufficient depth to select the appropriate tools for specific applications,
- apply the basic algorithms for sequence comparison and modify them in a simple way,
- work independently on simple tasks from comparative genomics and
- - present and critically discuss the results of their practical work.

Content

Lecture “Sequence Analysis and Genomics”:
- Exact and approximate search in sequence data
- Local and global alignment of sequences
- Phylogenetic reconstruction in theory and practice

A special lecture is offered on one of the following topics:
- “Evolutionary Algorithms”: Combinatorial Optimization Problems; Simulated Annealing; Value Landscapes; Genetic Algorithms; Genetic Programming
- “Hidden Markov Models in Bioinformatics”: Basics of HMMs: Baum-Welch and Viterbi algorithms; parameter estimation; pairwise alignments with HMMs; profile HMMs for sequence families; multiple alignments with learning from profile HMMs.
- “Prebiotic evolution”: Astrophysical basics; Prebiotic chemistry; Chemical reaction networks; The RNA world and alternative scenarios; Mathematical models: Quasispecies, hypercycle, and co; The genetic code
- “Population Genetics”: Introduction to the theoretical foundations and tools of population genetics and population genomics.
- “Epigenetics”: Types of epigenetic modifications; definition of epigenetics; introduction to experimental techniques with a focus on their evaluation; mapping of sequencing data; peak calling methods;

- “High-throughput sequencing”: bioinformatic definition of genome and gene; generation and analysis of omics data such as genomes, transcriptomes and proteomes; algorithms for the analysis of large amounts of data from high-throughput sequencing, including high-speed alignment algorithms based on suffix arrays and the Burrows Wheeler transformation such as “BWA” and “BOWTIE”; algorithms for the reconstruction of genomes based on De Bruijn graphs.

A practical course is offered in one of the following subject areas:
- “Nucleic Acids”: practical use of standard programs (including “blast”, “clustal” and “muscle”) for genome-wide search and sequence comparison; search for structured information, such as protein-coding regions, non-coding RNAs or regulatory elements in genomes with the aid of current tools and methods (e.g. “Proteinortho”, “RNAz” or “Augustus”); use of data sources such as the “UCSC Genome Browser”.
- “Phylogenetic reconstruction”: Reconstruction of phylogenies with standard tools such as “phylip”, “MEGA” or “NeighborNet”; problem-oriented selection of a method (maximum parsimony, maximum likelihood or distance-based); visual representation of events and changes on evolutionary time scales (e.g. with “TreeViewer” or “iTOL”)
- “High-throughput sequencing”: databases and standard file formats of sequencing data; basic evaluation and quality control of data from sequencing experiments; practical introduction to basic evaluation programs such as “samtools”, “bedtools” or other evaluation methods made available online; graphical representation of results.

- “Population genetics”: Methods for analyzing data on genetic polymorphisms and genomic diversity as well as mathematical models for modeling population genetic effects (such as mutation, drift and selection) in evolution. In the practical courses, students are encouraged to work independently; the focus is not on the results, but on creating and refining solution approaches. The implementation takes place in a 2-week block practical course. An exercise accompanies the lecture in which presented algorithms are implemented and deepened and presented programs are applied. - Language of instruction: English or German - Examination language: English or German

Participation Requirements
None.

Pre-Examination Requirements	**Examination**
Completed final report in course project (15 minutes)	Oral exam, 30 min

Bioinformatics of RNA- and Protein-Structures

10-202-2208 – compulsory elective – 2nd semester

Workload				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	-	15	60
Self-study [h]	84	-	28	68

Objectives

After actively participating in this module, students should be able to:

- describe RNA and protein folding using the underlying physical and chemical processes and laws,
- apply the relevant standard algorithms and modify them in a simple way,
- independently work on tasks from the field of structural biology and develop suitable work-flows, and
- present and critically discuss the results of such work

Content

Content of the main lecture "Bioinformatics of RNA and protein structures":

- "RNA secondary structures": thermodynamic folding, folding kinetics, phylogenetic structure reconstruction, protein threading
- "3D structures": molecular dynamics and molecular modelling, distance geometry protein folding, models from statistical mechanics, lattice models.

An exercise accompanies the lecture, in which the algorithms presented are implemented and deepened and the programs presented are applied.

Additionally, a special lecture is part of the module, and will treat one of the following subject areas:

- “Interaction and modification of biomolecules": representation, recognition and prediction of sequence motifs that occur in connection with the interactions of biomolecules (DNA, RNA, protein); functionality of specific HTS methods for measuring interactions, e.g. ChIP-seq, CLIP-seq, Y2H, and their computer-assisted evaluation; approaches for adapting folding algorithms for modeling interactions between RNA molecules; complexity and structure of protein-protein interaction networks.
- “Bioinformatics in Epigenetics": Variability and stability of DNA methylation and histone modification patterns; necessary steps and algorithms for the evaluation of large amounts of data from high-throughput sequencing in the field of epigenetics, including 3D organization of the nuclear genome, Hi-C-seq, abstraction and modeling of epigenetic processes and their dynamics, e.g. Gillespie algorithm; approaches of models for ‘epigenetic switches’ and ‘chromatin computation’.
- Translated with DeepL.com (free version)
- Translated with DeepL.com (free version)
- "Theory and application of dynamic programming": editing distance on sequences and trees, longest common subsequences and partial order, Bellman’s principle, algebraic dynamic programming.
- "Analysis of gene expression data": fundamentals of gene expression and micro-array technology; clustering algorithms and machine learning methods for gene expression data; expression databases.
- "Fitness landscapes and molecular dynamics": pathways of protein and RNA folding; simulated annealing; neutral networks; knowledge-based potentials.
- "Modelling of tissue organisation processes": Cellular automata for simulating growing cell aggregates; Stochastic description of growth of multi-part systems on a grid: master equations; Deterministic limit of the stochastic description; Stochastic description of colloid particles in the continuum: Langevin equations; From the colloid particle to the cell: adding cell growth and cell division; Cells as deformable, compressible objects: basic equations from continuum mechanics; Modelling of tumour growth *in vitro*: hybrid approach to combining single-cell representations with continuum equations for nutrients; Two-dimensional fluid and elastic membranes; Tissue layers: early embryogenesis and intestinal glands.

A course project is part of the module. The project will relate to one of the following subject areas:

- "RNA structures": Practical use of the "Vienna RNA package" and other tools for handling RNA structures
- "Protein structures": Practical aspects of protein structure prediction, including homology search and modeling (e.g. with Rosetta) and protein threading with "Critical Assessment of Techniques for Protein Structure Prediction" (CASP) as a basis.
- "From structure to function": Computer methods and software for the functional characterization of RNAs or proteins. (e.g. with the help of dN/dS tests, co-evolution analyses, ancestor reconstruction and annotation of protein domains)

Participation Requirements
None.

Pre-Examination Requirements	**Examination**
Completed final report in course project (15 minutes)	Oral exam, 30 min

Physiological chemistry

11-BCH-207 – compulsory elective – 2nd semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
To impart general knowledge of the physiological mechanisms of signal transmission. Imparting knowledge of the main hormonal systems in the human body. Understanding the functions and specific metabolic pathways of various organs.

Content
Signal transduction: membranes, signaling and receptor classes (nuclear receptors, G-protein-coupled receptors, receptor tyrosine kinases). Molecular endocrinology: general concepts, insulin, catecholamines, thyroid hormones, proopiomelanocortin system, adrenal hormones, calcium homeostasis, body growth, reproductive endocrinology. Biochemistry and function of organs: blood, liver, pancreas, adipose tissue, extracellular matrix, cartilage and bone, brain. Integration of energy metabolism in the organism. Methods for the investigation of molecular-physiological issues.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Oral Exam, 30 min

Bioengineering: Biofabrication of Organ-on-Chip Technologies

11-BCH-0823 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15		75
Self-study [h]	50	65		65

Objectives

Based on the lecture, students can apply and critically reflect on the essential principles of biofabrication in the field of biomicrofluidics and biosensor technology to practical, chemical-biological problems. In the practical course, students learn how to create chip designs independently using CAD programs and, based on this, how to manufacture biochips using various microsystem techniques. After active participation in the module, students will be able to plan and carry out the analysis of tissue cultures using specific optical and bioelectronic methods. In the accompanying seminar, students will independently develop research questions in the field of current biofabrication and present them using all available media.

Content

Basic strategies and methods of micro- and biofabrication as well as the analysis of organ-on-chip systems for biotechnological applications. Design, assembly technology and material science for the production of biochips using additive (3D printing) and photolithographic (clean room) processes. Integration of tissue models on microelectrode arrays and microfluidic chips. Teaching of analytical methods to characterize biochips and their integrated tissue cultures. Furthermore, current approaches on biochips in the field of analysis of cellular physiology, signalling pathways, organ replacement or high-throughput screening in the context of drug development and safety testing are discussed.
The courses can be accompanied by tutorials.

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral Exam, 15 min (Weighting 1) Seminar presentation 15 min (Weighting 1)

Biophysical Methods in Medicine and Biology

09-BIO-0808 - compulsory elective - 2nd semester

Workload 10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	-	-	90
Self-study [h]	180	-	-	0

Objectives

- Background knowledge and theoretical handling of different biomedical relevant methods and processes
- Practical exercises in handling, advantages and assessment of methodological limits

Content

- **NMR**
  Basic knowledge of spectroscopy, protein structure analysis, 2D NMR experiments (COSY, TOCSY, HSQC), isotopic labelling of proteins
  Examples: structure of membrane proteins and amyloids
- **MRT**
  Basic knowledge of MR imaging in research and medicine, detection options in the human body,
  Examples: zebra fish as a model for alzheimer's disease
- **Fluorescence Methods (Confocal Microscopy) and Radiation based Methods (X-Ray, CT, Nuclearmedical Methods)**
  Basic knowledge of the methods, labelling of (multiple) fluorescence molecules, cell applications; from Ion Beam Methods (PIXE) up to CT, scintigraphy, PET
  Examples: drug delivery systems
- **Mass Spectroscopy**
  Basic knowledge and characteristics of different MS-approaches (EI, ESI, MALDI) desorption approaches for analysis of surfaces (MS imaging)
  Examples: analysis of lipids
- **Molecular Dyanmics Simulations**
  Monitoring structure, function and dynamics of proteins with computer simulations

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral Exam, 30 min

Biochemistry of Receptors and Signal Transduction

11-BCH-0801 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
Knowledge and understanding of receptors, their ligands and signal transduction mechanisms, as well as their applications, learning how to carry out binding and signal transduction assays

Content
Basic mechanisms of signal transduction in cells Knowledge of the main receptor classes as well as their ligands and signal transduction mechanisms, activation and regulation of signalling in living cells In particular, steroid receptors, G protein-coupled receptors, tyrosine kinase-coupled receptors and ligand- and voltage-gated ion channels are discussed. Furthermore, down-stream effects, such as phosphorylation, ubiquitinylation, activation/deactivation of transcription factors, cell migration and cytoskeleton rearrangements are discussed. Apoptosis versus growth, proliferation and cell cycle responses are included. Further topics include knowledge of the function and mechanisms of transport proteins. The courses can be accompanied by tutorials.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation (20 min) 1 Practical Course Protocol	Oral Exam, 30 min

Clinical Chemistry and Pathobiochemistry

09-BCH-0812 - compulsory elective - 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	75	-	-	30
Self-study [h]	135	-	-	60

Objectives

- Acquisition of knowledge of the fundamentals of clinical chemistry and pathobiochemistry including quality management in medical laboratories.
- Understanding of the biochemical principles of disease development in humans.
- Understanding of the principles of important laboratory medical methods for the diagnosis of human diseases.
- Interpretation of laboratory medical findings.

Content

A) General Clinical Chemistry:
Pre- and post-analytics, quality assurance in laboratory medicine, special analytical methods: homogeneous and heterogeneous immunoassays, mass spectrometry, immunology, flow cytometry, multiplex analysis.

B) Applied Clinical Chemistry:
Hematology and hematological diseases; coagulation disorders, thrombosis diagnostics and hemophilia; inflammation and sepsis; emergency diagnostics; acid-base and water balance disorders; carbohydrate metabolism disorders, insulin resistance, metabolic syndrome and diabetes mellitus; lipoprotein diagnostics, lipid metabolism disorders and atherosclerotic diseases; myocardial infarction diagnostics; heart failure; gastrointestinal diseases as well as liver and pancreatic diseases; Kidney Diseases and Urine Diagnostics; Endocrinological Diseases and Hormone Diagnostics; Diseases of the Central Nervous System and Cerebrospinal Fluid Diagnostics; Immunological Diseases and Allergy Diagnostics; Therapeutic Drug Monitoring and Toxicology, Pediatric Laboratory Diagnostics; Newborn Screening, Rare Metabolic Diseases and Special Metabolic Diagnostics; Tumor Diagnostics; Molecular Diagnostics; Biomarkers; Biobanking and Clinical Studies

Participation Requirements

none

Pre-Examination Requirements	**Examination**
Participation in practical courses offered	Written Exam 30 min

RNA Biochemistry

11-BCH-0804 – compulsory elective – 2nd semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	80	-	65

Objectives
Understanding of RNA functions in transcription and regulation of cellular processes in pro- and eukaryotes; natural and artificial ribozymes; molecular biological use and medical applications of microRNAs, antisense RNA, RNA interference and ribozymes; RNA viruses: influenza and SARS-CoV2; mRNA-based vaccines

Content
RNA functions; RNA world; RNA-based catalysis; in vitro evolution strategies for the development of new functions in RNA molecules: aptamers and ribozymes; riboswitches; preparation and handling of in vivo and in vitro RNA; characterization of RNA/RNA and RNA/protein interactions.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral exam, 30 min

Molecular Genetics

11-BCH-0813 – compulsory elective – 2nd semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15		75
Self-study [h]	50	65		65

Objectives
Knowledge of molecular genetic regulatory mechanisms in pro- and eukaryotes; learning and carrying out gene mapping and complementation studies on simple model organisms; mutational analysis

Content
Genetics of bacteriophages and mobile genetic elements; position-specific recombination and transposition; organelle genetics; methods of recombinant gene expression; methods for the identification of genetic elements (e.g. transposon tagging, enhancer trapping); molecular mechanisms of ageing; 1st, 2nd and 3rd generation DNA sequencing methods; artificial genomes and molecular circuits

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Oral exam, 30 min

Transgenesis in Science and Medicine

11-BCH-0816 – compulsory elective – 2nd semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	30	-	75
Self-study [h]	60	60	-	45

Objectives
The module teaches current concepts of manipulation and characterization of model organisms in basic research and medicine. The focus is on the design and production of transgenic model organisms (from unicellular organisms to mammals). Various phenotyping pipelines and modern analysis methods as well as legal regulations are taught.

Content
Lecture: Targeting constructs, database work, recombination, chem. Mutagenesis, inducible transgenes, reporter constructs, ES cell culture, injection techniques, various model organisms (yeast, worm, fish, mouse), primary cell culture from transgenic animals (microglia, kidney cells), characterization of transgenic model organisms (SHIRPA, laboratory analysis, histology, etc.), legal basis (genetic engineering, animal experimentation). Seminar: Current research topics and methodological developments in the manipulation and characterization of model organisms. Selected key papers are presented and discussed by the students during the lecture. Students learn how to handle and present scientific work and methods. Practical course: Targeting vector construction; recombination using E. coli, genotyping; histology of tissues from reporter strains; transgenesis on C. elegans, cultivation of ES cells; various phenotyping methods of transgenic model organisms

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation (20 min) 1 Practical Course Protocol	Written Exam, 90 min

Biotechnology and Cell Culture Techniques

11-BCH-0704 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
Knowledge and understanding of methods for cell and tissue cultivation as well as tissue engineering. Implementation of methods for the generation of 3D *in vitro* reaggregates and tissue equivalents and their use for cell biology issues. Application of classical methods for the characterization of 2D and 3D tissue cultures (microscopy, immunocytochemistry / expression analysis of markers) as well as modern bioelectronic real-time monitoring techniques for the analysis of cellular properties such as migration behaviour.

Content
Fundamentals of eukaryotic cell culture, use of cells, biomaterials and complex scaffold structures for tissue engineering. Organ-specific development and cultivation of 2D, 3D and complex tissue models for *in vitro* and therapeutic applications. Functional real-time monitoring of cell culture conditions and cell functions with microsensors. The courses can be accompanied by tutorials. In the seminar, each student must give a 15-20 minute presentation on a given topic and then discuss it together.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Oral Exam, 30 min

Chemical Biology

13-BCH-0814 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45 h	15 h	-	75 h
Self-study [h]	60 h	30 h	-	75 h

Objectives
Methods for investigating protein functions using small organic molecules

Content
1. Introduction to chemical biology 2. Biochemical and cell-based assays for bioactivity analysis of chemical substances 3. Enzymes as target structures for organic substances: protein kinases and their inhibitors, activity-based proteomics 4. Protein-protein interactions as target structures for organic compounds: peptidic and non-peptidic inhibitors, approaches for the development of new antitumor drugs, small-molecule inhibitors of SH2 domains, syntheses of phenylphosphate mimetics, synthesis of prodrugs 5. Targeted protein degradation: hydrophobically-tagged small molecules, proteolysis-targeting chimera (PROTACs). 6. Bioorthogonal chemistry: Staudinger ligations, Cu(I)-catalyzed azide-alkyne cycloaddition (CuAAC), ring strain-mediated cycloadditions

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Practical Course Protocol	Written Exam, 90 min

From Substance to Drug

11-BCH-0815 – compulsory elective – 2nd semester

Workload				
10 credit points = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	75	-
Self-study [h]	50	65	65	-

Objectives
Knowledge of modern drug development and molecular concepts of drug-target interaction

Content
Focus topic: Modern drug development, molecular interactions between drugs and target structures, computer-aided methods in drug development, development of protein and peptide therapeutics, natural product therapeutics and antibiotics, biogenic drugs including immunotherapeutics, protein dynamics The courses can be accompanied by tutorials

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Exercise Protocol	Wrtten Exam, 90 min

Molecular Anthropology

31-BIO-0805 – compulsory elective – 2nd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	30	15	-	75
Self-study [h]	50	65	-	65

Objectives
Understanding molecular evolution in terms of genome, transcriptome, and proteome evolution; using DNA sequences (ancient and modern) to study population history. Evolutionary processes and selection in the course of human evolution; analysis of ancient DNA; analysis of DNA sequencing data; understanding of evolutionary models in relation to DNA sequences; analysis of human migration and demographic processes; analysis of human-associated microbial communities and pathogens.

Content
Mechanisms of genome evolution; understanding of evolutionary mechanisms (drift, positive, negative and balancing selection; Preparation and analysis of RNA and DNA, especially ancient DNA; analysis methods for large data sets (e.g., whole genomes). The courses can be accompanied by tutorials**.**

Participation Requirements
none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation 1 Practical Course Protocol	Oral Exam, 90 minutes, in groups of students

Graphs and Biological Nets

10-202-2205 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	15	-	45
Self-study [h]	84	28	-	83

Objectives

After active participation in the module “Graphs and Biological Networks”, students will be able to
- formulate and explain basic terms and concepts of graph theory,
- model biological questions as graph-theoretical problems and solve them using suitable algorithmic approaches and
- interpret and critically discuss the results in the context of the biological problem.

Content

Basic Lecture:
- Basic properties of graphs: Context, planarity, circles, colorings
- Random graphs

Special lecture/seminar: current research topics, e.g.
- Metabolic networks: flow analysis, organizations, network evolution
- Gene regulatory networks: dynamics, stability,
- Models of complex biological networks: growing networks, scale-free, self-similarity

Participation Requirements

none

Pre-Examination Requirements	**Examination**
1 Seminar Presentation (30 min) Practical Course Results	Oral Exam, 30 minutes

Working as a Scientist in the Lab and in the Office

11-BCH-0903 – compulsory – 3rd semester

Workload				
5 credits = 150 hours of work				
Teaching units				
	Lecture	Seminar	Colloquium	Practical course
Attendance time [h]	30	30	15	-
Self-study [h]	30	45	0	-

Objectives
Learning working methods and techniques in the scientific presentation of data, publication of results, data access, literature and patent research, learning methods of personnel management and responsibility as well as conflict resolution

Content
Methods for obtaining scientific data and their presentation (lecture, publication, literature and patent research), concepts of personnel management and responsibility, as well as conflict resolution, business management aspects in science Exemplary preparation of literature, personnel management and presentation in the seminar, as well as participation in current scientific colloquia The courses can be accompanied by tutorials.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
none	Scientific poster

Practical Laboratory Course

11-BCH-0904 – compulsory – 3rd semester

Workload				
15 credits = 450 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	-	15	-	180
Self-study [h]	-	35	-	220

Objectives
Learn techniques and methods that qualify students to write a Master's thesis

Content
Practical implementation of current methods in biochemistry that are required for the preparation of a Master's thesis. Learning special techniques to prepare for independent scientific work The courses can be accompanied by tutorials. In the seminar, each student must give a 30-minute presentation on a given topic and then discuss it together

Participation Requirements
6 completed compulsory elective modules of compulsory elective placeholders 1-6, 4 of which were passed

Pre-Examination Requirements	**Examination**
none	Written report

Entrepreneurship Management

11-BCH-0960 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	-	30	30	-
Self-study [h]	-	120	120	-

Objectives

After successfully participating in the module, students will be able to describe the fundamentals of entrepreneurship management. They will be capable of independently developing solutions for real-world problems in a team setting, thereby deepening their knowledge autonomously. Building on this, they will be able to independently derive, develop, and present corresponding business models and business plans from entrepreneurial ideas.

Content

Within a lecture series, fundamental knowledge and skills in the field of entrepreneurship management are imparted, providing insights into the practice of starting a business. This lecture series is designed to accompany students throughout the module and enable them to implement a semester project.

The content of the lecture series is aligned with the progression of a practical project, primarily covering the following topics:

- Business model
- Market research
- Marketing and sales in a startup
- Organization of a startup
- Financing of startups
- Team management

In an exercise session that alternates with the lectures, students are given topic-specific tasks to deepen the knowledge conveyed. The tasks, oriented around the project questions presented, are to be solved independently by the students.

Participation Requirements

Pre-Examination Requirements	**Examination**
	Project work: Presentation (10 minutes) with written report (12 weeks)

Methods and Approaches in Geomorphology, Applied Geoecology and Quaternary Science

12-GGR-PG01 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]	45	-	60	-
Self-study [h]	105	-	140	-

Objectives
Expansion of knowledge of working methods in physical geography in the areas of basic research and practice-oriented applications; methods of data acquisition and interpretation, multiproxy approaches, model applications

Content
In the lectures, advanced methods and concepts of landscape-related environmental research are presented using selected examples of geomorphology, applied geoecology and Quaternary research. Within the exercises, exemplary insights into data acquisition and interpretation are given.

Participation Requirements
none

Pre-Examination Requirements	**Examination**
-	Written Exam 90 min

English for Biosciences C1

30-BCH-0905 – compulsory elective – 3rd semester

Workload				
10 credits = 300 hours of work				
Teaching units				
	Lecture	Seminar	Exercise	Practical course
Attendance time [h]		90		
Self-study [h]		300		

Objectives

Speaking and comprehension skills in subject-, study- and work-related communication situations at level C1 of the Common European Framework of Reference for Languages.

Specific learning and communication strategies are addressed as well as awareness of English as an international academic and professional language.

In detail, participants should acquire the skills to
- understand longer conversations on abstract and complex scientific topics, even if they are not clearly structured and if the meaning is only implicit; recognise a wide range of technical and scientific language expressions and linguistic registers;
- understand in detail long, complex scientific texts;
- formulate clear, detailed descriptions and give presentations on complex topics;
- write clear, well-structured texts on various complex study and science-related topics, emphasising relevant central aspects, elaborating points of view in detail, supporting them with reasons and relevant examples and concluding with an appropriate conclusion;
- express themselves fluently, spontaneously and almost effortlessly orally; use a wide range of subject-related vocabulary flexibly; search for formulations that are barely recognisable;
- express themselves in written texts with clarity and precision, adapting flexibly and effectively to the addressees;
- convey the main ideas in long and complex texts clearly, fluently and in a structured manner, even to addressees outside the relevant subject area or outside the university.

Content

Students expand and deepen their application-related lexical, grammatical, and phonetic knowledge as well as text and discourse patterns in technical and scientific English for a wide range of complex situations in the life sciences, e.g. in order to understand and use longer, complex (specialised) texts on academic and professional topics related to their studies. Students will be able to give presentations in their subject area, participate effectively in a (seminar) discussion and adequately produce various long, complex texts related to higher education or their profession, e.g. present the results of a scientific study, write an abstract or a review. Students will deepen their knowledge of various aspects that may arise in the context of English-language subject-related communication in the professional and academic world.

Participation Requirements

Placement test or proof of English language skills at the level of a basic Abitur course completed with 'good' (level B2 of the Common European Framework of Reference for Languages)

Pre-Examination Requirements	**Examination**
None	Presentation, 20 min Written examination, 90 min