MODULE HANDBOOK

Bachelor Quantitative Biology

Bachelor Quantitative Biology PLUS

Dear Quantitative Biology students,

The following module descriptions contain important information on the individual modules according to the examination regulations set forth in 2021. In particular, they detail:

- the people responsible for and the organization of the modules (contact persons, type of enrolment);
- the content and the learning competencies (skills, abilities, outcomes) of each module;
- the type and scope (workload) of the courses and the examination modalities;
- formally required as well as desired prerequisites for the participation in each module.

This information is intended to assist you in planning your studies and in choosing the advanced modules.

AIMS OF THE STUDY PROGRAMME

Heinrich-Heine-University Düsseldorf (HHU) in cooperation with the University of Cologne (UoC) offers a Bachelor of Science degree program in two variants: a 3-year variant, Quantitative Biology (qBio), and a 4-year variant Quantitative Biology PLUS (qBio+). All students go through a common basic phase that lasts 5 Semesters. Before the end of this basic phase, they can either decide to continue in the 3-year variant, or they can apply to switch into the 4-year variant (Fig.1). The 4-year variant is designed to give outstanding students an opportunity to widen their horizon in the field of quantitative biological research in academia and/or industry. qBio+ gives the students more freedom to plan a stay abroad and provides space for additional, intensive research-related training.

The goal of the Quantitative Biology degree programme is to provide students with a solid and broad basic education in biology, intertwined with the quantitative skills required in all branches of modern biological and biomedical research, including the competence in biomathematics, bioinformatics, and biostatistics required to generate insights from the large quantitative datasets being generated within biological fields. The study program aims to support prospective students with different interests in biology, equipping them for success in a biological research world that is becoming increasingly quantitative.

Graduates with outstanding achievements during the bachelor's programme also have the possibility to directly pursue a fast-track doctorate. The bachelor's programme teaches the basic principles of biology, data science, and modelling as well as providing training in the application of scientific methods. Students learn to critically evaluate scientific theories and methods and to work independently in theoretical and practical areas. The bachelor's programme is designed to improve the students' ability to judge scientific claims and to promote their ability to express themselves, to communicate and work in teams, and to participate competently in society.

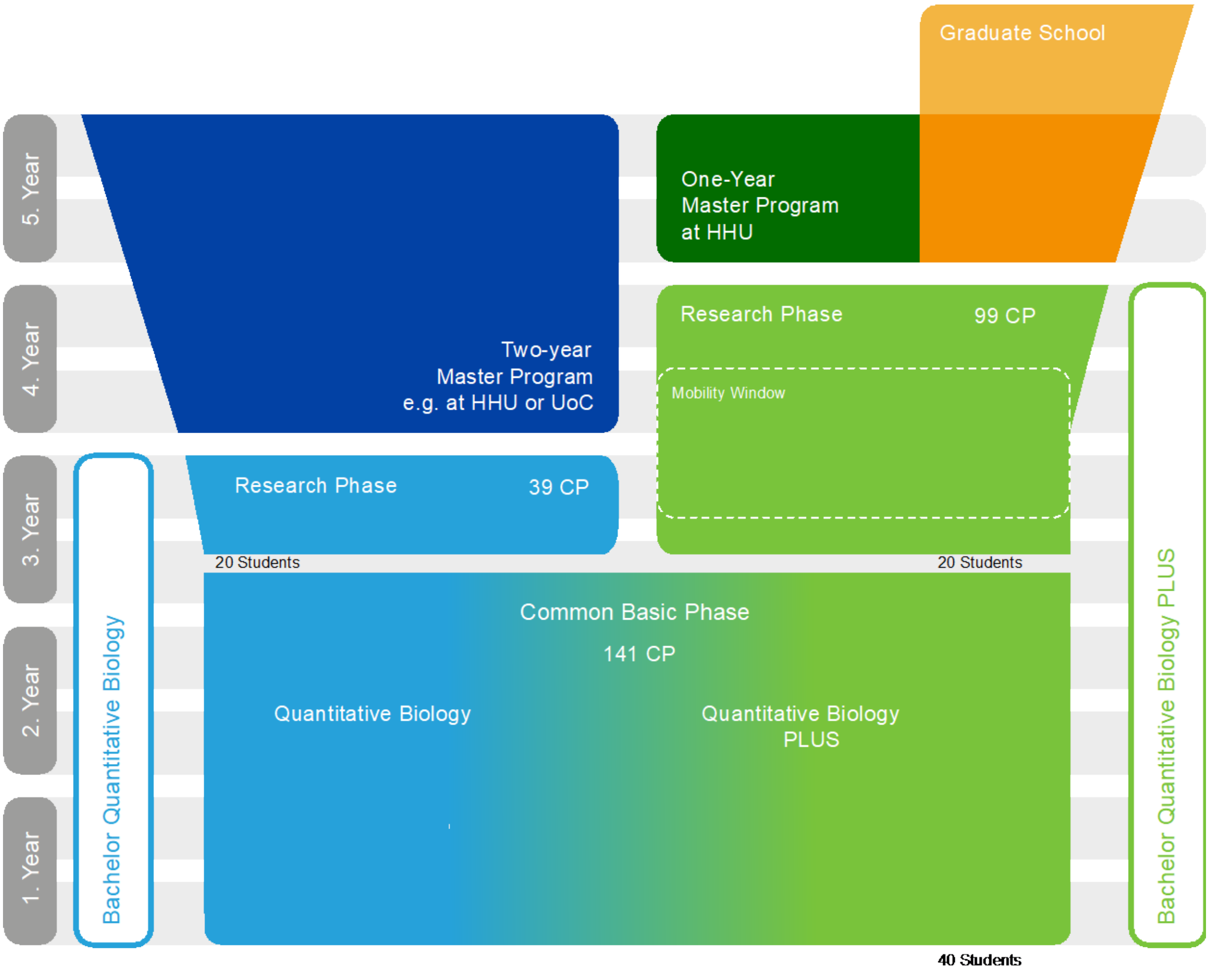

Figure 1: Overview of all Quantitative Biology courses of study

All variants of the Bachelor's programme include a five-semester common basic phase. In the 3-year qBio variant, the basic phase is followed by a one-semester research phase. The 4-year qBio+ variant extends the research phase to three semesters, where the added content can be tailored to each student's unique interests, providing opportunities to study abroad and to pursue academic or industrial research. If desired, students of the qBio variant can move on to a two-year Masters study programme, while students of the 4-year qBio+ variant can alternatively choose to pursue an abridged one-year Master's degree. Graduates of qBio+ have the opportunity to gain extended methodological competence and experience in quantitative biological research, and to acquire intercultural skills and thus the ability to work constructively in an international environment.

Programme Learning Outcomes

Graduates with the Bachelor of Science degree in Quantitative Biology (qBio/qBio+) have acquired the following basic subject specific skills:

1. the ability to approach biological processes quantitatively and analytically through the intensive, integrated study of the fundamentals of mathematics, statistics and computer science;

2. the mastery of basic experiments in molecular and cell biology as well as the responsible experimental handling of organisms;

3. a sound knowledge of complex models for biological processes and the ability to develop simple models by themselves;

4. a deeper understanding of the theories and methods in their selected areas of life sciences.

5. the competence to assess current developments in the field of life sciences and their quantitative-analytical methods, taking into account social, scientific and ethical findings.

STUDY PLANS

WORKLOADS

Credit points (CP) reflect each module’s workload, defined as the estimated time required to achieve the expected learning outcomes. Credit points are awarded according to the European Credit Transfer and Accumulation System (ECTS). One credit point corresponds to approximately 30 hours of time invested by a student. The workload consists not only of the sum of the attendance time (contact time) in courses, but also encompasses the time for self-study (revision of lectures, working on assignments, learning for final examinations, preparation and follow-up of practical courses, etc.).

As a general rule, students are expected to spend at least the same amount of time for self-study as for attendance. If students complete a practical course (e.g., with 4 SWS=Semester-Wochenstunden), we assume that students invest the same amount of time (an additional four hours per week) to prepare and follow up the practical course. For lectures, we assume a more elaborate self-study plan: students should invest two hours of follow-up work for each hour of lecture in order to successfully pass the exam. Thus, the student is present for 60 hours in a four SWS lecture and usually needs twice as much - i.e. 120 hours - for self-study. The workload for a four SWS lecture is therefore 180 hours, which corresponds to 6 CP.

COMMON BASIC PHASE

All modules in the first five semesters of the joint basic phase are mandatory, that is, all students have to complete them successfully. To best distribute the workload across and within semesters and to avoid delays in the completion of the degree, it is recommended to complete these modules as scheduled (see below).

Most modules take place on specific weekdays throughout the official lecture periods (“Vorlesungszeiten”). However, courses that involve experimental lab work are typically scheduled in a compact block at the end of each semester.

EXAMINATION SLOTS FOR THE BASIC MODULES

The examinations for the mandatory modules of the basic phase take place in regularly recurring examination slots. Typically, the first and third examination slots take place in the three weeks following the lecture period. The second and fourth examination schedules take place up to three weeks before the lecture period of the following semester (illustrated in Fig. 2 for courses offered in the winter semester). In order to complete the Bachelor's programme within the standard period of study, we recommend that students take each exam at the first offered date.

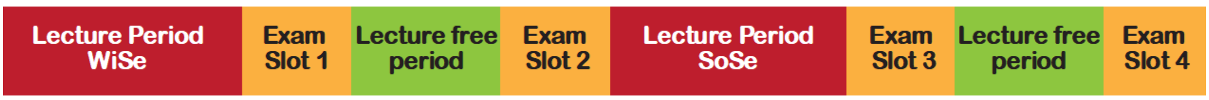

Figure 2: Schematic representation of the scheduling of the examination slots relative to the lecture period (WiSe = winter semester, SoSe = summer semester).

COURSE CURRICULUM: BACHELOR QUANTITATIVE BIOLOGY (3-YEAR VARIANT)

The total workload of the 3-year variant (qBio) is 180 CP. The basic phase is followed by a research phase that culminates in the bachelor thesis. Students have to choose one elective module among those offered in the biology bachelor programmes of HHU and UoC (called “V-Modul” at HHU and “Bio-Wahl” at UoC). Alternatively, students can do a research-based internship at a national or international university of their choice. The elective modules are usually offered in blocks of four weeks and typically combine lectures with all-day practical lab work; the four weeks are often split into an attendance phase and a self-study phase, during which students write protocols or present seminars and examinations are conducted.

The elective modules allow students to gain deeper insights into specific sub-fields of biology and serve as an intensive introduction to laboratory work. In particular, the elective modules encourage students to solve problems independently, to extend their methodological competence, to deepen their knowledge, and to develop teamwork skills as well as oral and written presentation skills. The thematic orientation of the elective-modules is largely based on the research focuses of the institutes and working groups at HHU and UoC. Students can choose elective modules from the electronic course catalogue (LSF).

In addition to the elective modules, the research phase entails a course on project planning, a project internship (which may serve as an introduction to the topic of the bachelor thesis), and the bachelor thesis. In order to complete the bachelor thesis, the modules of the basic phase and one elective module must have been successfully completed.

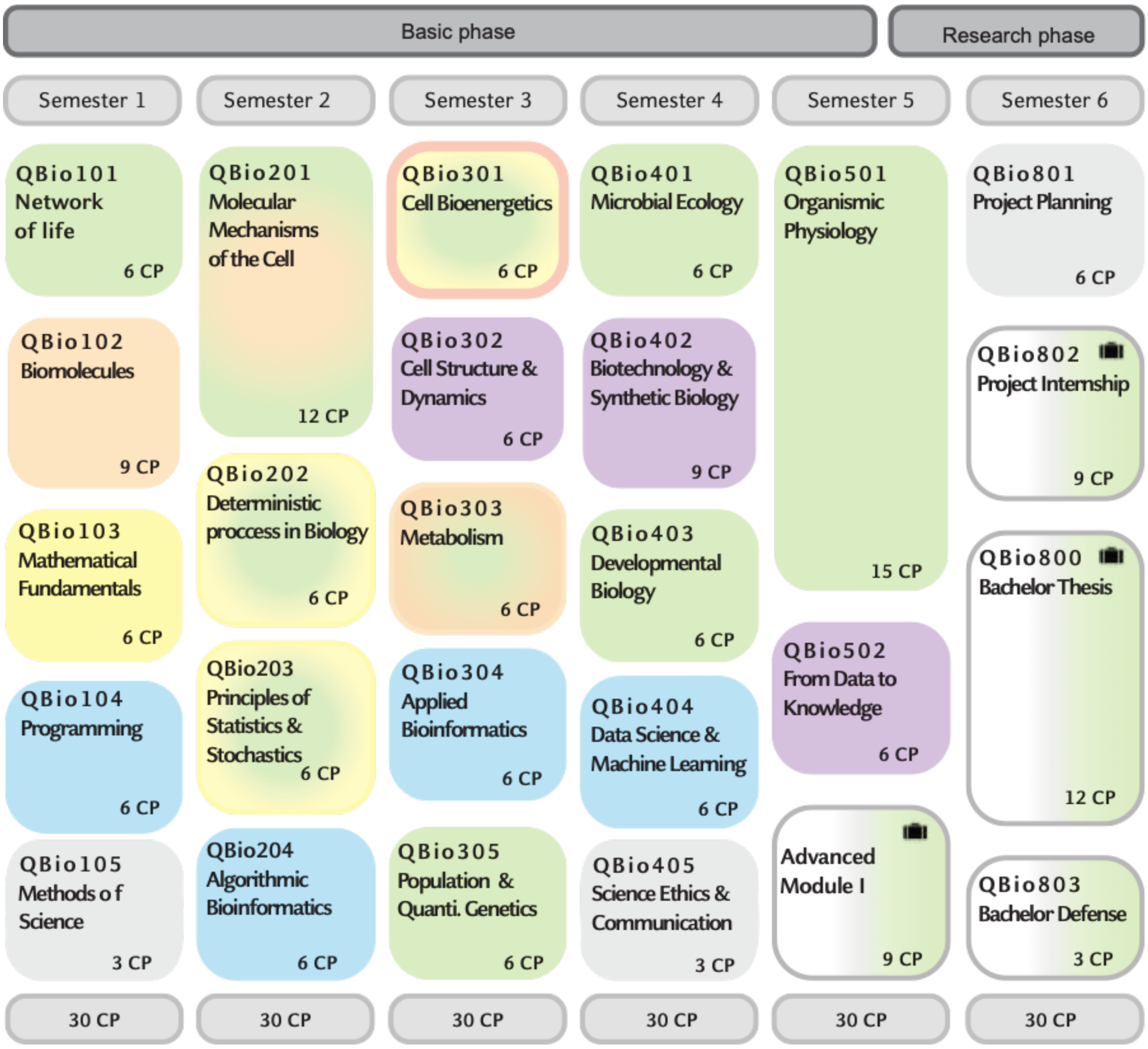

Figure 3: Typical study plan for the 3-year variant (qBio)

COURSE CURRICULUM: BACHELOR QUANTITATIVE BIOLOGY PLUS (4-YEAR VARIANT)

The total workload of the qBio+ variant is 240 CP; students can apply for a transition from qBio to qBio+ in their 5th semester. In the qBio+ variant, the research phase is extended to three semesters. Depending on their interests and the availability of places, students can acquire credit points at our partner universities (Michigan State University (USA), Purdue University (USA), University of Western Australia (Australia), Washington State University (USA)) or at other national or international universities. Students can also do an industrial internship. Finally, students can participate in the various elective modules offered by HHU and UoC. Students also get a chance to explore other subjects besides biology in the module Studium Integrale (Interdisciplinary Selection).

In addition to the elective modules, the research phase entails a course on project planning, a project internship (which may serve as an introduction to the topic of the bachelor thesis), and the bachelor thesis. In order to complete the bachelor thesis, the modules of the basic phase and two elective modules must have been successfully completed.

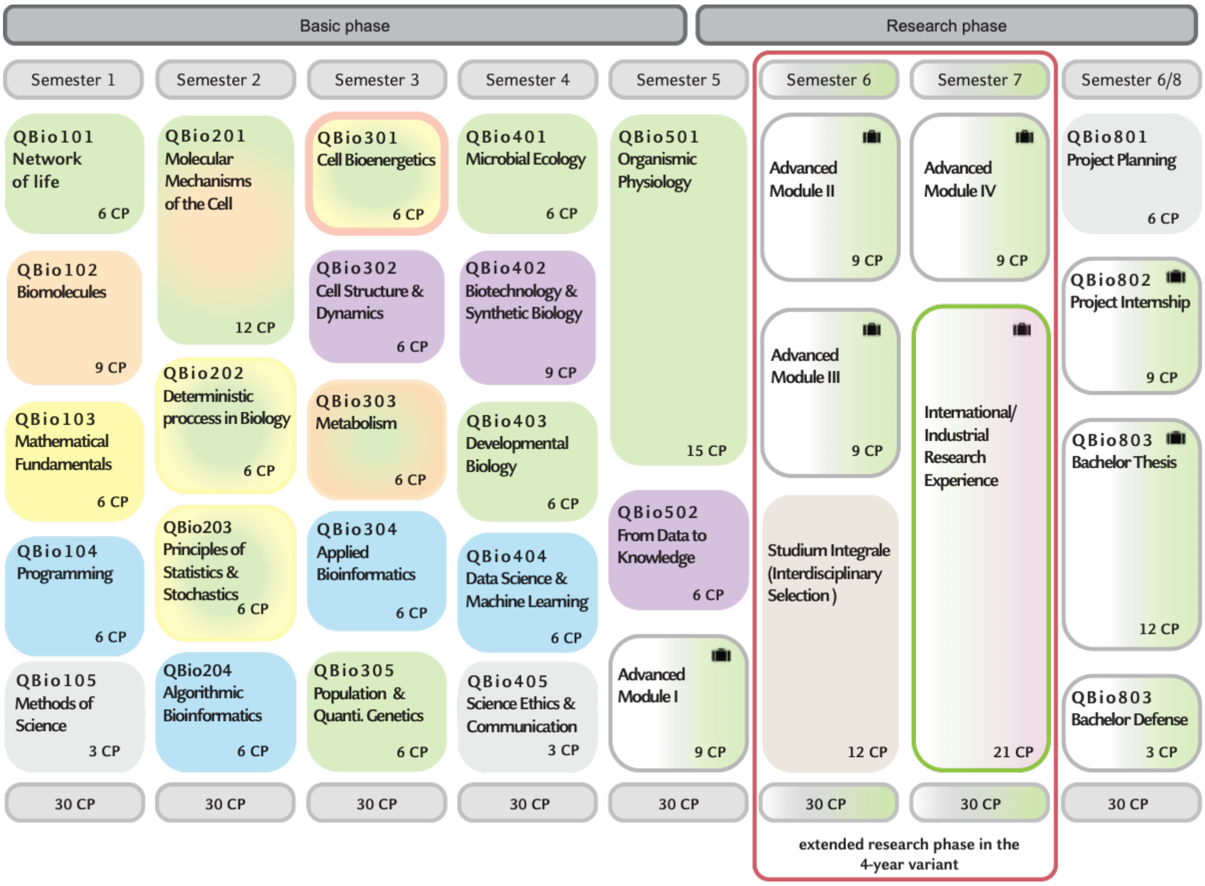

Figure 4: Typical study plan for the 4-year variant (qBio+)

TEACHING METHODS

The modules employ various teaching methods, including lectures, exercises, practical courses, and seminars. The choice of teaching methods offered in the individual modules is directly related to the respective learning objectives and the competences to be acquired by the students.

Lectures provide an overview of the field and form the prerequisite for recognising basic connections and for learning techniques and procedures. Lectures are designed according to the overarching goals of the study programme and the didactic concept of the lecturer.

In the majority of the modules, the contents acquired in the lectures are deepened through exercises. In the exercises, students solve tasks in self-study, either individually or in small groups. The solutions are typically submitted in written form and are corrected and evaluated. During the attendance time of the exercises, students present and discuss their solutions. The achievement of the learning objectives of lectures and exercises is usually monitored through an exam at the end of the semester.

Practicals (laboratory work) introduce students to experimental working techniques and procedures. Students acquire practical knowledge and skills which they need to solve typical problems in quantitative biology. The recommended study plan includes one practical module in each semester, which is organised in a block of 2-3 weeks. Learning outcomes are typically tested in oral examinations and/or through the submission of assignments and reports, which are discussed with the students and evaluated. Attendance during the practical is mandatory.

In seminars, students present a scientific publication on a topic chosen by (or in cooperation with) the seminar leader. The students research the necessary material and prepare the presentation slides according to professional and didactic aspects. The aim is for students to convey the topic to other seminar participants in a technically correct and didactically appropriate manner. The seminar leader evaluates the preparation and presentation performance and discusses the evaluation with the student. Attendance at seminars is generally mandatory.

Guided learning projects are offered in particular in the elective courses of the 4-year variant, qBio+. Here, the lecturer prepares an individual learning programme for the student, which is tailored to the specific objective of the teaching project. The programme can include a guided study of the literature and the teaching of special experimental or quantitative techniques. The review of the learning objectives and the assessment are usually carried out by means of a report (term paper) and a seminar.

The final thesis is based on a student's independent research on a scientific topic under supervision of an experienced researcher. The thesis presents the scientific background, the research, and its interpretation through an independently written text, which in the case of Bachelor's theses should be between 20-40 pages. The final thesis is evaluated by two reviewers, one of whom is generally the student's supervisor. Theses at external institutions such as research institutes or companies are possible upon application. On the basis of such an application, the head of the examination committee examines the suitability of the proposed project and the external supervisor and, if necessary, appoints this person as a first reviewer.

The following modules, (with the exception of Advanced Modules and Studium Integrale) are exclusively available to the students of Bachelor Quantitative Biology (qBio/qBio+).

First Semester

QBio101: Network of Life

Module Responsible: Prof. Dr. Eva Nowack				Version: 30/04/2022
Module Organizer: Prof. Dr. Eva Nowack				**Type:** Compulsory
Lecturer: Prof. Dr. Eva Nowack, Dr. Ovidiu Popa				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 2 SWS 2 SWS	**Group Size** P: 40 P: 40	**Frequency** Every Winter Semester	

Learning Competencies:

The students have acquired the basic knowledge of the reticulated processes of life evolution. They learned how life may have evolved from inorganic matter and how geo-chemical/physical processes impacts evolutionary routes which resulted in the diversification of life. The students gained basic insights into the connectivity of underlying mechanisms that shapes prokaryotic and eukaryotic life. In addition, they are able to rudimentary describe diversity and reconstruct phylogenetic relationship between different phyla.

After completing the exercises, students are experienced to

- search information on a topic of interest and evaluate the information source.
- divide a scientific question in testable hypotheses.
- present and discuss scientific results.
- apply basic techniques to describe phylogenetic relationships and group affiliation.

Content:

In the “Network of Life” module, students get an overview of the central molecules and elements of life. They learn about the origin of life from inorganic matter and how evolution resulted in the diversification of life. Over the course of the module, students get to know central concepts in evolution such as biological information, genes and inheritance, mutation and variation, horizontal gene transfer and endosymbiosis and they compare different theories of evolution. Using the Tree of Life, the students learn about the complexity and interconnectedness of life and the systematics of selected taxonomic groups.

- Building Blocks of Life
    - Nucleic Acids
    - Proteins
    - Lipids
    - Energy
    - Membranes
    - Metals and Cofactors

- Conditions and Origin of Life
    - RNA World
    - Black Smoker
    - Clay and Lipids
    - Wet and Dry Cycles
- Basics of Ecology
- Biological Information
    - Schrödinger
    - Muller
- Genes and Inheritance
    - Darwin and Lamarck
    - Dellbrück-Luria
    - Watson-Crick
- Mutations and Variations
    - History of Life on Earth
    - LUCA
    - Great Oxidation Event
    - Cyanobacteria
    - Geochemical Changes on Earth
    - Earth, Moon and Time
    - Important Events on History of Life of Earth
- Natural selection
- Phylogeny
- Viruses
- Prokaryotes
    - Bacteria
    - Archaea
- Horizontal Gene Transfer
- Endosymbiosis
    - Mitochondria
    - Chloroplasts
    - Multiple Endosymbiosis
- Origin of the cell nucleus
    - Gene Transfer to Nucleus
- Eukaryotes
    - Protists
        - Single Celled Eukaryotes
        - Diversity of protists
    - Fungi and Animals
        - Multiple Cells
        - Systematics
        - Main Differences Between Groups
    - Algae, Moss, and Plants
        - Multiple Cells
        - Systematics
        - Main Differences Between Groups

Conditions of Participation: Enrolled in Quantitative Biology
Examination: One written examination about the content of the lectures (70% of the final grade) Exercises throughout the module (30% of the final grade)
Prerequisites for Awarding Credits for this Module: Passed written exam and successful completion of exercises.
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Campbell Biology, 12th edition, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Rebecca Orr, ISBN: 9780135988046
Further Information:

QBio102: Biomolecules

Module Responsible: Dr. Sabine Metzger				**Version:** 30/04/2022
Module Organizer: Dr. Sabine Metzger				**Type:** Compulsory
Lecturer: Dr. Sabine Metzger				
Total Working Time 270 h	**Credit Points** 9 CP	**Contact Time** 105 h	**Self Study** 165 h	**Duration** 1 Semester
Course Components Lecture: Exercise: Lab Rotation:	 3 SWS 2 SWS 2 SWS	**Group Size** P: 40 P: 40 P: 20	**Frequency** Every Winter Semester	

Learning Competencies:
The students can explain the basic principles of inorganic and organic chemistry and the fundamental properties of biomolecules. They also will be able to understand the nature of elements, atoms, and compounds. They will be able to explain the different chemical reactions, the structure and function of the building blocks of life.

The acquired skills in chemical and biochemical theories will enable the students to apply these methods to the experiments in the practical part. The students can perform basic procedures in the lab and operate scientific instruments. They will be able to produce solutions and samples of adequate quality for different experimental methods and to acquire experimental data of sufficient quality and quantity. In addition, they can properly plot, analyse, and interpret the experimental results. The students will also possess the ability to assess the significance, precision, and accuracy of the results.

Content:
- Important Biological Elements
- Atom
  - Electron, Proton, Neutron
  - Orbitals
- Chemical Bonds
- Chemical Reactions
- Chemical Equilibrium
- Acid Base Reactions
- Redox Reactions
  - Oxidation Number
  - Redox Systems
  - Redox Pairs
  - Nernst Equation
- Carbon Based Life and Molecules

- Alkanes
- Alcohols
- Amines
- Radikale Substitution
- Nucleophile Substitution
- Eleminierungsreaktionen
- Aldehyde and Ketones

- Biomolecules
  - Sugars
  - Nucleic Acids
    - DNA
    - RNA
  - Peptides
    - Proteins
  - Fatty Acids
- Structures of Macromolecules
  - DNA Double Helix
  - RNA Structures
  - Proteins
    - Primary
    - Secondary
    - Tertiary

Conditions of Participation:
Enrolled in Quantitative Biology

Examination:
Learning portfolio consisting of
- One written examination based on the content of the lectures (60% of the final grade)
- Exercises (20% of the final grade)
- Protocol (20% of the final grade)

Prerequisites for Awarding Credits for this Module:
- Passing Exercises (50% of Exercise Sheets)
- Passing Written Exam
- Successful Participation in the Lab Course

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:
An Introduction to Chemistry for Biology Students (George Sackheim)
Molecular Biology of the Cell (Bruce Alberts, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter)

Further Information:

QBio103: Mathematical Fundamentals

Module Responsible: Prof. Dr. Markus Kollmann				**Version:** 02/01/2022
Module Organizer: Prof. Dr. Markus Kollmann				**Type:** Compulsory
Lecturer: Prof. Dr. Markus Kollmann				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 3 SWS 1 SWS	**Group Size** P: 40 P: 40	**Frequency** Every Winter Semester	

Learning Competencies:
Students understand the concept of an invertible function and its relation to equation solving. They understand the central concepts of linear Algebra, such as the properties of a linear vector space and the meaning of Null Space and Range for linear mappings. They understand the concept of differential calculus and can applied it to higher dimensions. They understand the properties of complex numbers and why they can appear in solving Eigenvalue problems. They are familiar with Taylor expansions and its application to convex optimisation problems.

Content:
In this first semester module, the students repeat and deepen basic arithmetic operations, systems of inequalities, and equation solving. They get introduced into Linear Algebra with focus on solving systems of linear equations. In addition, exponential and logarithmic functions are introduced and the basics of differential and integral calculus are explained. This course serves as preparation for the mathematics-intensive courses in the following semesters and is intended to bring all students to the same level of knowledge in order to compensate for possible differences in previous knowledge of mathematics.

- Basic Calculus
- Equation Solving
- Vector Spaces
- Linear System of Equations
- Eigenvalue Problems
- Functions and Differentiation
- Integration
- Vector Analysis
- Fourier Series

Conditions of Participation: Enrolled in Quantitative Biology
Examination: Learning portfolio consisting of • One written examination about the content of the lectures (80% of the final grade) • Exercises (20 % of the final grade)
Prerequisites for Awarding Credits for this Module: • Passing Exercises (min of 80% seriously tried questions) • Passing Written Exam
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: - A Biologist's Guide to Mathematical Modeling in Ecology and Evolution (Sarah P. Otto and Troy Day) ISBN: 9780691123448
Further Information: -

QBio104: Programming

Module Responsible: Prof. Dr. Martin Lercher	**Version:** 30/04/2022
Module Organizer: Prof. Dr. Martin Lercher	**Type:** Compulsory
Lecturer: Dr. Mayo Röttger**,** Dr. Andrea Schrader	

Total Working Time	**Credit Points**	**Contact Time**	**Self Study**	**Duration**
180 h	6 CP	75 h	105 h	1 Semester

Course Components		**Group Size**	**Frequency**
Lecture:	3 SWS	P: 40	Every Winter Semester
Exercise:	2 SWS	P: 40	

Learning Competencies:
After passing this course students should be able to

- Explain and apply the basic principles of computer programming.
- Apply the different dynamic data structures covered in the course.
- Design simple algorithms and implement them in the programming language Python
- Develop different algorithmic solutions to the same problem and evaluate their efficiency
- Perform basic data analyses and visualize the results

Content:
This module provides basic programming knowledge in the object-oriented programming language Python. In addition, introductory aspects of algorithms and data structures are discussed.

- Introduction to Programming and the Linux command line
- Introduction to Python and Jupyter Notebooks; primitive data types and variables
- Built-in data types: numeric types (int, float, complex), sequence types (list, tuple, str, range), dictionaries (dict) and sets (set)
- Control structures
- Functions and Packages
- Data streams and file handling
- Regular expressions
- Hashing
- Introduction to numeric calculations with Numpy
- Introduction to Pandas DataFrame objects
- Design and efficiency of computer algorithms; complexity classes
- Introduction to scientific graphics with Matplotlib
- User-defined data structures: Classes

Conditions of Participation: Enrolled in Quantitative Biology
Examination: Written Exam
Prerequisites for Awarding Credits for this Module: Passing Written Exam
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Think Python - How to Think Like a Computer Scientist, 2nd Edition, Version 2.2.23 Data Structures and Algorithms in Python
Further Information: -

QBio105: Methods of Science

Module Responsible: Prof Dr Martin Lercher				**Version:** 30/04/2022
Module Organizer: Prof Dr Martin Lercher				**Type:** Compulsory
Lecturer: Prof Dr Martin Lercher				
Total Working Time 90 h	**Credit Points** 3 CP	**Contact Time** 30 h	**Self Study** 60 h	**Duration** 1 Semester
Course Components Exercise:	2 SWS	**Group Size** P: 40	**Frequency** Every Winter Semester	

Learning Competencies:

This module introduces fundamental methodologies used in science, both on a practical and on an abstract level. Students are acquainted with the process of scientific publication and the central role of citations in scientific communication, and they learn how to identify and read relevant scientific literature. They learn how to structure and write scientific papers and lab protocols, what makes scientific graphics effective, and how to effectively summarize a project or procedure.

Furthermore, students are made aware of the central role of hypothesis testing and falsification in science and understand the difference between scientific and non-scientific forms of knowledge generation. After the course, they appreciate the role of creativity in science and are able to distinguish and characterize the two mental modes of scientific thought. They learn to distinguish the process of science from its communication, and acknowledge resulting biases in the literature.

Content:

Part I: Practical methodology

- Literature research and effective reading of the scientific literature
- Citing scientific publications
- Document structures of manuscripts and protocols
- Structured formatting of documents
- Effective graphics and tables
- Effective textual and graphical summaries
- The scientific publication process
- Presenting scientific results
  - Oral presentations at seminars and conferences
  - Scientific posters
  - Outreach to the public
- Good scientific practice
  - Avoiding plagiarism
  - Best practices in science

- Data management and reproducibility

Part II: The scientific method

- Falsification and the impossibility to prove a scientific hypothesis
- The role of auxiliary hypotheses and assumptions
- Paradigms and paradigm shifts in science
- The Iron Rule of science: solving all disputes by observation only
- The white lie of science: storytelling in scientific papers
- Distinguishing day science (data generation and hypothesis testing) and night science (generation of ideas to be tested)
- The different languages of day and night science
- Questions versus hypotheses
- The role of explorative data analysis
- Publication biases, p-hacking, and the reproducibility crisis

Conditions of Participation:
Enrolled in Quantitative Biology

Examination:
Project Work

Prerequisites for Awarding Credits for this Module:
Passing Project Work

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:
Michael Strevens: The Knowledge Machine. Allen Lane, 2020.
Alan Chalmers: What is this thing called science? University of Queensland Press, Open University press, 4th edition, 2013.
Itai Yanai & Martin Lercher: The Night Science Collection. Genome Biology, 2020-2021, https://www.biomedcentral.com/collections/night-science.

Further Information: -

Second Semester

QBio201: Molecular Mechanism of the Cell

Module Responsible: Prof. Dr. Ilka Axmann				**Version:** 30/04/2022
Module Organizer: Prof. Dr. Ilka Axmann				**Type:** Compulsory
Lecturer: Prof. Dr. Ilka Axmann, Prof. Dr. Matias Zurbriggen, Prof. Dr. Markus Pauly, Dr. Vicente Ramírez				
Total Working Time 360 h	**Credit Points** 12 CP	**Contact Time** 150 h	**Self Study** 210 h	**Duration** 1 Semester
Course Components Lecture : Exercise: Practical :	 5 SWS 3 SWS 2 SWS	**Group Size** P: 40 P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:

The students have basic knowledge of the fundamental molecular mechanisms of the cell. Knowledge on cellular structures as well as processes involved in the flow of information in a cell, e.g. transcription, translation, replication, cell cycle, gene regulation and signalling.
After completing the module, students are able to

- reproduce comparatively the structure of a cell as well as the process of gene expression of pro- and eukaryotes (gene organization and regulation, transcription, translation and post-translational modifications of proteins).
- explain processes of the cell cycle, cell division and replication.
- explain selected molecular biological methods (see content) and name their areas of application.
- deal under supervision with the basic measuring instruments and apparatus of molecular biology and to explain how they work.

Content:

1. The cell
   - Prokaryotes and eukaryotes; Components of prokaryotic and eukaryotic cells; Structural features of cells; Multicellularity and cell specialization; Cell division, Cell cycle, Mitosis, Meiosis
   - Cell membranes and their dynamics: structure of biological membranes; Recognition and adhesion of cells; Membrane transport; Endo- and exocytosis; Endomembrane system, glycosylation, cytoskeleton, chemical syntheses and information processing
   - energy conversion in chloroplasts and mitochondria [-> QBio301: Cell Bioenergetics]
2. Genes
   - Gene expression in prokaryotes and eukaryotes: gene organization; Transcription (promoters, RNA polymerases and their auxiliary factors); genetic code; Translation

(ribosomes, tRNAs, translation process); Transport and post-translational modification of proteins
- Regulatory RNAs: RNAi, microRNAs, CRSPR-Cas
- Replication of DNA: Enzymatic DNA Synthesis; Meselson Stahl experiment; Chemism of enzymatic DNA synthesis;
- How DNA polymerases work; Replication mechanism. Leader strand + follower strand, strand polarity, okazaki fragments, polymerase processivity, clamp protein, replisome. Origin of replication in prokaryotes and eukaryotes. Telomeres + telomerase. Replication accuracy: Proofreading. Mismatch repair.
- DNA mutations: genotype, phenotype, selection. Mutation types. Direct repair, base and nucleotide excision repair, linking of non-homologous strand ends.
- Homologous recombination: Holliday structure, splice + patch recombinants. SOS response + cell cycle control
- Epigenetics: histone modifications, DNA methylation
- Mobile genetic elements: insertion element, transposon, transposon replication

3. Microbes and viruses [-> QBIO101: Network of Life]
   - Genome diversity, structure, general replication cycle, lysis + lysogeny, retrovirus, transcription + replication, viroid, prion
   - bacteria: cellular structure, morphology, cell division, growth control, pathogenicity, virulence factors, DNA exchange through transduction, transformation, conjugation, F-plasmid, resistance mechanisms.
   - Gene regulation: end product inhibition, lac operon, substrate induction, antibiotic effect, antibiotic resistance and mechanisms. Resistance plasmid.
   - Genome, essential genes, restriction and modification (restriction enzymes).
4. Molecular Biology Applications
   - DNA sequencing, polymerase chain reaction (PCR), DNA mapping, sequencing, DNA fingerprinting, recombinant DNA technology, recombinant DNA technology: cloning, mapping, restriction and ligation, cDNA cloning, gene inactivation. Heterologous gene expression.
   - Biotechnology
   - Monogenic diseases
   - Stem cells (types and concepts), mitosis, cell cycle, cell communication and signal chains, apoptosis, cancer development

Conditions of Participation:
Enrolled in Quantitative Biology

Examination:
Learning portfolio consisting of
- One written examination based on the content of the lectures (50% of the final grade)
- Exercises (25% of the final grade)
- Protocol (25% of the final grade)

Prerequisites for Awarding Credits for this Module:
- Passing Exercises (50 % of Exercise Sheets)
- Passing Written Exam
- Successful Participation at The Lab Course

Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Molekulare Genetik Knippers Molecular Biology 3rd Edition Authors: David Clark Nanette Pazdernik Michelle McGehee 2018 Molecular Biology of the Cell (Sixth Edition) by Bruce Alberts 2014 Molecular Biology Principles and Practice (Cox and Doudna)
Further Information:

QBio202: Deterministic processes in Biology

Module Responsible: Prof. Dr. Oliver Ebenhöh				**Version:** 30/04/2022
Module Organizer: Prof. Dr. Oliver Ebenhöh				**Type:** Compulsory
Lecturer: Prof. Dr. Oliver Ebenhöh				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 3 SWS 1 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:

The students have basic knowledge how to describe, simulate and analyse various biological systems with differential equations. They understand how to translate biological processes into dynamic equations. They can independently develop and simulate simple mathematical models, and critically interpret their simulation results in context of available experimental data.

After completing the module, the students are able to

- translate biological systems into sets of differential equations
- implement and numerically integrate differential equation systems using the programming language Python
- understand the basic principles in model building and improvement
- interpret experimental observations using mathematical models as theoretical frameworks

Content:

This module builds upon the mathematical foundations taught in “Mathematical Fundamentals” to introduce the students into principles of mathematical modelling using differential equation systems. For this, in particular the calculus and linear algebra skills are required, and as a consequence, will be revised and covered in more depth. The module also builds on the programming skills acquired in the first semester module “Programming”.

A main focus of this module is the construction and derivation of deterministic mathematical models. Approaches will be discussed how a biological system can be abstracted, simplified, and thus translated into mathematical equations. An equally important focus is the analysis of differential equations, the computational simulation of models, and the interpretation of the results.

- Ordinary differential equations (ODEs)
    - Stationary states
    - Linearised systems
        - Eigenvalues, eigenvectors, characteristic polynomial, complex numbers
        - Jacobian

- Bistability
- Oscillations
- Bifurcations
- Limit cycles
- Non-autonomous systems

- Application of ODEs to biological systems
  - Chemical and biochemical reactions
  - Metabolic networks
  - Signalling networks
  - Gene expression networks
  - Microbial growth
  - Ecosystem dynamics
- Partial differential equations
  - Space, time, mass, density
  - Diffusion, heat conductivity
  - Reaction-diffusion systems
  - Pattern formation

Conditions of Participation:
Passed Module QBio103

Examination:
Learning portfolio consisting of
- One written examination based on the content of the lectures (50% of the final grade)
- Exercises (50% of the final grade)

Prerequisites for Awarding Credits for this Module:
- Passing Exercises (50 % of Exercise Sheets)
- Passing Written Exam

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:
A Biologist's Guide to Mathematical Modeling in Ecology and Evolution (Sarah P. Otto and Troy Day) ISBN: 9780691123448
Systems Biology (Edda Klipp, Wolfram Liebermeister, Christoph Wierling, Axel Kowald) ISBN-13: 9783527675661
In addition, current publications in the field of study will be made available before the beginning of the module.

Further Information:

QBio203: Principles of Statistics & Stochastic

Module Responsible: Prof. Dr. Benjamin Stich				**Version:** 30/04/2022
Module Organizer: Prof. Dr. Benjamin Stich				**Type:** Compulsory
Lecturer: Prof. Dr. Benjamin Stich, Dr. Ovidiu Popa				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 75 h	**Self Study** 105 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 2 SWS 3 SWS	**Group Size** P: 40 P: 40	**Frequency** Every Summer Semester	

Learning Competencies:
The significance of experimental studies depends decisively on the choice of a suitable experimental design and the corresponding statistical modelling. After successful completion of the module, the participants know the basic principles of experimental design and can plan simple experiments according to statistical aspects. The participants have basic knowledge of probability in the context of statistical analyses. They have the ability to formulate hypotheses from questions of interest. They know different data types as well as the basic statistical tests that are applied to them. The participants recognize when to apply a parametric or a non-parametric test.
They will have a basic knowledge how to use the statistical software R for statistical analyses.

Content:
Lecture:

- Introduction in R
- Data types
- Descriptive statistics
- Probability distribution
  - Discrete
  - Continuous
  - Sample Space
  - Normal distribution
  - Binomial distribution
  - Univariate vs multivariate
- Probability Single and Multiple Events
- Likelihood Function
  - Discrete vs Continuous
  - Maximum likelihood
- Null hypothesis

- Type I and II error
- Statistical tests for different combinations of dependent and independent variables
  - nomial
  - ordinal
  - metric data
- Principles of experimental design
- Stochastic processes-
  - master equation
  - markov chains

Exercises:

The theoretical basics are taught in the lecture before the exercises. In the exercises the contents are deepened by analysing example data sets mainly from plant sciences with the software R.

Conditions of Participation:
Passed Module QBio103

Examination:
Learning portfolio consisting of

- One written examination based on the content of the lectures (50% of the final grade)
- Exercises (50% of the final grade)

Prerequisites for Awarding Credits for this Module:

- Passing Exercises (50 % of Exercise Sheets)
- Passing Written Exam

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:

The Analysis of Biological Data (3rd ed. 2020) Michael C. Whitlock, Dolph Schluter, W.H.Freeman & Co Ltd, ISBN: 978-1-319-32534-3

Design and Analysis of Experiments (2nd ed. 2017) Angela Dean, Daniel Voss, Danel Draguljić, Springer, ISBN: 978-3-319-52248-7

R Bioinformatics Cookbook: Use R and Bioconductor to perform RNAseq, genomics, data visualization, and bioinformatic analysis(2019), Packt Publishing, ISBN-13 : 978-1789950694

Further Information:

QBio204: Algorithmic Bioinformatics

Module Responsible: Prof. Dr. Gunnar Klau				**Version:** 30/04/2022
Module Organizer: Prof. Dr. Gunnar Klau				**Type:** Compulsory
Lecturer: Prof. Dr. Gunnar Klau, Dr. Alissandra Denton				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 2 SWS 2 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:
After this course, students will be able to

- apply basic algorithmic design principles, prove correctness and analyze running times
- differentiate between tractable and intractable algorithmic problems and understand the consequences
- distinguish different classes of algorithms
- understand and apply classic bioinformatics algorithms
- implement many of these algorithms in the programming language Python;
- select an appropriate algorithm to solve a given task.

Content:

- Algorithms and Complexity
- Exhaustive Search: DNA Motifs
- Greedy Algorithms: Genome Rearrangements
- Dynamic Programming: Sequence Alignment
- Graph Algorithms: Sequencing
- Combinatorial Pattern Matching: Suffix Trees
- Phylogenetic Trees and Molecular Evolution

Conditions of Participation:
Passed Module QBio104 and QBio103

Examination:
Written examination based on the content of the lectures. The grade is based only on the written exam. Admission to the exam is by successful completion (more than half of the points of the assignments) of the weekly exercise sheets.

Prerequisites for Awarding Credits for this Module: • Passing Exercises (50 % of Exercise Sheets) • Passing Written Exam
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Neil C. Jones, Pavel A. Pevzner: An Introduction to Bioinformatics Algorithms. The MIT Press, 2004.
Further Information:

Third Semester

QBio301: Cell Bioenergetics

Module Responsible: Prof. Dr. Oliver Ebenhöh				**Version:** 30/04/2022
Module Organizer: Prof. Dr. Oliver Ebenhöh				**Type:** Compulsory
Lecturer: Prof. Dr. Oliver Ebenhöh, Prof. Dr. Martin Lercher, Jun.-Prof. Dr. Wolfgang Hoyer				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 75 h	**Self Study** 105 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 4 SWS 1 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Winter Semester	

Learning Competencies:

The students have basic knowledge of thermodynamic principles and understand how to apply the concepts to processes in the life sciences. They understand how to quantitatively describe fundamental biophysical processes in cell and molecular biology. The students can independently analyse and interpret their experimental data. They are able to document data appropriately and to convincingly present their results in written and oral form.

After completing the module, the students are able to

- describe chemical reaction energetics quantitatively
- explain processes that drive energy conversion
- understand the physical basis of fluorescence
- perform experiments to characterise enzyme kinetics and protein folding
- understand cellular growth as a thermodynamic process

Content:

In the third semester, the “Cell Bioenergetics” module takes up content from the modules “Deterministic processes of biology”, in which fundamentals in mathematical modelling of biological systems are taught, and “Biomolecules”, which introduced the chemical foundation of living systems. "Cell Bioenergetics" will complement the picture by explaining the thermodynamic foundation of many fundamental biological processes.

After an introduction of basic thermodynamic concepts (temperature, energy, entropy, thermodynamic potentials, energy converters), these concepts will be applied to a number of central phenomena, including chemical reactions, free energies in chemical bonds, enzyme kinetics, protein folding and aggregation, energy conversion through gradients over biological membranes, and microbial growth.

- Thermodynamics fundamentals
  - Temperature
  - Thermodynamic potentials

◦ Free energy in chemical bonds, free energy change in chemical reactions, equilibrium ◦ Entropy ◦ Laws of Thermodynamics ◦ Chemical potential ◦ Reaction kinetics • Membrane-bound processes ◦ Gradients ◦ Passive and active transport ◦ Energy converters ◦ Antiporters and symporters • Molecular motors • Crowding • Enzyme kinetics • Association/dissociation, binding, protein aggregation, polymerisation • Fluorescence ◦ Physical basis ◦ Application as biological measurement technique • Thermodynamic models of microbial growth ◦ Macrochemical equations ◦ Black-box models ◦ Cells as energy converters
Conditions of Participation: Passed Modules QBio102 and QBio202
Examination: Learning portfolio consisting of • One written examination based on the content of the lectures (60% of the final grade) • Exercises (30% of the final grade) • Protocol (10% of the final grade)
Prerequisites for Awarding Credits for this Module: • Passing Exercises (50 % of Exercise Sheets) • Passing Written Exam
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Physical Biology of the Cell (Rob Phillips, Jané Kondev, Julie Theriot), ISBN 13:9780815344506 Biothermodynamics, The Role of Thermodynamics in Biochemical Engineering (Stockar, Urs Von; Wielen, Luuk A. M. van der), ISBN-13: 9781466582170 In addition, current publications in the field of study will be made available before the beginning of the module.

Further Information:

QBio302: Cell Structure and Dynamics

Module Responsible:	Version:
Prof. Dr. Guido Grossmann	30/04/2022

Module Organizer:	Type:
Prof. Dr. Guido Grossmann	Compulsory

Lecturer:
Prof. Dr. Guido Grossmann, Jun.-Prof. Dr. Mathias Beller, Dr. Sebastian Hänsch, Dr. PiauSiong Tan

Total Working Time	Credit Points	Contact Time	Self Study	Duration
180 h	6 CP	75 h	105 h	1 Semester

Course Components		Group Size	Frequency
Lecture:	2 SWS	P: 40	Every Winter Semester
Practical:	3 SWS	P: 20	

Learning Competencies:
After completing this module, students will be able to

- describe the fundamental differences of cellular organization among kingdoms of life
- describe emergence mechanisms, structures and functions of sub-cellular compartments and organelles
- explain the optical light-path and components of a basic optical microscope
- choose the appropriate microscopic technique to address specific biological questions
- employ computational analysis to extract quantitative information from imaging datasets

Content:
This module will use qualitative and quantitative microscopy to explore cell biological structures and processes. Through imaging of fixed and live specimens, the students will learn about the organization of cells across a range of uni- and multicellular species. To this end, the students will be introduced to the physical basics of optics, build their own fluorescence microscopes from scratch and perform image acquisition and quantitative analysis on cellular structures. In addition, students will become familiar with the use of labeling techniques and sample preparation, as well as various modern microscopy methods.

The module is subdivided into two parts - a technical and a biological part - which will be taught in an alternating fashion (topics with same numbers below will be taught on subsequent days).

Part A - Imaging Technology

A1 - Optics: properties of light (e.g. refraction, diffraction, magnification, image, optical aberrations); Optoelectronics: excitation light sources and detectors

A2 - Labeling techniques: fusions of fluorescence proteins, antibody/ nanobody staining tag constructs & fluorophores).

A3 - Optical sectioning: principles of confocal and two-photon microscopy

A4 - Sample preparation and time lapse imaging of labelled structures, genetically encoded biosensors or markers in live specimens, microfluidic imaging platforms.

A5 - Image processing and quantitative analysis: Do's and Don'ts in data processing, filtering, thresholding & segmentation, particle tracking, co-localization.

A6 - Electron microscopy, super-resolution microscopy, F-techniques.

Part B - Cell Biology

B1 - Biological scales, cell organization, differences between bacterial and eukaryotic cells, types of extracellular matrices including cell walls and capsules

B2 - Cellular organelles; nucleus, ER, vacuoles, mitochondria, chloroplasts,symbiogenesis, organelle contact sites

B3 - Cytoskeleton & cell-cell contacts, cellular membranes, TGN

B4 - Dynamic processes in cells; vesicle trafficking, mitosis, cell movement

B5 - Cell metabolism, cellular signaling, homeostasis

B6 - Subcompartments of cellular organelles, membrane nanodomains, phase separation

In addition to lectures and practical parts, students will present selected techniques in microscopy and related topics in oral presentations (15 min).

Conditions of Participation:
Passed Modules QBio101 and QBio201

Examination:
Learning portfolio consisting of

- One written examination (60% of the final grade)
- Practical performance (20% of the final grade) based on active participation, documented in daily protocols, and presence/attendance (80% of the practicals).
- Oral presentation (20% of the final grade)

Prerequisites for Awarding Credits for this Module:

- Participation in practical exercises: Minimum 1 of possible 20 pt
- Participation in oral presentation: Minimum 1 of possible 20 pt
- Passing the written exam: Minimum 30 of 60 pt
- Minimum total cumulative points: 50 of 100 pt

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:
Recommended: Alberts et al. (2015) Molecular biology of the cell. Norton & Company, 6th ed.; ISBN: 978-0815344643

Optional: Hecht, Eugene (2016) Optics. Pearson; 5th edition; ISBN: 978-1292096933

Further Information:

QBio303: Metabolism

Module Responsible: Prof. Nadine Töpfer				**Version:** 30/04/2022
Module Organizer: Prof. Nadine Töpfer				**Type:** Compulsory
Lecturer: Prof. Nadine Töpfer, Prof. Tatjana Hildebrandt				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 3 SWS 1 SWS	**Group Size** P: 40 P: 40	**Frequency** Every Winter Semester	

Learning Competencies:
After completing the module, students can explain the concept of metabolism as a network of coupled reactions which hand-over metabolites. Coming from the understanding of the key aspects of important building blocks of metabolism over the generic features of enzymatic reactions they will expand their knowledge to the modus operandi of selected biochemical pathways before they expand to looking at cellular metabolism on a network scale. They will determine key parameters of enzymatic reactions by quantitative analyses and learn methods to estimate the dynamic change of metabolites as well as the optimization of a metabolic network to predict e.g. the accumulation of a certain end product.

Content:
- Building blocks of metabolism (life)
  - energy transformation and electron transfer
  - carbohydrates
  - amino acids, proteins
  - lipids
  - nucleotides, DNA
- Enzymes
  - working with enzymes
  - enzyme function
  - enzyme classes
  - regulation
  - kinetics
- Introduction to metabolism
  - Quantifying metabolism
  - Bioenergetics and thermodynamics
  - Chemical logic and common biochemical reactions
  - Biological oxidation-reduction reactions
  - Nernst equation and how to calculate ΔG from it
  - Regulation of metabolic pathways

- Metabolic pathways
    - Glycolysis
    - Gluconeogenesis
    - Pentose phosphate pathway
    - TCA cycle
    - Respiratory chain & oxidative phosphorylation
    - Photosynthesis
    - Fatty acid metabolism
    - Amino acid metabolism
    - Nucleotide metabolism
- Modelling metabolism
    - Kinetic modelling
        - Ordinary differential equations (ODE) to model enzymatic reactions
        - Kinetics and reaction order considerations
    - Flux-balance modelling
        - The stochiometric matrix
        - Parameterization
        - Linear modelling / programming
        - Optimization & objective function
    - 13C-Metabolic flux analysis
        - Experimental design labelling strategy
        - Tracer feeding experiment
        - Analysis of isotopomers
        - Flux estimation

Conditions of Participation:
Passed Modules QBio102 and QBio202

Examination:

- Written Exam

Prerequisites for Awarding Credits for this Module:

- Passing Exercises (7 out of 8 biochemistry exercises, 50% of the points for computational exercises)
- Passing Written Exam

Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: David Nelson & Michael Cox: Lehninger Principles of Biochemistry. MacMillan, 8th Edition, 2021. Jeffrey Orth, Ines Thiele & Bernhard Palsson: What is flux balance analysis? Nature Biotechnology 28:245–248 (2010). Additionally, current literature will be provided at the beginning of the module.
Further Information:

QBio304: Applied Bioinformatics

Module Responsible: Prof. Dr. Björn Usadel				Version: 30/04/2022
Module Organizer: Prof. Dr. Björn Usadel				**Type:** Compulsory
Lecturer: Prof. Dr. Björn Usadel				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 2 SWS 2 SWS	**Group Size** P: 40 P: 40	**Frequency** Every Winter Semester	

Learning Competencies:
Students can enumerate major bioinformatics databases and standard tools used in common workflows, and they can list the major content in some of these. Students can explain how quick pattern matching can be used to solve some simple biological problems and are able to conduct such analyses in practice.

Students are able to explain the differences in modern sequencing technologies and judge when these would be appropriate. Students can describe the problem of multiple testing and confidently choose different methods to overcome this problem. They can apply R and Bioconductor to analyse modern NGS data and they are able to practically run similarity searches and multiple alignments using state of the art tools.

At the end of the course, students will be able to plan experiments for the practical analysis of typical large-scale biological data sets.

Content:
Lecture:
- The lecture will introduce and recapitulate modern omics technologies and their inherent bioinformatic/statistical challenges.
- A second section will focus on the analysis of the corresponding data using R and, on the statistics, underlying the data analysis.
- The final section will introduce major databases and their applications as well as biological pathway tools and how these help in defining possible hypotheses.

Practical Course:
- Analysis with R
- Introduction to Bioconductor
- Analysis of RNAseq datasets
- Visualization of data and biological pathway analyses
- Application of major tools, including BLAST and multiple sequence alignment tools
- Application of „simple “pattern matching to shape biological hypotheses

Conditions of Participation: Passed Module QBio104 and QBio204
Examination: Project Work
Prerequisites for Awarding Credits for this Module: Passing Project Work
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Current publications in the field of study will be made available before the beginning of the module.
Further Information:

QBio305: Population & Quantitative Genetics

Module Responsible: Prof. Dr. Maria von Korff Schmising				**Version:** 30/04/2022
Module Organizer: Prof. Dr. Maria von Korff Schmising				**Type:** Compulsory
Lecturer: Prof. Dr. Maria von Korff Schmising, Prof. Dr. Juliette de Meaux, Dr. Markus Stetter				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 3 SWS 1 SWS	**Group Size** P: 40 P: 40	**Frequency** Every Winter Semester	

Learning Competencies:
After completing the module, students can:

- describe types and sources of genetic variation and explain methods for the detection and characterisation of genetic diversity
- define and describe important population and quantitative genetic concepts such as: genetic drift, gene flow, natural selection, selective sweep, mating systems, heritability and quantitative traits
- infer population histories and signatures of selection from genetic and genomic data.
- Explain and estimate components of phenotypic variation from experimental data
- Understand and apply statistical methods for QTL detection and association mapping
- evaluate results from crossbreeding and breeding experiments and develop explanatory models.
- Describe the genetic and genomic changes implicated in crop domestication

Content:

- Origin of molecular diversity
  - Types of mutations (and how to detect them)
  - Models of mutations
- Detection and Quantification of genetic variation
  - Heterozygosity
  - DNA sequence variation (SFS, pi, theta)
- Genetic differentiation
  - Fst, PCA, STRUCTURE
- Neutral theory
- Recombination and linkage disequilibrium
- Selection
  - Types of selection (positive, balancing, purifying)
  - Detection of selection (sweeps, Fst outliers, Ka/ks)

- Demography
    - Expansion, bottlenecks, subpopulations, migration
- Quantitative Trait variation
    - Quantitative characters, Breeding type,
- Variance and covariances and heritability
    - Estimation of genetic variance and covariance from experiments
- Mapping quantitative traits
    - Experimental and natural populations, QTL analysis, Association analysis, marker assisted selection
- Epistasis, dominance
- Quantitative evolutionary genetics
    - adaptive evolution, fitness
- Domestication genetics

Conditions of Participation:
Passed Module QBio203

Examination:
Learning portfolio consisting of:
- One written examination (50% of final grade)
- Exercise (50% of final grade)

Prerequisites for Awarding Credits for this Module:
- Passing the exercises (50 % of Exercise Sheets)
- Passing the written exam

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature: -
‘’A primer of molecular population genetics” by Asher Cutter
“Principles of population genetics” Hartl and Clark
“Quantitative Genetics” by Armando Caballero
“Evolution and selection of quantitative traits” by Walsh and Lynch
“Population Genetics” by M.B. Hamilton, 2009
“An introduction to quantitative genetics” Falconer D.S.

Further Information: -

Fourth Semester

QBio401: Microbial Ecology

Module Responsible: Prof. Dr. Bart Thomma				**Version:** 30/04/2021
Module Organizer: Prof. Dr. Bart Thomma				**Type:** Compulsory
Lecturer: Prof. Dr. Bart Thomma				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 75 h	**Self Study** 105 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 3 SWS 2 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:

In the Microbial Ecology course students will learn about the occurrence, diversity and activity of various types of microorganisms (archaea and bacteria, protozoa, fungi, and viruses) in various kinds of ecosystems. Furthermore, students will gain insight into the wide array of associative interactions of microorganisms that occur in symbioses with other microorganisms as well as with host organisms, and that range from mutualism through commensalism to parasitism.

After completing the module, students are able to:

- explain interactions of microorganisms with their biological and physico-chemical environment
- reproduce mechanisms for detection, identification and functional characterization of microorganisms and their roles in whole microbial communities at the DNA- and RNA-level
- explain theories on genome stability, gene fluxes and their links to adaptation
- reproduce mechanisms of quorum sensing and quorum quenching in cell-to-cell communication and cross talk between microorganisms
- understand the role of microorganisms in various types of symbiotic interactions as well as communication and cross talk between microorganisms and their hosts such as in the mammalian intestine, in plant-microbe interactions, in the soil and in aquatic biospheres

Content:

Microbial ecology is exploration of the diversity, the abundance and the distribution of microorganisms, and the study of the interactions of their interactions with each other, the environment, and other living organisms such as human, animal and plant species. Microorganisms form essential and influential parts of ecosystems, as they play crucial roles in various types of symbioses, but also in biogeochemical cycles and in anthropogenic phenomena such as climate change and pollution. In microbial ecology, the dynamics of microbial compositions and the effects that they have on ecosystems is addressed.

Lecture Microbial Ecology

- Biosphere
  - Ecosystems Dynamics
  - Habitats
  - Role in Ecosystem
  - Microbes and Climate
- Nutrient Cycles / Organism-Environment Interaction
  - Carbon fixation
  - Nitrogen fixation
  - Methane Metabolism
  - Sulfur Metabolism
  - Metals
  - Microbes and Pollution
- Ecosystems
  - Symbiosis
  - Microbiomes
  - Microbe-Host Interactions
    - Mutualism
    - Parasitism
      - Microbe - Animal
      - Microbe - Plant
  - Microbe-Microbe Interactions
    - Two Component System
    - Quorum Sensing/Quenching

Conditions of Participation:
Passed Modules QBio101 and QBio201

Examination:
Project Work

Prerequisites for Awarding Credits for this Module:
Passing Project Work

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:
Students will be directed towards recent Microbial Ecology landmark publications at the start of the module

Further Information:

QBio402: Biotechnology & Synthetic Biology

Module Responsible: Prof. Dr. Matias Zurbriggen				**Version:** 20/03/2024
Module Organizer: Prof. Dr. Matias Zurbriggen				**Type:** Compulsory
Lecturer: Prof. Dr. Matias Zurbriggen, Prof. Dr. Julia Frunzke, Prof. Dr. Nick Wierckx, Jun. Prof. Dr Hannes Beyer, Prof. Dr. Dietrich Kohlheyer, Dr. Stephan Thies, Dr. Leonie-Alexa Koch				
Total Working Time 270 h	**Credit Points** 9 CP	**Contact Time** 120 h	**Self Study** 150 h	**Duration** 1 Semester
Course Components Lecture: Exercise: Practical:	 3 SWS 3 SWS 2 SWS	**Group Size** P: 40 P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:

The students are familiarized with the principles, approaches and applications of synthetic biology and metabolic engineering, both on the theoretical and experimental side. This includes microorganisms, animal and plant systems (white, red and green). The students are introduced into the development and application of engineering approaches in biology. This comprises advanced technologies like biosensors, microfluidics and optogenetics. Students learn how to work with microbial and animal/plant cell cultures, and are guided in a small project from cloning and cultivation up to biocatalyst design, bioreactor cultivation and product purification. In addition, the students are taught the practical handling of bioreactors or fermenters and how they can use various parameter measurements to infer the growth and performance of organisms. The students get an introduction into bench to business approaches.

Content:

<u>Lecture:</u>

- Metabolic and Biochemical Engineering
  - Fundamentals of metabolism
  - History of Biotechnology: past, present, future
  - Changing/rerouting metabolism, role of transporters
  - Laws of Growth, Fermentation
  - Microfluidics
  - Key performance indicators of biotechnology
  - Downstream processing
  - Regulatory framework
  - Microbial platforms: photosynthetic and non-photosynthetic bacteria, yeast, fungi, algae.
  - Products: bulk and fine chemicals, polymer precursors, biopharmaceuticals
  - Substrates: sugars, sugar polymers, plastics
- Phage Biotechnology:
  - Applications of phages for sustainable biocontrol
  - Phage therapy

- Application of bacterial immune systems for genetic and genome engineering (ResMod, CRISPR/Cas)

- New enzymes:
  - Metagenomics. Protein engineering function/mechanism. Directed evolution approaches.
  - Selection vs Screening: high-throughput screening (Laboratory) and Computational Methods (*in silico*), link to synthetic biology: identify/develop biocatalysts to close gaps in synthetic metabolic networks.
  - Industrial applications.
  - Combination with chemistry, biohybrid systems.
- Synthetic Biology: Design-Build-Test-Learn cycle
  - Synthetic biology engineering principles
  - Product specification – bioparts – mathematical modelling – prototyping – testing – validation
  - Synthetic molecular modules and circuits - logic gates
  - Synthetic signal and metabolic networks
  - Synthetic regulation, switches
  - Optogenetics
  - Synthetic molecular tools: biosensors, CRISPR, designer nucleases
  - Enabling technologies: flow cytometry, microfluidics, advanced microscopy, bioprinting, AI – Machine learning algorithms, cell culture, tissue engineering and organoids
- Synthetic biology applications: white-green-red
  - Biopharmaceutical design and production. Regulatory frameworks, clinical trials.
  - Biomedicine/personalized medicine. Immuno and cell-therapies. Gene therapy, living therapeutics.
  - Agriculture and designer foods, synthetic meat.
  - Production of fine and bulk chemicals
  - Synthetic evolution/evolutionary engineering: enhancing product tolerance, substrate utilization, growth coupling strategies to increase precursor supply/enhance production
  - Xenogenetics, synthetic organelles and cells. Bottom-up vs top-down approaches
  - Genome engineering/reduction. De novo engineering.
  - Reconstruction biology / concept of orthogonal systems. Applications in fundamental research.
  - Synthetic microbial communities
  - Synthetic tissues and organoids. Biological computing. Cybergenetics.
  - Synthetic biomaterials.
  - In vitro synthetic biology and synthetic diagnostics.

Practical:

- Molecular genetic basics for engineering (for bacteria): Plasmids, Genomic integration, gene expression
- Design and evaluation of transcription factor-based biosensors
- Microbial physiology: monitoring growth and production in microbial cultures
- Metabolic-Quiz: Analysing and interpreting bacterial strains with defects in central metabolism
- Special emphasis on the protocol writing (industry wise). Links to “Learning scientific approach” (S.1) and project practicals in S.6-8
- Corresponding introduction to an electronic lab-book

Theoretical Exercises with presentation/demonstration:

- Development of an automated data analysis pipeline using computer programming.
- “Who is who in Synthetic Biology?” – Research on the topics and pioneers of Synthetic Biology.

Conditions of Participation: Passed Modules QBio201
Examination: Learning portfolio consisting of: • One written examination (60% of the final grade) • Practical performance (20% of the final grade) based on active participation, submission of a written report and presence/attendance (80% of the practicals). • Presentation of the theoretical exercises (20% of the final grade)
Prerequisites for Awarding Credits for this Module: • Passing written exam • Submitted complete protocol of sufficient quality • Presentation of theoretical exercises
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Due to rapid development of the fields dealt with in this module, current publications will be made available before the beginning of the module
Further Information: The practical course will take place at the Forschungzentrum Jülich. A shuttle bus between the HHUD campus and the research center will be made available.

QBio403: Developmental Biology

Module Responsible: Prof. Dr. Rüdiger Simon				Version: 30/12/2020
Module Organizer: Prof. Dr. Rüdiger Simon				**Type:** Compulsory
Lecturer: Prof. Dr. Rüdiger Simon, Prof. Dr. Guido Grossmann				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	3 SWS 1 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:
After completing the module, students can:

- explain the fundamental challenges of multicellular life on the example of various model organisms.
- design an experiment that enables them to perform quantitative analyses of developmental plasticity and robustness.
- perform simulations of patterning events using computer simulations.

Content:
Students will be introduced to the basic principles underlying multicellularity and organismal development, such as cell adhesion, cell-cell communication, cellular and planar polarity, as well as cell differentiation. To understand common strategies and specific solutions during evolution, we will investigate the developmental programs from rather simple and transiently multicellular organisms like the amoeba Dictyostelium discoideum, to plants (Arabidopsis thaliana, Pisum sativum, Brachypodium distachyon, Zea mays) and animals (Drosophila melanogaster, Xenopus laevis, Gallus gallus domesticus, Mus musculus and Homo sapiens).

In a first exercise, the students will conceptualize, plan and perform an experiment with the purpose to follow the development in a model system of their choice, use video documentation and extract quantitative information to investigate phenotypic plasticity and robustness.
In a second exercise, the students will use computer simulations to understand the relative importance of various parameters such as diffusive signaling compounds on the formation of biological patterns.

Specifically, the following topics will be covered:

- Cell Identity
    - Cell Potency
    - Differential Gene Expression and Metabolic Profile
    - Apoptosis

- Cell Differentiation
    - Epigenetic
    - Regeneration
    - Reprogramming: Stem Cell → Soma Cell → Stem Cell
    - Cell Division Control
    - Cell Elongation
- Cell-Cell Communication / Cell Signaling
    - Reception - Transduction - Response
    - Bistability
    - Ultrasensitivity & positive feedback loops
    - Local vs. systemic signaling
    - Hormonal signaling
    - Exemplary signaling pathways
- Pattern Formation
    - Reaction Diffusion System
    - Elastic Instability
    - Turing Pattern
    - Phyllotaxis
- Plant Development
    - Model organisms
    - Patterning of the embryo
    - Meristems
    - Reproduction
    - Differentiation
- Animal Development
    - Model organisms
    - Pattern formation
    - Gastrulation
    - Morphogenesis
    - Reproduction
    - Differentiation

Conditions of Participation:
Passed modules QBio201 and QBio202

Examination:
Learning portfolio consisting of:

- 2 Exercises (15% each of final grade)
- One written examination (70% of final grade)

Prerequisites for Awarding Credits for this Module:

- Participation in exercises: Minimum 1 of possible 15 pt
- Passing the written exam: Minimum 35 of 70 pt
- Minimum total cumulative points: 50 of 100 pt

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language: English
Literature: Barresi, Michael J. & Scott F. Gilbert (2020). Developmental Biology. International Twelfth Edition. New York, Oxford: Sinauer Associates, Oxford University Press.
Further Information: -

QBio404: Data Science and Machine Learning

Module Responsible: Prof. Dr. Achim Tresch				**Version:** 30/04/2021
Module Organizer: Prof. Dr. Achim Tresch,				**Type:** Compulsory
Lecturer: Prof. Dr. Achim Tresch, Prof. Dr. Andreas Beyer, Dr. Andrea Schrader				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 75 h	**Self Study** 105 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 3 SWS 2 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:
Students can analyse high-dimensional, biological data by methods of machine and statistical learning using the statistical software R. They acquire a repertoire of computer-based methods for dimension reduction, for supervised and unsupervised learning tasks and estimation problems as they occur in omics data. Students are aware of the peculiarities of high-dimensional statistics and large data sets (e.g. curse of dimensionality and multiple testing) and can critically assess third-party analyses.

Content:
Principles & basic techniques for Machine Learning:
- Risk minimization
- Optimization (convexity, gradient descent, backpropagation, Nelder-Mead)
- Sampling (rejection sampling, Markov Chain Monte Carlo)
- Cross validation, Bootstrap
- Boosting
- Statistical testing

Supervised learning:
- Classification (logistic regression, Support Vector Machines, decision trees)
- Regression ((generalized) linear models, regularization, interactions)
- Random forests
- Neural networks

Unsupervised learning:
- Clustering (k-means, Gaussian mixtures, hierarchical clustering)
- Hidden Markov models
- Autoencoders

Dimension reduction:
- Principal Components Analysis
- Stochastic neighborhood embedding (SNE/t-SNE)

Practical skills: Analysis of high-dimensional data, statistical packages in R / Bioconductor
Conditions of Participation: Passed Module QBio203 and QBio103
Examination: Learning portfolio consisting of • One written examination about the content of the lectures (50% of the final grade) • Exercises (50% of the final grade)
Prerequisites for Awarding Credits for this Module: • Passing Exercises (50 % of Exercise Sheets) • Passing Written Exam
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Mathematics for Machine Learning; Deisenroth, MP; Faisal, AA; Ong, CS; Cambridge University Press: Cambridge (2019) Pattern Recognition and Machine Learning; Bishop, Christopher M.; Springer (2011) The Elements of Statistical Learning: Data Mining, Inference, and Prediction; Hastie, T; Tibshirani, R; Friedman, J; Springer (2009)
Further Information:

QBio405: Science Ethics & Communication

Module Responsible: Prof. Dr. Guido Grossmann				Version: 30/04/2021
Module Organizer: Prof. Dr. Guido Grossmann				**Type:** Compulsory
Lecturer: Prof. Dr. Guido Grossmann, Dr. Divykriti Chopra-Ufer				
Total Working Time 90 h	**Credit Points** 3CP	**Contact Time** 60 h	**Self Study** 30 h	**Duration** 1 Semester
Course Components Seminar Exercise	2 SWS 2 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Summer Semester	

Learning Competencies:
After completing the module, students will be able to
- define good scientific practice and identify scientific misconduct,
- discuss scientific topics in an ethical context,
- communicate science to a wider audience.

Content:
In this module, students will deal with scientific communication and ethical questions related to biological sciences. The range of topics range cover central questions of science ethics, such as good scientific practice and scientific fraud, as well as science journalism and the successful realization of public outreach projects.

In the first part, basic ethical standards will be defined as well as forms of scientific misconduct, esp. plagiarism, falsification and fabrication, as well as topics such as "conflict of interest", fake news and science communication. Reasons, consequences and prevention measures will be discussed.

In the second part, ethical questions will be discussed on the example of specific topics of modern life sciences. For each topic, the students should prepare arguments for and against and be able to represent them in a discussion group. In the face-to-face event, the ethical problems are discussed in the group.

Topics:
- Animal experiments, clinical studies and big pharma
- Cloning, Genetic Engineering, Genome Editing, and Synthetic Biology
- Artificial intelligence
- Biopiracy and patents
- Modern agriculture, fertilizers and pesticides, climate change and meat consumption
- In vitro fertilization, abortion, gene therapy and designer babies

• Euthanasia and life-prolonging measures In the practical part, the students will, in small groups, conceptualize and carry out a scientific outreach or scientific communication project on a topic of their choice.
Conditions of Participation: Passed Modules QBio105, QBio302 and QBio305
Examination:
Prerequisites for Awarding Credits for this Module: • Participation in 80% of the seminars • Participation in the outreach exercise
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: https://www.dfg.de/en/research_funding/principles_dfg_funding/good_scientific_practice/in-dex.html Friesner, J, Colón-Carmona, A, Schnoes, AM, et al. Broadening the impact of plant science through innovative, integrative, and inclusive outreach. Plant Direct. 2021; 5:e00316.
Further Information: -

Fifth Semester

QBio501: Organismic Physiology

Module Responsible: Prof. Dr. Stanislav Kopriva	**Version:** 30/12/2020
Module Organizer: Prof. Dr. Stanislav Kopriva	**Type:** Compulsory

Lecturer:
Prof. Dr. Stanislav Kopriva, Prof. Dr. Andreas Weber, Prof. Dr. Ute Höcker, Dr. Takaki Maekawa, Dr. Natalia Kononenko

Total Working Time	**Credit Points**	**Contact Time**	**Self Study**	**Duration**
450 h	15 CP	165 h	285 h	1 Semester

Course Components		**Group Size**	**Frequency**
Lecture:	7 SWS	P: 40	Every Winter Semester
Exercise:	2 SWS	P: 40	
Practical:	2 SWS	P: 20	

Learning Competencies:
After completing the module, students know:

- the similarities and differences in the physiology of plants and animals.
- the concepts of disease and homeostasis
- signalling pathways, hormones, and receptors
- mechanisms of interaction with environment

They are able to describe anatomy of both in quantitative terms, end explain evolution and adaptation.
They obtain theoretical knowledge in the lectures, which will be deepened in the exercises through reading and presenting scientific papers to key content. In the practical part the students will learn to handle basic model organisms, perform experiments, record, evaluate, and present experimental data.

Content:
In the "Organismic Physiology" module, students Instead of dividing the lecture into two parallel parts, the common aspects of animal and plant physiology are taught, highlighting the similarities at structure and molecular level. The main contents are:

- Shape & Function
- Movement/locomotion
- Nutrition/mineral nutrition
- Transport/circulation
- Respiration
- Immunity
- Stress and disease
- Communication/Hormones

- Circadian clocks
- Homeostasis
- Sensory systems
- Size & Metabolic rate
- Biofilms
- Autophagy

Conditions of Participation:
Passed modules QBio201 and QBio302

Examination:
Learning portfolio consisting of
- One written examination (50% of final grade)
- Presentation (25% of final grade)
- Protocol (25% of final grade)

Prerequisites for Awarding Credits for this Module:
- Passing the presentation and written exam
- Successful participation in the practical course

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:
Campbell Biology, 12th edition, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Rebecca Orr, ISBN: 9780135988046
Additionally, current publications in the field of study will be made available before the beginning of the module.

Further Information: -

QBio502: From Data to Knowledge

Module Responsible: Prof. Dr. Andreas Weber				**Version:** 30/04/2021
Module Organizer: Prof. Dr. Andreas Weber				**Type:** Compulsory
Lecturer: Prof. Dr. Andreas Weber				
Total Working Time 180 h	**Credit Points** 6 CP	**Contact Time** 60 h	**Self Study** 120 h	**Duration** 1 Semester
Course Components Lecture: Exercise:	 3 SWS 1 SWS	**Group Size** P: 40 P: 20	**Frequency** Every Winter Semester	

Learning Competencies:
The students are able to select appropriate analytical methods and instruments to effectively and critically solve analytical questions in biochemistry, molecular biology and structural biology. They can name the physical laws on which the respective measurement method is based, describe observed phenomena and explain physical relationships. Students can compare alternative measurement methods with each other, specify the methodological limits and justify the selection of a suitable measurement method. They will be able to understand the different types of data produced, data processing, and data analysis. Students can design proper experimental strategies, including proper sampling and sample preparation, selection of external and internal standards as well as proper negative and positive controls.

Content:
DNA-Analytics:
- Classical and next-generation DNA sequencing methods
- Application of NGS to quantitative and qualitative analysis of genome structure and gene expression
- Establishment of metabolic pathways and Genetic Networks via Gene Expression Analysis
- Determination of the Function of Genes via their Network Position
- Determination of Biomarkers for Diseases

Proteomics:
- Targeted vs. Untargeted Quantification of Proteins
- Mass Spectrometry
- Chromatography
- HPLC
- 2D Gel Electrophoresis
- Label-free and label-based quantification
- Analysis of protein interaction and post-translational modification
- Cryo-EM

- NMR Spectroscopy
- X-Ray Crystal Structures

Metabolomics:

- Targeted vs. Untargeted Quantification Strategies
- Mass Spectrometry
- Chromatography
- Optical tests
- Steady-state and dynamic analysis of metabolism
- Cell-specific and subcellular metabolism
- Genetically-encoded metabolite sensors
- Databases
- Assays
- Screenings

Organismic Level

- Quantitative Imaging
- FACS and Flow Cytometry

Conditions of Participation:
Passed modules QBio201, QBio301and QBio303

Examination:
Learning portfolio consisting of

- One written examination (50% of the final grade)
- Exercises (50% of the final grade)

Prerequisites for Awarding Credits for this Module:

- Passing Exercises (50 % of Exercise Sheets)
- Passing Written Exam

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature:
Analytical Methods and Concepts in Biochemistry and Molecular Biology(2018), Friedrich Lottspeich, Joachim Engels, ISBN: 978-3-527-33919-8

Further Information:

Fifth – Seventh Semester

Advanced Module I-IV

The following courses are available as advanced module I, II, III and IV for the students of qBio and qBio+
qBio students can choose one of the following elective courses in the 5. semester.
qBio+ students can choose from the following elective courses in the 5., 6., and 7. semester.

List of elective modules (V-Module) available at Heinrich Heine University

V403 - Genomics and Molecular Biology of Plants
V404 - General Microbiology
V406 - The Cell Nucleus: Functional Organization and its Role in Neurodegenerative Diseases
V409 - Molecular Population Genetics
V411 - Principles of Eucaryotic Microbiology I
V413 - Genetic Mechanisms of Pattern Formation during Invertebrate Development
V415 - Molecular Techniques in *Drosophila melanogaster*
V418 - Genetic and Molecular Principles of Microorganisms
V416 - Transcriptional Control in Vertebrates
V421 - Data Evaluation and Data Illustration
V422 - Photo-oxidative Stress in Plants
V423 - Molecular Biophysics: X-ray Structure Analysis
V425 - Molecular Biophysics: Hydrodynamics
V426 - Basic Principles in Microbiology and Enzyme technology
V428 - NMR Spectroscopy of Biological Macromolecules
V429 - PC Based Analysis and Presentation of biological Data
V430 - Plant Biochemical Genetics
V431 - Solid-State NMR-Spectroscopy in Structural Biology
V434 - Cell Biology and Physiology
V436 - Biochromatography
V435 - Analysis of Protein Interactions by NMR Spectroscopy
V440 - Plant Evolution
V441 - Ecological and systematical field course
V446 - Foundations of Biodiversity and Evolution
V462 - Molecular and clinical Immunology
V465 - Stem Cell Biology and Regenerative Medicine
V474 - Genomics and Molecular Biology of Plants
V484 - Phenotypic Adjustment of Plants
V485 - Model Organism Drosophila
V487 - Systematics of flowering plants
V488 - Molecular Evolution
V490 - Diseases of the central nervous system+
V492 - Protein Folding and Protein Misfolding Diseases
V493 - From genome sequence to protein expression

V496 - Plant Quantitative Genetics V501 - Physical Biology of the Cell V506 - Symbiosis and the evolution of eukaryotic compartments V507 - Glycobiology V509 - Principles of population and quantitative genetics V508 - Bioacoustics V510 - Theory of Biological Networks V515 - How to engineer stress tolerant crops V516 - Developmental basis of tumor formation from intestinal stem cells V517 - Ecological Developmental Biology V518 - Electrical signals in the nervous system V519 - Intracellular signal-transduction in Arabidopsis The detailed description for the elective modules offered by biology department of HHU can be found on the following link https://www.biologie.hhu.de/studium/studierende/modulvergabe.html
List of elective modules (Wahlpflicht-module) available at University of Cologne Bioanalytics Biology of Freshwater Algae Experimental Ecology Fundamentals of Developmental Biology Molecular Plant Nutrition Signal Molecules and Communication in Plants Animal Physiology and Neurobiology Introduction to Biodiversity Genetics Model Systems and Methods In Cell Biology Molecular Plant Physiology Recombinant Proteins Module Descriptions Summer Semester Fundamentals of Developmental Biology Zoo Biology Molecular Plant Physiology Electron- Microscopic Methods in Cell Biology The detailed description for the elective modules offered by biology department of UoC can be found on the following link https://biologie.uni-koeln.de/studium-lehre/bachelor-of-science/wahlpflichtmodule-i-und-ii

Studium Integrale (Interdisciplinary Selection)			
Module Responsible: Chairperson examination committee			**Version:** 30/12/2020
Module Organizer: Coordinator Bachelor Programme Quantitative Biology PLUS			**Type:** Compulsory
Credit Points 12 CP	**Contact Time** Variable	**Self Study** Variable	**Duration** Variable
Course Components Lecture Exercise Practical Seminar	**Group Size** P: Variable	**Frequency** Every Winter and Summer Semester	
Learning Competencies: The students are able to familiarise themselves with a subject area(s) in HHU or UoC that is not related to their subject. They can reflect on the individually chosen contents of the module, justify their choice and write a written reflection. More details can be found on the UoC website at https://portal.uni-koeln.de/studium/studierende/studium-integrale-extracurriculare-ange-bote/studium-integrale-details			
Content: Variable depending on the course, students can choose from areas other than Biology like, • Economy/ Social sciences / Law • Medicine/ Health/ Psychology • Mathematics/ Computer Science • Literature • Culture/ Art/ Media/ Music • History/ Cultures & Societies/ Politics • Ethics/ Philosophy/ Religion • Education & Rehabilitation • Chemistry/ Earth Sciences/ Physics • Gender & Diversity • Languages • IT skills			
Conditions of Participation: Enrolled in Quantitative Biology			
Examination: Depending on the individual module chosen.			

Prerequisites for Awarding Credits for this Module: Depending on the individual module chosen and submission of a written reflection
Factor for the Overall Grade: No grade will be given
Language: Variable
Literature: Depending on individual modules
Further Information: -

International/ Industrial Research Experience

Module Responsible: Chairperson examination committee			**Version:** 30/12/2020
Module Organizer: Coordinator Bachelor Programme Quantitative Biology PLUS			**Type:** Compulsory
Credit Points 21 CP	**Contact Time** Variable	**Self Study** Variable	**Duration** 4 months
Course Components Lecture Exercise Practical Seminar	**Group Size** P: 1	**Frequency** Every Winter and Summer Semester	

Learning Competencies:
The students can reflect on the content of the topics, concepts and strategies of the individually selected research area in a laboratory at an international university or at a company and transfer them to other subjects. They are able to plan and carry out a scientific project independently. They have learned to access further scientific literature and to formulate scientific hypotheses based on it. They are able to develop experimental strategies to test these hypotheses. They have expanded their methodological competence to a high degree. The students can present their own results appropriately in a scientific presentation.

Content:
Depending on the individual research area chosen.

Conditions of Participation:
Enrolled in Quantitative Biology

Examination:
Learning portfolio consisting of:
- Presentation of the internship project (50% of the final grade)
- Written report on the internship project (50% of the final grade)

Prerequisites for Awarding Credits for this Module:
- Successful presentation of the internship project
- Passing the written report

Factor for the Overall Grade:
No grade will be given.

Language:
Variable

Literature:
Further Information: -

Sixth/Eighth Semester

QBio801: Project Planning

Module Responsible: Prof. Dr. Matias Zurbriggen	**Version:** 23/11/2020
Module Organizer: Prof. Dr. Matias Zurbriggen	**Type:** Compulsory

Lecturer:
Prof. Dr. Lutz Schmitt, Prof. Dr. Matias Zurbriggen, Prof Dr. Benjamin Stich

Total Working Time	**Credit Points**	**Contact Time**	**Self Study**	**Duration**
180 h	6 CP	60 h	120 h	1 Semester

Course Components		**Group Size**	**Frequency**
Lecture:	2 SWS	P: 40	Every Summer Semester
Seminar:	2 SWS	P: 20	

Learning Competencies:
After completing the module, students:
- develop and write a research-based concept for a research project:
- convincingly demonstrate the relevance of their research approach;
- describe the methods to be used and justify their choice;
- describe expected results plausible, identify and name potential obstacles and problems and plan targeted alternative strategies.
- understand the data types produced by a particular experiment and develop an appropriate data analysis scheme, including proper statistical analysis and data displays
- Time plan and budget (personal, resources);
- Presentation and defence of research proposal.

Content:
- Full Research Cycle
  - The Problem
  - Literature Research
  - Idea Development
  - Experimental Design
  - Data Analysis and Modelling
- Writing of a Research Proposal

Conditions of Participation:
Enrolled in Quantitative Biology

Examination:
Learning portfolio consisting of:
- Presentation of the project proposal (50% of the final grade)

• Project Description (written report) (50% of the final grade)
Prerequisites for Awarding Credits for this Module: • Passing the Presentation of the project proposal • Passing the Project Description (written report)
Factor for the Overall Grade: The grade is weighted according to the credit points (CP) in the overall grade.
Language: English
Literature: Current publications will be made available before the beginning of the module
Further Information: -

QBio802: Project Internship

Module Responsible: Prof. Dr. Andreas Weber				Version: 30/11/2020
Module Organizer: Coordinator Bachelor Programme Quantitative Biology				**Type:** Compulsory
Lecturer: All lecturers belonging to Biology, Informatic and Chemistry (HHU) and Biology (UoC) teaching faculty				
Total Working Time 270h	**Credit Points** 9 CP	**Contact Time** Variable	**Self Study** Variable	**Duration** 8 weeks
Course Components Project Internship		**Group Size** P: 1	**Frequency** Every Winter and Summer Semester	

Learning Competencies:
The students are able to plan and carry out a more comprehensive scientific project independently. They have made themselves familiar with the further scientific literature on their research topic and have formulated scientific hypotheses based on it. They are able to develop experimental strategies to test these hypotheses and to conduct the corresponding experiments afterwards. The experimental work can be used as a foundation for a subsequent bachelor thesis.

Content:
This module consists of 8 weeks of work in the laboratory (theoretical/ practical) or in field trials. The research seminar of the institute is attended at the same time. At this seminar the students work independently on a concrete project. This can also be a preparation for a possible Bachelor's thesis topic.

Conditions of Participation:
Enrolled in Quantitative Biology

Examination:
Learning portfolio consisting of Project work (50%), Protocol (25%) and Presentation (25%)

Prerequisites for Awarding Credits for this Module:
Passing the Project Work

Factor for the Overall Grade:
The grade is weighted according to the credit points (CP) in the overall grade.

Language:
English

Literature: Current publications will be made available before the beginning of the module
Further Information: -

QBio803: Bachelor Thesis

Module Responsible: Chairperson of the Examination Committee of Quantitative Biology Study Programme				Version: 30/11/2020
Module Organizer: Coordinator Bachelor Programme Quantitative Biology/Biology PLUS				**Type:** Compulsory
Lecturer: All lecturers belonging to Biology, Computer Science, and Chemistry at HHU and Biology and Medicine at UoC				
Total Working Time 450 h	**Credit Points** 15 CP	**Contact Time** Variable	**Self Study** Variable	**Duration** 3 months
Course Components Bachelor Thesis Bachelor Defence	12 CP 3 CP	**Group Size** P: 1	**Frequency** Every Winter and Summer Semester	

Learning Competencies

Students have acquired the following knowledge/competencies after completing the module:

- Working on a scientific problem in a self-chosen research area under guidance
- Abstract, logical, analytical thinking and building of meaningful chains of argumentation
- Complying with the rules of good scientific practice
- Expertise
  - Elaboration of a scientific topic under guidance
  - Literature research on a given topic
  - Application of skills and knowledge from modules and the technical literature to a scientific question
  - Specialized biological expertise and professional competence
  - Mastery of the advanced techniques and methods relevant to the problem
  - An Analytical approach to troubleshooting the application of scientific methods
  - Critical assessment against previous knowledge and presentation of own research results
  - Written and graphical representation of scientific findings
- Self-motivation and independent learning
  - Acquisition of specialist knowledge from the scientific literature
- Communication skills and ability to work in a team
  - Scientific communication skills
  - Data presentation and discussion in written and spoken form
  - Ability to write a scientific report on a project carried out independently
- Project and time management:
  - Organizational skills, realistic time and work planning
  - Critical classification and presentation of current research results

Content: The subject of the bachelor thesis is determined by the supervisor of the thesis, usually in consultation with the candidate.
Conditions of Participation: In the 3-year study programme (qBio), students can register the thesis at the earliest when the entire basic phase and one of the elective modules have been successfully completed. Students in the 4-year variant (qBio+) must additionally have completed a second elective module.QBio202
Examination: Written report of the results: bachelor thesis (80%) Seminar lecture with discussion (20%)
Prerequisites for Awarding Credits for this Module: Successful completion of the scientific project defined with the supervisor, and its professional presentation in a written thesis that is submitted before the assigned deadline. Additionally, the content of the thesis must be presented professionally in the seminar.
Factor for the Overall Grade: The grade for the bachelor thesis contributes to the overall grade with twice its weight in terms of credit points (CP).
Language: English
Literature: Current publications will be made available before the beginning of the module
Further Information: - The bachelor thesis is <u>not</u> a final thesis. It can, but does not have to be completed at the end of the course of study. The bachelor thesis project is handed out and supervised by a full-time professor or another habilitated member of the Faculty of Mathematics and Natural Sciences of HHU or UoC. The topic usually comes from the research area of the supervisor. On application, it is also possible to carry out a bachelor thesis at another faculty or university; in this case, the student must seek a second supervisor who is a faculty member of the Faculty of Mathematics and Natural Sciences at HHU or UoC. The student registers the bachelor thesis in the student portal after consultation with the supervisor. Instructions for registration, rules, examination regulations, and a guideline for writing the thesis as well as evaluation criteria for the review of the thesis can be found on the Quantitative Biology Website. <u>Important notes</u> • The student must be matriculated in the qBio or qBio+ programme when submitting the thesis. • The issued topic can be returned by the examinee only once and only within four weeks of the issue. • The processing time is 3 months. In exceptional circumstances (such as an extended illness of the candidate or the breakdown of equipment central to the thesis project), the examination committee may extend the processing time by up to 6 weeks upon justified

request. The request for an extension of the processing time is submitted to the examination committee via the Student and Examination Administration.

- In the event of failure, the bachelor thesis may only be repeated once.