MSc Quantitative Life Science

Study Program Handbook

1 Program Overview

1.1 Background

Life Science is the study of living organisms and the processes of life. It embraces several classical scientific disciplines including aspects of biology, biochemistry, medicine, pharmacy, chemistry and bioengineering, and it thus contributes to solving many societal challenges ranging from health care and nutrition to global warming. While traditionally considered a science based on qualitative experiments, the emergence of new technologies, like next-generation sequencing, super-resolution imaging and high-resolution mass spectrometry, lead to a wealth of quantitative data offering the opportunity for a deeper understanding of the most fundamental processes of life.

According to Galileo “Mathematics is the language, in which God has written the Universe" or in the words of S. Devi “Mathematics is a systematic effort of solving puzzles posed by nature”. Quantitative Life Science relates biological systems to mathematics. In the last century, living organisms were still considered too complex for quantitative assessment and computational modelling due to the plethora of different molecules and processes that govern cellular biology and interaction. Additionally, any living organism is exposed to a multitude of environmental factors and xenobiotics that further influence organismal function and behavior.

In the 21st century, however, the situation has dramatically changed. Modern experimental technologies emerged that allow a comprehensive analysis of living organisms, which have been termed the science of Omics. For example, modern mass spectrometry can obtain information on the molecular composition and content of a biological sample within a few hours of measurement time. Likewise, the genomes of whole organisms containing genetic information in billions of nucleotides can nowadays be sequenced within hours or days, thereby generating terabytes of data a month in many laboratories. Concomitantly, modern data science has caught up in the last decade with this development, providing suitable hardware to store and process the immense amount of data obtained. With the help of novel approaches such as machine learning and artificial intelligence, scientists are now able to not only manage big datasets but also extract meaningful insights and ultimately knowledge from biological databases. All these developments call for a Master program reflecting these developments in the Life Sciences offered by Constructor University.

To leverage this vast amount of data and perform successful research in this age of big data, scientists thus require logical rigor and numerical literacy allowing them to analyze and interpret these new forms of data. Hereby the current developments in the field of information technology, like *high-performance computing* and machine learning, will prove invaluable tools towards these aims. Moreover, developing new hypothesis and design experiments exploiting the full potential of these new technologies requires a deep understanding of their scopes and limitations.

While mastering these skills is crucial to participate in this on-going revolution in the field of life science and assume leadership roles in scientific research in academia and industry. Therefore, and in contrast to *classical* Life Science, Quantitative Life Science places an emphasis on numerical data, obtained by experimental measurements, processed and generalized by mathematics and the tools of modern data science.

1.2 Concept

The Quantitative Life Science (QLS) Master Program *at Constructor University* prepares Life Science students for a successful career in academia or industry through an interdisciplinary education combining cutting-edge quantitative experimental techniques as well as the computational expertise to generate, critically evaluate, fully understand and utilize the associated data. Additional cornerstones of the program are a strong research component, specialization through diverse electives, and transferable skill courses reflecting real-life science and business requirements.

The majority of Life Science graduates continue to study for a PhD degree. Hence, our study program MSc Quantitative Life Science provides the opportunity for individual specialisation as well as the skills and knowledge to successfully conduct independent research in a PhD program at Constructor University or other world-class universities. An international campus and a close interaction between teachers and students provide an intellectual and social environment that offers numerous opportunities for personal development and for working in diverse teams.

Students will also learn how to operate as a member of a team in a research group and contribute as a reliable and valuable collaborator, and even a responsible leader in larger projects. The faculty advises, encourages, and supports students to think and study independently, conduct autonomous background reading, solve problems alone or in teams, and bring new ideas and solutions to seminars and tutorials for discussion. The MSc in Quantitative Life Science is a truly interdisciplinary program. It benefits from a broad faculty expertise offering modules that range from various branches of Life Science and Chemistry interlinked with computer science and software engineering.

1.3 Qualification Aims

1.3.1 Educational Aims

The MSc in Quantitative Life Science aims to educate independent scientific researchers able to pursue a successful career at the intersection of life science and computer science.

For this, the students will broaden and deepen their knowledge of innovative computational approaches, state-of-the-art experimental techniques, and theoretical concepts in Quantitative Life Science with a particular focus on the Omics disciplines. These technical and programming skills combined with subject-matter expertise will enable students to work in a scientific environment.

Students will gain experience, applying these skills in actual research projects and learn how to advance scientific knowledge by developing original research hypotheses and designing, planning, and executing the wet-lab and dry-lab experiments to test them. They will also gain the necessary numerical literacy and scientific rigor to scrutinize, interpret and defend experimental results or computational simulations to international scientific standards.

Students will refine their skills to visualize their data, efficiently communicate results and concepts to scientific audiences through oral presentations, written research proposals or scientific publications, and discuss them with their peers.

Throughout the MSc program the students will refine their ability to reflect on their own performance, work in diverse teams and act as a responsible, ethical, and effective stakeholder in the scientific community and beyond.

1.3.2 Intended Learning Outcomes

By the end of this program, students will be able to:

1. Describe complex technical and conceptional advances in the Life Sciences in depth and with specific focus on Omics technologies, like genomics, transcriptomics, proteomics, and metabolomics.

2. Understand common computational tools, algorithms, and databases for data processing, analysis and visualization used in the life sciences.

3. Critically examine and creatively apply intricate techniques to perform quantitative experiments, obtain reliable data, and answer complex scientific questions in the life sciences at high scientific and ethical standards.

4. Scrutinize and implement innovative bioinformatics approaches to obtain, examine, and compare Life Science data.

5. Construct comprehensive mathematical models and detailed computational simulations to generate and test hypothesis in the field of biology or chemistry.

6. Scrutinize and critique scientific results, experimental approaches, and research hypothesis from all fields of quantitative life science.

7. Construct original and innovative research hypothesis and design experiments to test them individually or as a team in actual research projects and a master thesis.

8. Apply professional writing, communication, and presentation techniques, combined with state-of-the-art visualization tools to effectively communicate with scientific and non-scientific audiences.

9. Understand the chances, risks, and approaches of applying scientific research in modern society considering ethical and commercial aspects while following and defending ethical, scientific, and professional standards.

10. Take responsibility for their own learning, personal and professional development and role in diverse teams, evaluating critical feedback and self-analysis.

1.4 Target Audience

The study program MSc Quantitative Life Science is designed for students with a strong background in Life Science and related subjects, aiming to pursue a career in research and are excited to exploit the potential of big-data technologies and computer-assisted analysis.

As a consecutive second-degree program, the students should hold a BSc in related fields such as biology, cell biology, biochemistry, chemical biology, chemistry, pharmacy, biotechnology, and bioinformatics, and be proficient in English, the language of education.

Moreover, the program aspires to attract international students from a variety of cultural and geographical backgrounds to foster a diverse community with room for exchange and creativity.

1.5 Career Options

The program primarily prepares the students for a career as independent scientists either in academia or industry. Staying in academia, we expect the students to pursue a PhD degree, and the independent research in the master thesis as well as advanced electives, provide the perfect basis for this endeavour. In industry, graduate student can, thanks to their technical skills, directly contribute as research scientists, with the *transferable skills courses* providing the necessary skills to assume leadership roles.

Future graduates of this program will transfer to PhD programs or will take up positions in various fields and industries, most notably the biotechnology sector, pharmaceutical industry, agrochemical industry, analytical service providers, food industry NGOs, academia or governmental regulatory authorities.

Furthermore, the logical thinking, numerical literacy and computational skills transferred in the program also allows the graduate to pursue careers in highly quantitative Jobs, like management consulting or financial services.

The Career Service Center (CSC) helps students in their career development. It provides students with high-quality training and coaching in CV creation, cover letter formulation, interview preparation, effective presenting, business etiquette, and employer research as well as in many other aspects, thus helping students identify and follow up on rewarding careers after graduating from Constructor University. For further information, please contact the Career Service Center (CSC) (https://constructor.university/student-life/career-services). Furthermore, the Alumni Office helps students establish a long-lasting and global network which is useful when exploring job options in academia, industry, and elsewhere.

1.6 Admission Requirements

The Quantitative Life Science master program requires students to hold at least a good bachelor's degree in the areas of Life Science or related Areas. Applicants need to prove a strong interest in the contents of the study program in a motivation letter. The general "Admission and Enrollment Policies" of Constructor University apply (see Academic policies | Constructor University). Social commitment as well as extracurricular and voluntary activities during undergraduate studies, e.g. university service, clubs, varsity, social work, etc. will be considered.

Additionally, participants should possess elevated analytical, problem solving and verbal communication skills which must be substantiated in recommendation letters.

Study at Constructor University takes place in a highly intercultural environment. It is therefore necessary to be willing to join such a multicultural-international community and work together with students and faculty across various fields of interest at Constructor University.

Admission to Constructor University is selective and based on a candidate's university achievements, recommendations and self-presentation. Students admitted to Constructor University demonstrate exceptional academic achievements, intellectual creativity, and the desire and motivation to make a difference in the world.

The following documents need to be submitted with the application:

- Letter of motivation
- Curriculum vitae (CV)
- Official or certified copies of university transcripts
- Bachelor's degree certificate or equivalent
- Language proficiency test results (minimum score of 90 (TOEFL), 6.5 (IELTS) or 110(Duolingo)).
- Copy of Passport
- Letter of recommendation

Formal admission requirements are subject to higher education law and are outlined in the Admission and Enrollment Policy of Constructor University.

For more detailed information about the admission visit:
Application Information | Constructor University

1.7 More information and contacts

For more information on the study program please contact the Study Program Coordinator:

1) Dr Nikolai Kuhnert, Professor of Chemistry, nkuhnert@constructor.university
2) Dr Felix Jonas, Assistant Professor of Biochemistry, fjonas@constructor.university

or visit our program website: XXXXXX

For more information on Student Services please visit:
https://constructor.university/student-life/student-services

2 The Curriculum

2.1 The Curriculum at a Glance

The MSc in Quantitative Life Science is a 2-year full-time in-presence program with 120 ECTS points, divided into four semesters. The first three semesters are each composed of a mixture of core, elective, transferable skills courses, and a strong research component, while the fourth and final semester is dedicated to the Master thesis.

The first semester is a foundational semester, in which students from different educational backgrounds primarily get acquainted with the most foundational concepts in the Life Sciences and acquire solid computational skills. The second and third semester focus on different aspects of the Quantitative Life Science and further allow the students to explore their own interests in research projects and electives, while also refining their transferable skills. The fourth and final semester is reserved for the Master Thesis where students can apply their skills in their own independent research project.

The modules are grouped in five categories, the mandatory CORE modules (30 CP), the mandatory elective modules (15 CP), the transferable skill modules (15 CP), the research modules (30 CP) and Master Thesis (30 CP).

2.2 Schematic Study Scheme

MSc Degree in *Quantitative Life Science (QLS) (120CP)*

Semester					
4	**Master Thesis** (m, 30 CP)				
3	Computational Life Science - Modelling and Simulations (m, 5 CP)	Omics II - Proteomics and Metabolomics (m, 5 CP)	Lab Rotation QLS III (m,10 CP)	Intellectual Property and Commercialization (m, 5 CP)	Elective III (me, 5 CP)
2	Experimental Techniques (m, 5 CP)	Omics I - Genomics and Transcriptomics (m, 5 CP)	Lab Rotation QLS II (m, 10 CP)	Scientific Writing (m, 5 CP)	Elective II (me, 5 CP)
1	Guided Self-study (Chemistry, Biology, Math/Physics) (m, 5 CP)	Data tools for the Life Sciences (m, 5 CP)	Lab Rotation QLS I (m, 10 CP)	Scientific Presentations (m, 5 CP)	Elective I (me, 5 CP)
Area	**CORE 30 CP**		**Research 30 CP**	**Transferable Skills 15 CP**	**Elective 15 CP**

m = mandatory
me = mandatory elective

MSc Degree in *Quantitative Life Science*
Elective Modules

	Quantitative Life Science Electives		
	Molecular Simulations (me, 5 CP)	Biochemical Engineering - From Cells to Processes (me, 5 CP)	Structure Elucidation (me, 5 CP)
	Machine Learning in Cheminformatics (me, 5 CP)	Quantitative Cell Biology (me, 5 CP)	Supramolecular Chemistry (me, 5 CP)
Area	**Computational LS**	**Cellular LS**	**Chemical LS**

2.3 Study and Examination Plan

MSc Degree in Quantitative Life Science							
Matriculation Fall 2025							
Module Code	**Program-Specific Modules**	**Type**	**Assessment**	**Period[1]**	**Status[2]**	**Semester**	**CP**
Semester 1							**30**
	CORE Area						**10**
XXXX	**Module: Guided Self-Study**				**m**	**1**	**5**
XXXX	Guided Self-Study	Self-study/Tutorial	Written examination	Examination period			
XXXX	**Module: Data Tools for the Life Sciences**				**m**	**1**	**5**
XXXX	Data Tools for the Life Sciences Lecture	Lecture/Tutorial	Written examination	Examination period			**2.5**
	Data Tools for the Life Sciences Project	Project	Project report	During semester			**2.5**
	Elective Area				**me**		**5**
	- students choose one module from those listed below						
	Research Area						**10**
XXXX	**Module: Lab Rotation QLS I**				**m**	**1**	**10**
XXXX	Lab Rotation QLS I - Lab	Lab	Laboratory Report	Examination period			**7.5**
XXXX	Lab Rotation QLS I - Seminar	Seminar	Presentation	During semester			**2.5**
	Transferrable skills Area						**5**
XXXX	**Module: Scientific Presentations**				**m**	**1**	
XXXX	Scientific Presentations	Lecture/Seminar	Portfolio	During semester			
Semester 2							**30**
	CORE Area						**10**
XXXX	**Module: Experimental Techniques**				**m**	**2**	**5**
XXXX	Experimental Techniques	Lecture	Written examination	Examination period			
XXXX	**Module: Omics I - Genomics and Transcriptomics**				**m**	**2**	**5**
XXXX	Omics I - Genomics and Transcriptomics	Lecture	Written examination	Examination period			
	Elective Area				**me**		**5**
	- Students choose a module from those listed below.						
	Research Area				**m**		**10**
XXXX	**Module: Lab Rotation QLS II**				**m**	**2**	**10**
XXXX	Lab Rotation QLS II - Lab	Lab	Laboratory Report	Examination period			**7.5**
XXXX	Lab Rotation QLS II - Seminar	Seminar	Presentation	During semester			**2.5**
	Transferrable Skills Area						**5**
XXXX	**Module: Scientific Writing**				**m**	**2**	**5**
XXXX	Scientific Writing	Seminar	Term Paper	During semester			
Semester 3							**30**
	CORE Area						**10**
XXXX	**Module: Computational Life Sciences - Modelling and Simulations**				**m**	**3**	**5**
XXXX	Computational Life Sciences - Modelling and Simulations	Lecture	Written examination	Examination period			
XXXX	**Module: Omics II - Microbiomics, Proteomics, and Metabolomics**				**m**	**3**	**5**
XXXX	Omics II - Microbiomics, Proteomics, and Metabolomics	Lecture	Written examination	Examination period			
	Elective Area				**me**		**5**
	- Students choose a module from those listed below.						
	Research Area				**m**		**10**
XXXX	**Module: Lab Rotation QLS III**				**m**	**3**	**10**
XXXX	Lab Rotation QLS III - Lab	Lab	Laboratory Report	Examination period			**7.5**
XXXX	Lab Rotation QLS III - Seminar	Seminar	Presentation	During semester			**2.5**
	Transferrable Skills Area						**5**
XXXX	**Module: Intellectual Property and Commercialization**				**m**	**3**	**5**
XXXX	Intellectual Property and Commercialization	Lecture	Oral Examination	flexible			

Semester 4							**30**
	Master Thesis						**30**
XXXX	**Module: Master Thesis QLS**				**m**	**4**	**30**
XXXX	Master Thesis QLS		Thesis Oral Examination				
Total CP							**120**

[1] Each lecture period lasts 14 semester weeks and is followed by reading and examination days. Written examinations are centrally scheduled during weeks 15 and 16. For all other assessment types, the timeframes indicated in the above

[2] m = mandatory, me = mandatory elective

Elective Area *Students choose 15 CP of manadatory electives*							
	Computational Life Science						**10**
XXXX	**Module: Machine Learning in Cheminformatics**				**me**	**3**	**5**
XXXX	Machine Learning in Cheminformatics	Lecture, Semianr	Project Assessment	During semester			
XXXX	**Module: Molecular Simulations**				**me**	**3**	**5**
XXXX	Molecular Simulations Lecture	Lecture	Written examination	Examination period			2.5
xxxx	Molecular Simulations Lab	Lab	Laboratory report	During semester			2.5
	Chemical Life Science						**10**
XXXX	**Module: Supramolecular Chemistry**				**me**	**1 or 3**	**5**
XXXX	Supramolecular Chemistry	Lecture	Written examination	Examination period			
XXXX	**Module: Structure Elucidation**				**me**	**2**	**5**
XXXX	Structure Elucidation	Lecture	Written examination	Examination period			
	Cellular Life Science						**10**
XXXX	**Module: Quantitative Cell Biology**				**me**	**3**	**5**
XXXX	Quantitative Cell Biology seminar	Seminar	Written examination	Examination period			2.5
XXXX	Quantitative Cell Biology tutorial	Tutorial	Presentation	During semester			2.5
XXXX	**Module: Biochemical Engineering - From Cells to Processes Modeling and Analysis of Complex Systems**				**me**	**1 or 3**	**5**
XXXX	Microbial Engineering	Lecture	Written examination	Examination period			2.5
XXXX	Advanced Bioprocess Engineering and Digitalization	Lecture	Written examination	Examination period			2.5
	Other Areas						
	- A set of modules from other study programs will be provided as further electives. Please see CampusNet for further information						
Total CP							**30**

2.4 Core Area: 30 CP

Modules of the CORE area convey the essential concepts as well as key experimental and computational approaches in quantitative life science. Hence all of the following six Core modules (30 CP) are mandatory (m) to pursue a master's degree in quantitative Life Science:

- CORE Module: Guided self-study (m, 5 CP)
- CORE Module: Data Tools for the Life Sciences (m, 5 CP)
- CORE Module: Experimental Techniques (m, 5 CP)
- CORE Module: Omics I - Genomics and Transcriptomics (m, 5 CP)
- CORE Module: Omics II - Microbiomics, Proteomics, and Metabolomics (m, 5 CP)
- CORE Module: Computational Life Sciences - Modelling and Simulations (m, 5 CP)

2.5 Research Area: 30 CP

The QLS master program provides the unique opportunity conduct actual research to explore different scientific areas by providing three laboratory rotations (semesters 1-3, 10 CP per semester). To pursue a master's degree in quantitative Life Science, the following three Research modules (30 CP) need to be taken as mandatory modules (m):

- Research: Lab Rotation QLS I (m, 10 CP)
- Research: Lab Rotation QLS II (m, 10 CP)
- Research: Lab Rotation QLS III (m, 10 CP)

2.6 Elective Area: 15 CP

To further deepen their knowledge in selected areas, students may choose elective modules. To fulfil the requirement for a QLS master, students need to take three of the following mandatory elective modules (me). To meet the credit requirement, any modules from the three indicated areas can be combined.:

Computational Life Science:

- CHOICE Module: Machine Learning in Cheminformatics (me, 5 CP)
- CHOICE Module: Molecular Simulations (me, 5 CP)

Chemical Life Science:

- CHOICE Module: Supramolecular Chemistry (me, 5 CP)
- CHOICE Module: Structure Elucidation (me, 5 CP)

Cellular Life Science:

- CHOICE Module: Quantitative Cell Biology (me, 5 CP)
- CHOICE Module: Biochemical Engineering - From Cells to Processes (me, 5 CP)

2.7 Transferable Skills Area: 15 CP

In the transferable skills area, three mandatory modules (15 CP) need to be taken. In these modules, the students learn how to present scientific data in oral and written format. Furthermore, they will explore options to secure their intellectual property rights in a scientific setting and for commercialization.

- Transferable Skills: Scientific Presentations (m, 5 CP)
- Transferable Skills: Scientific Writing (m, 5 CP)
- Transferable Skills: Intellectual Property and Commercialization (m, 5 CP)

2.8 Master Thesis (30 CP)

In the fourth semester, students conduct independent research in one of the participating research groups. To complete this module, students write a mandatory master thesis guided and supported by their research supervisor, worth of 30 credit points.

- Thesis Module: Master Thesis QLS (m, 30 CP)

3 Quantitative Life Science Graduate Program Regulations

3.1 Scope of these Regulations

The regulations in this handbook are valid for all students who entered the Quantitative Life Science graduate program at Constructor University in Fall 2025. In case of conflict between the regulations in this handbook and the general policies for Master Studies, the latter apply (see Academic policies | Constructor University).

In exceptional cases, certain necessary deviations from the regulations of this study handbook might occur during the course of study (e.g., change of the semester sequence, assessment type, or the teaching mode of courses).

In general, Constructor University therefore reserves the right to change or modify the regulations of the program handbook also after its publication at any time and in its sole discretion.

3.2 Degree

Upon successful completion of the study program, students are awarded a Master of Science (MSc) degree in Quantitative Life Science.

3.3 Graduation Requirements

In order to graduate, students need to obtain 120 credit points. In addition, the following graduation requirements apply:

- Students need to complete all mandatory components of the program as indicated in chapter 2 of this handbook

3.4 Other Program-specific Policies & Practices

Close contact and cooperation between program representatives and students are crucial. Therefore, regular meetings are held to continuously evaluate the program, its modules and workshops, supervision, and opportunities. In doing so, the Study Program Chair and involved faculty gain important insights into students' experiences, demands, and overall impressions of the program. On the module component level, students are asked to perform module component evaluations to ensure that the modules are high-quality and that lecturers can make any necessary changes.

The study program chair makes intensive use of this feedback as well as feedback from laboratory heads to improve the learning environment, the program's offering, and its progress. The current program was shaped through input from previous experiences and discussions with several stakeholders, including students and industry practitioners.

In exceptional cases, certain necessary deviations from the regulations of this study handbook might occur during the course of study (e.g., change of the semester sequence, assessment type, or the teaching mode of courses). Constructor University Bremen reserves therefore the right to modify the regulations of the program handbook.

For biological and chemical safety in laboratory work both regulations within German law (e.g. Arbeitsschutzgesetz, Gefahrstoffverordnung, Chemikaliengesetz etc) apply as well as University internal health and safety regulations. Students are handed out the relevant regulations at the beginning of the program. Furthermore, attendance of S1, S2, and Laser safety instructions are mandatory prior to any laboratory work. Before joining a research group, students are given laboratory specific safety instructions (research group specific laboratory regulations).

4 Modules

4.1 Core Area (30 CP)

4.1.1 Guided Self-study

Module Name:	Guided Self-study
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	1
Semester:	1
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Felix Jonas
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	
Seminar:	
Lab:	
Tutorial:	35 h
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	Number	Type	CP
Guided Self Study	XXXX	Self-study / Tutorial	5

Module Description

Quantitative Life Science stands at the intersection of Life Science and Data Science. Successful research in this field necessitates a solid foundation in the life sciences as well as Mathematics and Physics. Hence, basic knowledge in any of these areas is a pre-requisite for most other courses in this program.

In this “Guided Self-study” module, the students will thus, depending on their academic background, recapitulate or acquire the necessary knowledge. The content is divided into three broad areas, Biology, Chemistry and Mathematics/Physics with their own learning goals. These goals are based on the expected knowledge after an undergraduate degree in chemistry, biochemistry or molecular/cellular biology.

Based on a self-test in all three content areas, each student together with a faculty member will build a personalized learning plan. Since most successful candidates will come with expertise in at least one field, usually only one or two areas of focus will require revision or additional learning. All students are expected to take two areas. The student will then study these selected topics in an “inverted classroom” setting. For this, reading materials and other learning materials (videos, exercises) will be provided by the program faculty. In addition, regular tutorial sessions will be offered to enable students to discuss the topics with the respective subject matter experts. The formation of study groups will be encouraged. In the written examination, only the selected focus areas will be tested for.

Intended Learning Outcomes

By the end of this module, students will be able to:

Chemistry:
Organic chemistry:

1. Define the structure and properties of carbon-containing compounds.
2. Explain common reaction mechanisms and catalysts.
3. Apply the basics of reaction kinetics to organic reactions.

Physical Chemistry

4. Discuss energetics of chemical reactions.
5. Discuss chemical reaction rates, diffusion, partition and transport processes.

Analytical Chemistry:

6. Discuss quantitative methods and methods for separating and purifying organic/biological compounds.
7. Describe Spectroscopic methods for identifying and characterizing compounds.

Biology;
Biochemistry:

1. Explain the structure, properties and function of biological macromolecules
2. Demonstrate the principles of enzymes and enzyme kinetics on unknown chemical reactions.
3. Remember basic metabolic pathways (Glycolysis, TCA cycle).
4. Understand the mechanistic basis of transcription and translation in eukaryotes and prokaryotes.

Cell Biology:

5. Describe the cellular organization in eukaryotes and prokaryotes.
6. Understand the basics of protein production, targeting, transport and degradation.
7. Apply the principles of regulation of biological process and biological signaling pathways.

Biotechnology:

8. Discuss molecular biology techniques and basics of genetic engineering.
9. Apply the fundamentals of material and energy balances to novel bioprocesses.
10. Recognize the basics of Metabolic engineering.
11. Memorize bioreactor types and modes.

Math/Physics:

Math

1. Understand the basics of linear algebra and solve simple problems.
2. Recognize ordinary differential equations and implement numerical solving methods.

Statistics

3. Interpret data using simple descriptive statistics.
4. Perform statistical tests for effect size and significance.
5. Explain basic concepts of Bayesian statistics.

Physics

6. Explain and implement the fundamental rules classical mechanics and thermodynamics.

Indicative Literature

- Cell Biology:
  Alberts et al., Molecular Biology of the Cell, Garland Science, latest edition
- Biochemistry:
  Nelson and Cox, Lehninger Principles of Biochemistry, Freeman Macmillan, latest edition.
  Stryer et. al., Biochemistry, Freeman Macmillan, latest edition.
- Chemistry:
  J. Clayden,N. Greeves, S. Warren. Organic Chemistry, 2nd Edition, Oxford University Press, 2012.
  Zumdahl and Zumdahl, Chemistry, Brooks Cole, latest edition;
- Math / Statistics:
  E. N. Bodine, S. Lenhart, and L. J. Gross. Mathematics for the Life Sciences. Princeton University Press, latest edition

- Physics:
  Zinke-Allmang et al., Physics for the Life Sciences, Nelson Education, latest edition.

Recommendations for Preparation

None

Entry Requirements

Recommended Knowledge, Abilities or Skills	Ability to obtain knowledge independently
Module Prerequisites	None
Module Co-requisites	-

Usability and Relationships to other Modules

This module provides the basic knowledge necessary to succeed in most modules of the program

Examination Type: Module Examination

Components	Assessment Type	Duration/Length	Weight	Scope (ILOs)
Guided Self Study	Written Examination	120 minutes (2 x 60 minutes)	100%	All ILOs of selected areas

Module completion: To pass this module, the module examination(s) has to be passed with at least 45%.

4.1.2 Data Tools for the Life Sciences

Module Name:	Data Tools for the Life Sciences
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	1
Semester:	1
4C-Model Reference:	-
Mandatory Status:	Mandatory for QLS
Module Components:	2
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Felix Jonas
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	17.5 h
Seminar:	
Lab:	
Tutorial:	17.5 h
Exam Preparation:	10 h
Independent Study:	80 h
Hours Total:	125 h

Module Components	Number	Type	CP
Data Tools for the Life Sciences - Lecture	xxxx	Lecture, Tutorial	2.5
Data Tools for the Life Sciences - Project	xxxx	Project	2.5

Module Description

The recent developments in the field of experimental life science allow researchers to collect data at an unprecedented scale and complexity not directly comprehensible to even educated scientists. Generating, analyzing, and concluding from these large data sets is at the heart of Quantitative Life Science and usually relies on modern computational tools.

Thus, this module provides the student with the fundamental skills for computer assisted processing, analyzing and visualizing large data sets from fields of biology and chemistry. A particular focus will be on multi-dimensional, numerical data common to most experiment types and usually stored in matrix format. Other more specific data types, like DNA sequences, protein sequences, and protein structures, will also be discussed. Moreover, in addition to classical data analysis, the students will also learn how to leverage large-language models to facilitate their interaction with computers.

The course will consist of lectures to introduce the students to the principles, guided tutorials, where the student can apply their skills to given problems, and homework assignment where the students apply their skills to selected case studies in a collaborative or individual settings.

In terms of computational data analysis, the students will learn how to construct hypothesis, and to select and apply advanced statistical tests to verify them. They will also learn how to utilize descriptive statistics to provide an informative overview of data. Additionally, the students will also acquire the basics of data fitting, dimensionality reduction, and machine learning to identify patterns in the data.

With respect to visualization, the student will be introduced to the diverse set of plot types, such as bar graphs, scatter plots, and heatmaps, and learn when and how to apply them. A particular focus will be on visualizing multidimensional data and using different scales and normalization techniques to match the nature of the underlying data and the desired hypothesis.

The topic of data processing will introduce the students to the concept of automated data processing routines, also known as “pipelines”. as well as equip them with the skills to build simple pipelines and understand more complex ones to convert experimental raw data sets from chemistry and biology into numerical matrixes.

Furthermore, the students will be exposed to ethical aspects and best practices of data analysis.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Discuss the fundamental principles of machine learning.
2. Implement dimensionality reduction and data fitting for large, multidimensional datasets.
3. Compare the advantages and limits of different statistical tests and graph types.
4. Examine and question common data processing routines in the Life Science
5. Select and defend different descriptive statistics, visualization techniques and statistical tests to highlight or examine certain data aspects.
6. Critique the use of different analysis and visualization techniques in the published papers.
7. Collaborate effectively, assume responsibility and leadership.

Indicative Literature

- McKinney Wes, Python for Data Analysis: Data Wrangling with pandas, NumPy, and Jupyter, 3rd Edition, New York: Oreilly Media, 2022
- David Landup, Data Visualization in Python with Pandas and Matplotlib, Stack Abuse, 2021
- Python Data Science Handbook: Essential Tools for Working with Data, 2nd Edition, O’Reilly Media Inc., 2022
- Statistics and Data Visualization with Python (Chapman & Hall/CRC The Python Series), 1st Edition, 2023

Recommendations for Preparation

Install coding program (e.g. Python) and familiarize yourself with the basic data types and syntax.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic understanding of data types and algorithms
Module Prerequisites	None
Module Co-requisites	None

Usability and Relationships to other Modules:
The methods and concepts learned in this module can be used in research projects as well as the master thesis. Moreover, the computational skills can be applied in several core and elective modules (e.g. Omics I and II, Quantitative Cell Biology etc.).

Examination Type: Module Component Examination

Components	Assessment Type	Duration/length	Weight	Scope (ILOs)
Data Tools for the Life Sciences -Lecture	Written Examination	60 minutes	50 %	1,3,4,6
Data Tools for the Life Sciences -Project	Project report	Approx. 8 pages	50%	2,3,5,7

Module completion: To pass this module, both module component examinations have to be passed with at least 45%.

4.1.3 Experimental Techniques

Module Name:	Experimental Techniques
Module Code:	-
CP:	5 ECTS
Frequency:	Annually (Spring)
Year:	1
Semester:	2
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Torsten John
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	Number	Type	CP
Experimental Techniques	xxxx	Lecture	5 ECTS

Module Description

Modern experimental Life Science heavily depends on data generation using a combination of very diverse techniques. The module aims to provide the student with a toolbox of key experimental methods that can address a multitude of diverse biological questions. Therefore, the course will discuss the theoretical background, the experimental protocol, the analysis framework as well as the strengths and weaknesses of each technique.

The methods and techniques presented in this module were selected according to the following criteria: 1. Relevance of key techniques that drove progress in Life Sciences over the last decades; 2. Techniques available at Constructor University Laboratories and available for Research Laboratory Components; 3. No overlap with techniques discussed in depth in other modules (e.g. mass spectrometry in Omics II or sequencing in Omics I).

Notably, key advances in published research will lead to constant revision and update of the techniques presented in this module since modern sciences' key driver is experimental technology.

Techniques presented include the following:

- Methods for studying energetics of biochemical processes (Microcalorimery, isothermal titration calorimetry ITC)
- Fluorescence-based methods (FRET, FACS, single photon etc.) including labelling strategies for incorporating fluorescent labels to biomolecules
- Spectroscopic techniques including NMR-, CD-, IR-, Raman-spectroscopy and their adaptation in microscopy.
- Separation techniques including separation of biomolecules (chromatography, electrophoresis, centrifugation etc.) and cell separation (flow cytometry)
- Methods for studying bio-molecular interactions, e.g. atomic force microsopy (AFM), surface plasmon resonance (SPR), quartz crystal microbalances (QCM), nano differential fluorimetry (nano-DSF)
- Cell culture methods, e.g. Primary co-culture or induced pluripotent stemcells.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Examine information content of experimental data
2. Apply appropriate experimental techniques for solving a scientific problem
3. Appraise and compare the scope and limitations of different experimental methods and techniques.
4. Explain the theoretical and practical aspects of the key experimental methods in Life Sciences

Indicative Literature

- Lottspeich and Engels, Bioanalytics, Wiley-VCH.

Recommendations for Preparation

Background literature for preparation provided by individual faculty.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic knowledge on separation, identification and quantification of biomolecules. Ability to generate and interpret experimental data
Module Prerequisites	Guided self-study
Module Co-requisites	

Usability and Relationships to other Modules

Content, techniques and methods learned in all Quantitative Life Science core, elective and transferrable skill modules will be applied to solve a real significant research question. Additional key experimental techniques form focus of other modules e.g. mass spectrometry (Omics II), sequencing (Omics I), microscopy (quantitative cell biology) or NMR spectroscopy and XRD diffraction (structure elucidation).

Examination Type: Module Examination

Components	Assessment Type	Duration /Length	Weight	Scope (ILOs)
Experimental Techniques	Written examination	120 minutes	100 %	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.1.4 Omics I – Genomics and Transcriptomics

Module Name:	Omics I - Genomics, Transcriptomics
Module Code:	-
CP:	5
Frequency:	Annually (Spring)
Year:	1
Semester:	2
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Felix Jonas, Prof Dr Marc-Thorsten Hütt
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	Number	Type	CP
Omics I - Genomics, Transcriptomics Lecture	xxxx	Lecture	5

Module Description

Since their identification as the main information carrier in any biological system, nucleic acids (DNA and RNA) have attracted researchers' interest for diverse purposes. While initially prohibitively expensive and time-consuming, the advent of next generation sequencing reduced the cost and time for DNA sequencing. Now, whole genomes and transcriptomes of organisms are accessible to research but demand new quantitative approaches for their analysis.

In this course, students will learn how to obtain and analyze data from three main omics categories, genomics, epigenomics, and transcriptomics, to answer fundamental and applied questions in the field of life science. Based on examples from recent scientific literature, the students will delve into the methods and data types associated with this field and discuss their interpretation, and their biological implications. Moreover, the homework assignment will allow the students to apply these new skills.

An omics project often follows a common strategy: Starting with experimental design, and data gathering, the data are then analyzed using established bioinformatics methods and integrated with existing information in databases to draw functional conclusions. An example is the defining the phenotypic state of cells in a disease from transcriptomics data: First RNA sequencing is performed to determine the transcriptome in healthy and affected individuals, then the sequencing reads are mapped to specific genes, which are subsequently compared between both groups (cases and healthy controls) in the cohort. Statically significant genes are then defined using established methods (like DESeq2) and, for example, integrated with information in the Gene Ontology (GO) database. The GO database contains assignments of categories of molecular function to each gene and can, with a few caveats, be used as a steppingstone towards a functional interpretation of the found gene sets.

Such paths from experiment and data to functional conclusions, as well as the most prominent examples of each step, will be highlighted in this course. We will provide insight into the established and advanced techniques in genomics, epigenomics and transcriptomics, e.g. Whole-Genome-Sequencing, ChIP-seq and single-cell RNAseq, as well as common bioinformatics tools used in this context and the theory behind them. We will also discuss relevant databases, the data formats they employ and the computational tools available for using them.

This collection of case studies and examples will provide a solid foundation for a deep practical understanding of this emerging field; which biological questions can be addressed with which combination of omics technology, databases, and computational methods.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Recall key concepts in genomics, epigenomics, and transcriptomics.
2. Explain the steps involved in an omics experiment from experimental design to functional conclusions.
3. Apply bioinformatics methods and integrated existing databases to analyze omics datasets and interpret the results.
4. Compare and contrast different bioinformatics tools, omics technologies and databases and their suitability for various omics analyses.
5. Design an experimental workflow for a specific biological question using omics techniques, relevant databases, and computational tools.
6. Assess the validity and reliability of omics data, analysis and biological interpretation.
7. Formulate recommendations for best practices in omics data analysis based on case studies and recent literature.
8. Collaborate effectively in group projects to analyze, interpret, and present omics data.

Indicative Literature

The course is based on recent scientific literature, which will be provided in the first session.

Recommendations for Preparation

Recapitulate the concepts and mechanisms of molecular genetics.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic knowledge of Molecular Biology, Biochemistry and Bioinformatics.
Module Prerequisites	Guided self-study Data Tools for the Life Sciences
Module Co-requisites	

Usability and Relationships to other Modules

This module is conceptionally linked to the Omics II Module, as it focuses on DNA and RNA, while the latter one focuses on Proteins and Metabolites. The experiments and analysis techniques introduced in this module will also support the topics discussed in the elective modules or find application in the research rotations or the master thesis.

Examination Type: Module Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Omics I-Lecture	Written Examination	120 minutes	100%	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

Module Achievement: Homework assignments have to be passed by an average of 45%.

4.1.5 Omics II - Microbiomics, Proteomics and Metabolomics

Module Name:	**Omics II - Microbiomics, Proteomics and Metabolomics**
Module Code:	-
CP:	5 ECTS
Frequency:	Annually (Fall)
Year:	2
Semester:	3
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Nikolai Kuhnert, Prof Dr Matthias Ullrich
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	Number	Type	CP
Omics II - Microbiomics, Proteomics, and Metabolomics	xxxx	Lecture	5 ECTS

Module Description

Modern Life Science has defined the sciences of Omics as methods for the global analysis of the most important groups of molecules. In Omics II, the investigation of the totality of microbial life (microbiomics), proteins (proteomics) and small molecule metabolites (metabolomics) of any given living organism or ecosystem forms the focus of the module. The module consists of two sections: Microbiomics and Proteomics/Metabolomics.

Microbiomics, proteomics and metabolomics depend on either deep nucleotide sequencing or high-resolution tandem mass spectrometry, respectively, as the key experimental techniques. Hence the two sub-modules will start with an introduction to these technique, experimental methods for genomic DNA extraction, protein isolation and purification, type of data generated and techniques and strategies (targeted versus shotgun) for mass spectrometry data interpretation both manually and by using software databases and algorithms.

A key element of Microbiomics is the definition and identification of the actual microbial ecosystem to be investigated. Likewise, a solid understanding of taxon units as well as differences between pro- and eukaryotes is needed. Amplicon sequencing as well as metagenome sequencing will be introduced. Ultimately, the course participants need to understand the basic principles of how high-throughput and deep nucleotide sequencing data are generated, and how the massive number of reads will be interpreted and classified to obtained output formats for publications.

Proteomics further depends on the use and exploitation of big data from genomic and proteomic databases, their conversion to predicted in silico MS libraries and identification of proteins. The basic operation of data handling will be covered and practiced in the module (data format conversion, common formats). The principles will be taught, and students asked to solve practice data starting with single proteins moving to whole organisms. Examples for the use of proteomics from microbiology, plants and humans will be additionally presented and discussed. Aspects of quantitative proteomics methods will be introduced.

In the Metabolomics section mass spectral data will be applied to identify and quantify primary and secondary metabolites using mass spectrometry data. Targeted and untargeted metabolomic strategies will be introduced and the use of MS databases practiced. Basic aspects of compound quantification will be revisited (GLP, need for chromatographic separation, authentic standards, surrogate standards, calibration curves, reproducibility etc). NMR will be introduced as an alternative quantitative metabolomic technique with low sensitivity.

Metabolomics science further requires extensive use of statistical methods to compare large number of experimental data sets with one another each containing thousands of analytes. Hence the basic concepts of multivariate statistics (PCA, PLSDA, LDA, hierarchical clusters) and machine learning approaches will be introduced, and practice examples given to the students to allow metabolome comparison and biomarker identification. Examples of metabolomes will be discussed from microorganisms, plants and humans.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Appreciate information content of amplicon and metagenome sequencing as well as mass spectrometry data
2. Understand microbiomics and proteomics workflows and apply them for simple examples
3. Interpret microbiome data to allow conclusions about the structure-function relationship in diverse microbial ecosystems
4. Use proteomic databases in conjunction with proteomic LC-MS software to identify proteins and metabolites
5. Compare proteomes and quantitative proteomic data to design hypothesis on biological function and mechanisms

6. Compare metabolomes using multivariate statistical methods and conclude and speculate on their biological significance and identify biomarkers
7. Critically evaluate the reliability and significance of omics data, including sequencing and mass spectrometry results, in the context of biological research.

Indicative Literature

- Microbiology, Bioanalytical Chemistry (Kurreck, Lottspeich, Engels, Springer 4th ed.)

Recommendations for Preparation

Background literature on microbiology, molecular biology, protein biochemistry, protein structure and function. Background basic biochemistry literature on primary and secondary metabolites. Revision of mass spectrometry and chromatography.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic knowledge on spectroscopic techniques (BSc level Analytical Methods), metabolism and proteins Understanding of chemical structure and bonding
Module Prerequisites	Guided self-study
Module Co-requisites	

Usability and Relationships to other Modules

According to Francis Crick's dogma of molecular biology (From genes to RNA to proteins to metabolites) this module is a complement to Omics I It has additional overlap with the elective structure elucidation module covering mass spectrometry. Statistical and quantitative methods discussed in other modules such Machine Learning, Quantitative Experiments in Life Science and Computational Life Science complement the content in this module and bring it to life for students from a different perspective.

Examination Type: Module Examination

Components	Assessment Type	Duration/length	Weight	Scope (ILOs)
Omics II - Microbiomics, Proteomics and Metabolomics	Written examination	120 minutes	100 %	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.1.6 Computational Life Science - Modelling and Simulations

Module Name:	Computational Life Science - Modelling and Simulations
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	2
Semester:	3
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Marc-Thorsten Hütt, Prof Dr Katrin Rosenthal
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	35 h
Independent Study:	55 h
Hours Total:	125 h

Module Components	Number	Type	CP
Computational Life Science - Modelling and Simulations	1	Lecture	5

Module Description

The course deals with the understanding of microbial cells and biocatalytic reaction networks as production systems for the synthesis of various products. At the core of these practical applications are fundamental questions involving mathematical modelling, simulation, and the computational analysis of metabolic systems. We will introduce the basic ideas of kinetic modelling and models of enzyme kinetics. We will illustrate how elementary ideas from linear algebra can be employed to simulated metabolic fluxes (a concept called flux-balance analysis) and how some biological conclusions about metabolic systems can already be drawn from the metabolic network alone. In this course we will discuss this approach and highlight the graph-theoretical methods enabling it.

As these descriptions – from the biological network as a black box to flux-balance analysis and mechanistic modelling – all employ very different levels of detail and have distinct computational challenges, it is important to discuss, which description is best suited for a given application and how the different descriptions fit together. A high degree of practical experience through (dry) laboratory and computer work ensures the ability to apply the acquired theoretical knowledge.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Understand the basic concepts of findable, accessible, interoperable, and reproducible (FAIR) data and data standardization and evaluate their importance for data exchange between disciplines, as well as experimental and dry-lab research.

2. Understand computational design of bioreactions and apply methods and tools used for the computational planning and optimization of biochemical reactions.

3. Understand the basics of mechanistic (based on the understanding of the underlying biological mechanisms) and empirical modelling (based on observed data) of biochemical reaction networks.

4. Apply and analyze different modelling techniques based on, e.g., ordinary differential equations (ODEs), one-factor-at-a-time (OFAT) experiments, and Bayesian optimization.

5. Application of specialized software to simulate and analyze biochemical networks and their dynamics, facilitating the understanding and prediction of their behavior. Evaluate the results and the biological conclusions that can be drawn from them.

Additional Learning Outcomes (Interdisciplinary Skills):

6. Collaborate effectively in group projects to model and simulate metabolic systems.

7. Communicate complex concepts of metabolic modelling and simulation clearly in presentations.

Indicative Literature

- Klipp, E., Herwig, R., Kowald, A., Wierling, C., & Lehrach, H. (2005). Systems biology in practice: concepts, implementation and application. John Wiley & Sons.
- Carbonell, P (2019), Metabolic Pathway Design: A Practical Guideline. Springer Nature Switzerland AG.

Recommendations for Preparation

None.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Fundamentals of Biochemistry and Metabolic Pathways.
Module Prerequisites	• Data Tools for the Life Sciences • Guided Self-study
Module Co-requisites	None

Usability and Relationships to other Modules

None.

Examination Type: Module Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Computational Life Science	Written Examination	120 min	100%	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.2 Research Area (30 CP)

4.2.1 Lab Rotation QLS I

Module Name:	**Laboratory Rotation QLS I**
Module Code:	-
CP:	10 ECTS
Frequency:	Annually (Fall)
Year:	1
Semester:	1
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	2
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	SPC (all faculty teaching)
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	
Seminar:	17.5 h
Lab:	182.5 h
Tutorial:	
Exam Preparation:	20 h
Independent Study:	30 h
Hours Total:	250 h

Module Components	**Number**	**Type**	**CP**
Laboratory Rotation QLS I - lab	xxxx	Lab	7.5 ECTS
Laboratory Rotation QLS I - Seminar	xxxx	Seminar	2.5 ECTS

Module Description

The laboratory rotations are part of the research focus of the Quantitative Life Science program. Students select a research field and supervisor among all participating faculty based on their knowledge and interest. In their chosen field (e.g. Medicinal chemistry, analytical chemistry, biochemistry, cell biology, computational chemistry etc.) students will receive intense training on experimental procedures, software, coding, instrument operation from the members of the research group selected. Following training they will receive a small research project to work. Throughout the project, discuss their results with their supervisor.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Plan and conduct wet- or dry-lab experiments in a Life Science research area where background knowledge exists.
2. Demonstrate ability to operate scientific instrumentation and master essential software.
3. Produce experimental data or perform computational dataset research.
4. Interpret and analyze experimental data.
5. Discuss and present their data and evaluate their significance.

Indicative Literature

- Provided by individual faculty depending on their field of research

Recommendations for Preparation

Attendance of laboratory safety instructions. Background literature for preparation provided by individual faculty.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic laboratory skills Attendance of safety instructions
Module Prerequisites	None
Module Co-requisites	Scientific Presentation

Usability and Relationships to other Modules

The module prepares for the following two laboratory rotations II & III and the Master thesis. Additionally, the analyses carried out might relate to other Core and elective modules e.g. work in analytical chemistry to Metabolomics and Structure elucidation or work in bioinformatics to Machine Learning or Advanced Molecular Simulations.

Examination Type: Module Component Examination

Components	Assessment Type	Duration/length	Weight	Scope (ILOs)
Lab rotation QLS I - Lab	Laboratory report	10-15 pages	75 %	1-4
Lab rotation QLS I - Seminar	Presentation	20 minutes	25 %	4,5

Module completion: To pass this module, both module component examinations have to be passed with at least 45%.

4.2.2 Lab Rotation QLS II

Module Name:	**Laboratory Rotation QLS II**
Module Code:	-
CP:	10 ECTS
Frequency:	Annually (Spring)
Year:	1
Semester:	2
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	2
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	SPC (all faculty teaching)
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	
Seminar:	17.5 h
Lab:	182.5 h
Tutorial:	
Exam Preparation:	20 h
Independent Study:	30 h
Hours Total:	250 h

Module Components	**Number**	**Type**	**CP**
Lab rotation QLS II - Lab	xxxx	Lab	7.5 ECTS
Lab rotation QLS II - Seminar	xxxx	Seminar	2.5 ECTS

Module Description

The laboratory rotations are part of the research focus of the Quantitative Life Science program. Students select a research field and supervisor among all participating faculty of their choice and interest. In their chosen field (e.g. Medicinal chemistry, analytical chemistry, biochemistry, cell biology, computational chemistry etc.) students will receive intensive training on experimental procedures, software, coding, instrument operation from the members of the research group selected. Following training they will receive a small research project to work on. The second laboratory rotation should be completed in a different research group with a different supervisor than the previous laboratory rotation I. This will expose the student to an alternative area of science and research style. Furthermore, it should allow for the (optional) development of collaborative research projects between different research groups in the Master thesis.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Independently acquire necessary background knowledge in a new area of research.
2. Plan and conduct experiments in a new area of research (i.e., other than rotation I)
3. Produce data sets in a Life Science research area.
4. Interpret and analyze experimental and computational data.
5. Discuss and present their experimental data and evaluate their significance.

Indicative Literature

- Provided by individual faculty depending on their field of research

Recommendations for Preparation

Attendance of laboratory safety instructions. Background literature for preparation provided by individual faculty.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic laboratory skills Attendance of safety instructions
Module Prerequisites	None
Module Co-requisites	

Usability and Relationships to other Modules

In combination with rotation I, the module prepares students for the laboratory rotations III and the Master thesis. Additionally, the research projects may relate to other Core and elective modules e.g. work in analytical chemistry to Metabolomics and Structure elucidation or work in bioinformatics to Machine Learning or Advanced Molecular Simulations.

Examination Type: Module Component Examination

Components	**Assessment Type**	**Duration/length**	**Weight**	**Scope (ILOs)**
Lab rotation QLS II - Lab	Laboratory report	10-15 pages	75 %	1-4
Lab Rotation QLS II – Seminar	Presentation	20 minutes	25 %	4,5

Module completion: To pass this module, both module component examinations have to be passed with at least 45%.

4.2.3 Lab Rotation QLS III

Module Name:	**Laboratory Rotation QLS III**
Module Code:	-
CP:	10 ECTS
Frequency:	Annually (Spring)
Year:	2
Semester:	3
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Module Components:	2
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	SPC (all faculty teaching)
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	
Seminar:	17.5 h
Lab:	182.5 h
Tutorial:	
Exam Preparation:	20 h
Independent Study:	30 h
Hours Total:	250 h

Module Components	Number	Type	CP
Lab Rotation QLS III - Lab	xxxx	Lab	7.5 ECTS
Lab Rotation QLS III – Seminar	xxxx	Seminar	2.5 ECTS

Module Description

The laboratory rotations are part of the research focus of the Quantitative Life Science program. It is recommended but not required that the Laboratory rotation III will take place in the laboratory of a faculty member already selected in Laboratory rotation I or II. Ideally, the Master thesis module will be carried out in the laboratory selected for Laboratory rotation III to allow for a more comprehensive analysis of the research topic. In this context, the Lab Rotation III by researching a more advanced topic with a higher degree of independence directly prepares for subsequent Master thesis. A laboratory rotation in an external laboratory is possible on special application, if supervised by a School of Science faculty member at Constructor University. Approval must be given by the SPC.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Independently plan and conduct experiments with a larger strategic perspective.

2. Independently establish new experimental protocols or analysis algorithms.
3. Produce experimental data / computational datasets in the Life Science
4. Solve experimental problems based on data obtained.
5. Read and implement information from scientific literature.
6. Interpret and analyze experimental and computational data in the Life Sciences.
7. Discuss and present their experimental data and evaluate their significance.

Indicative Literature

- Provided by individual faculty depending on their field of research

Recommendations for Preparation

Attendance of laboratory safety instructions. Background literature for preparation provided by individual faculty.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic laboratory skills Attendance of safety instructions
Module Prerequisites	None
Module Co-requisites	

Usability and Relationships to other Modules

The module prepares for the Master thesis as the participants are expected to show a higher level of independence in research strategy development. Additionally, the skills acquired and deepened in rotation III will help in designing and conducting the independent research project for the master thesis.

Examination Type: Module Component Examination

Components	Assessment Type	Duration/length	Weight	Scope (ILOs)
Lab Rotation QLS III - Lab	Laboratory report	10-15 pages	75 %	1-4
Lab Rotation QLS III – Seminar	Presentation	20 minutes	25 %	4,5

Module completion: To pass this module, both module component examinations have to be passed with at least 45%.

4.3 Transferable Skills (15 CP)

4.3.1 Scientific Presentations

Module Name:	**Scientific Presentations**
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	1
Semester:	1
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Thomas Nugent
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	17.5 h
Seminar:	17.5 h
Lab:	
Tutorial:	14 h
Exam Preparation:	
Independent Study:	76 h
Hours Total:	125 h

Module Components	**Number**	**Type**	**CP**
Scientific Presentations	xxxx	Lecture/Seminar	5

Module Description
This module consists of two parts: In the first half of the module, all participating faculty will introduce their research with presentations and subsequent discussions. In the second half, students will be asked to present a research publication of their own choice. The first part will enable students to observe different presentation styles and identify their fields of interest in Quantitative Life Science and potential supervisors for the lab rotations. In the second part, students will select a publication in the field of Quantitative Life Science, analyze it, and present it to their classmates. This presentation will focus on the motivation for the study, the different methodologies used, the obtained results, and the performed analyses. The students will also critically discuss the conclusions drawn by the authors.

To prepare students for their presentation, a few lectures will address how to give good scientific presentations, ranging from formal criteria, like the number and design of slides, the use of steady and clear language, and the importance of timing, to content-related topics, e.g., the role of published literature; framing, explaining, and wrapping up an argument; providing conclusions and an outlook of future work. Furthermore, tips pertaining to audience engagement (eye contact, body language, staying still, *etc.*), proper handling of (challenging) audience question, *etc*. will be discussed. During the remainder of the course, each student will give a 30-min presentation on a selected research publication. Each presentation will end with a question-and-answer section, which is followed by instructor feedback on the positive aspects as well as those for further improvement.

To learn how to give a presentation also means one can evaluate a presentation. This will be achieved by each student audience member via the completion of an evaluation form. The instructor will provide corrective feedback if your evaluation is lacking.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Analyse and critique scientific publications.
2. Organize ideas and convey them in a convincing, concise, and simple manner during a presentation
3. Demonstrate how to plan and manage the time allocated to a presentation
4. Prepare appealing yet informative slides for the presentation.
5. Use proper scientific wording and voice inflection to emphasize important concepts and keep the audience engaged.
6. Analyze and critique the presentations of their peers

Indicative Literature

- Not applicable

Recommendations for Preparation

To come with an open mind and flexibly adapt to capture your audience's attention.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Not applicable
Module Prerequisites	Not applicable
Module Co-requisites	Not applicable

Usability and Relationships to other Modules

Master's level study requires students to focus on a particular research area and in doing so you will engage in research. Presentations allow students to bring everything from the classroom to the research laboratory together, and thus prepare for the lab rotations in this study program but also for future job interviews and how to communicate science to other scientists.

Examination Type: Module Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Scientific presentations	Portfolio (presentation, evaluation forms)		100%	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.3.2 Scientific Writing

Module Name:	Scientific Writing
Module Code:	-
CP:	5
Frequency:	Annually (Spring)
Year:	1
Semester:	2
4C-Model:	n/a
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Katrin Rosenthal
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	
Seminar:	35 h
Lab:	
Tutorial:	
Exam Preparation:	35 h
Independent Study:	55 h
Hours Total:	125 h

Module Components	Number	Type	CP
Scientific Writing	xxxx	Seminar	5

Module Description

This module is designed to provide students with the skills and knowledge required for effective scientific writing. The module will cover the principles of clear and concise writing, structuring scientific papers and research proposals, presenting data and results, and understanding the submission and publication process. By the end of this module, students will be able to create well-organized, coherent, and persuasive scientific documents. The seminar will enhance critical thinking skills by evaluating scientific arguments and methodologies. The ability to gather relevant information and scientific references will be improved. The seminars provide theoretical foundations and examples of scientific writing with practical sessions for writing and revising texts.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Understand key components of scientific papers, structure and standards in scientific writing, including abstracts, introductions, methods, results, and discussions and compare different types of scientific documents, such as research articles, reviews, and case studies.

2. Apply principles of effective scientific writing to produce clear and concise sentences and paragraphs and use of appropriate formatting and citation styles in scientific documents.
3. Understand the purpose and importance of scientific writing and scientific communication and understand the publication process and peer review process.
4. Analyze and evaluate data presentation, tables and figures, as well as data interpretation to identify strengths and weaknesses in writing style and structure and evaluate scientific papers for logical flow, clarity, and adherence to conventions.
5. Apply their theoretical knowledge on a writing a short proposal about their own research

Additional Learning Outcomes (Interdisciplinary Skills)

6. Develop strong written communication skills that are applicable in both academic and professional settings.
7. Understand and apply principles of ethical writing, including avoiding plagiarism and ensuring proper attribution.
8. Promote a sense of integrity and responsibility in reporting and discussing scientific findings.

Indicative Literature

- Glasman-Deal H. (2009). Science Research Writing. Imperial College Press.
- Morris J.R., Jehn T.R., Vaughan C., Pantages E., Torello T., Bucheli M., Lohman D., Lue R., Harvard University (2007). A Student's Guide to Writing in the Life Sciences. Harvard University.

Recommendations for Preparation

None.

Entry Requirements

Recommended Knowledge, Abilities or Skills	None
Module Prerequisites	None
Module Co-requisites	None

Usability and Relationships to other Modules

This module provides foundational skills that are widely applicable across various disciplines:

- Writing research papers and theses
- Preparing grant proposals and research funding applications
- Communicating scientific findings
- Enhancing overall academic performance through improved writing and presentation skills

Examination Type: Module Examination

Components	Assessment Type	Duration/length	Weight	Scope (ILOs)
Scientific Writing	Term Paper	5 pages	100%	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.3.3 Intellectual Property and Commercialization

Module Name:	**Intellectual Property and Commercialization**
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	2
Semester:	3
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	NN
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	**Number**	**Type**	**CP**
Intellectual Property and Commercialization	xxxx	Lecture	5

Module Description

Intellectual property (IP) refers to any form of creation of the mind, and its legal protection ensures that people earn recognition or financial benefit from what they invent or create. This module provides a critical examination of intellectual property (IP) legal aspects exploring the various categories of IP protection available for novel creations. The core focus is on copyright and patents, both granting exclusive rights to inventors for a defined period. We will analyze the criteria for patentability, the different patent types, and the process of patent acquisition. The module will delve into the advantages of patents (including the ability to control the production, sale, and import of inventions) but also explore the limitations of patents (e.g., territorial restrictions and eventual expiration). The module also teaches the various paths to commercialization of IP, including licensing, sale, and establishment of a startup, and it especially focuses on aspects of regulatory affairs, product registration, on the financing, private or public, of any of these options. Finally, it explains the construction of a business plan and a pitch deck, and the selection of the team for a startup. Interactions with, and visits to, initiatives at the University, in the Constructor ecosystem, and in the city-state of Bremen are anticipated to provide an integrated view and help with first steps. By the end, participants will gain a comprehensive understanding of how copyrights and patents can be leveraged to protect inventions and drive innovation. This module is particularly valuable for researchers, aspiring inventors, and those with an entrepreneurial spirit.

Intended Learning Outcomes

By the end of this module, students will be able to:

A. Understand Intellectual Property

1. **Master Intellectual Property:** Comprehend IP concepts, distinguish IP categories, and evaluate their protection mechanisms.
2. **Copyright:** Grasp legal concepts of copyright.
3. **Patent Expertise:** Grasp patent law, including patentability criteria, types, acquisition, enforcement, and impact on innovation.

B. Commercialize Intellectual Property

3. **IP Commercialization:** Explore diverse paths for IP commercialization, identify funding sources, and construct effective business plans.
4. **Entrepreneurial Mindset:** Develop entrepreneurial skills, build high-performing teams, and leverage resources for IP venture success.

C. Achieve Strategic IP Management

5. **IP Strategy:** Analyze real-world case studies to understand IP's role in business strategy, risk management, and competitive advantage.
6. **IP Valuation and Licensing:** Evaluate IP assets, negotiate licenses, and understand the complexities of IP transactions.
7. **IP and Society:** Examine the ethical, legal, and societal implications of IP, considering issues like open innovation and IP policy.

Indicative Literature

- Reingand, N. (ed.), Intellectual Property in Academia: A Practical Guide for Scientists and Engineers, CRC Press, 2011, ISBN-10 1439837007.

Recommendations for Preparation

The previous modules in the Transferable Skills track, i.e., Scientific Presentations and Scientific Writing, are recommended preparation, while not being strict prerequisites.

Entry Requirements

Recommended Knowledge, Abilities or Skills	
Module Prerequisites	None
Module Co-requisites	None

Usability and Relationships to other Modules

The module belongs to the Transferable Skills.

Examination Type: Module Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Intellectual Property and Commercialization	Oral Examination	30 mins	100%	All

Module Completion: To pass this module, the module examination has to be passed with at least 45%.

4.4 Elective Area (15 CP)

4.4.1 Quantitative Cell Biology

Module Name:	**Quantitative Cell Biology**
Module Code:	-
CP:	5
Frequency:	annually (Fall)
Year:	2
Semester:	3
4C-Model Reference:	-
Mandatory Status:	Mandatory elective for QLS
Number of Module Components:	2
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Klaudia Brix
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	
Seminar:	17.5 h
Lab:	
Tutorial:	17.5 h
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	**Number**	**Type**	**CP**
Quantitative Cell Biology seminar	xxxx	Seminar	2.5
Quantitative Cell Biology tutorial	xxxx	Tutorial	2.5

Module Description

Complex organisms, like humans, consists of a multitude of different cell types with countless interactions, which are fundamental to all physiologic and pathologic processes. The module "Quantitative Cell Biology" aims at teaching students tools to resolve this heterogeneity of cell and tissue composition at the molecular level. For example, in microscope experiments well-defined biomarkers of specific intra- and extracellular components are stained and cells and tissues are imaged at high resolution. Multiplexing (using a broad range of markers) allows assessing cell and tissue heterogeneity in an integrative fashion. Cell types and tissue structures as well as biomarkers thereof will be introduced in the seminar. This knowledge will be applied during the practical tutorials, for example by performing microscopical inspection of stained specimen. Furthermore, the students will learn how to use computational tools to objectively, reproducible and rapidly examine and analyse microscope images in the age of high-content microscopy. Thus, the goal is to enable students to analyze cells and tissues qualitatively and quantitatively, thereby gaining information on their respective molecular composition and state. The participants will present results of individually chosen experimental settings as a module achievement.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Understand molecular composition of cells and tissues
2. Apply the concept of biomarkers
3. Analyse quantitative and qualitative changes of biomolecules in disease
4. Apply image analysis tools
5. Critically interpret quantitative changes in cellular biomolecules
6. Enhance personal competence in communicating and validating scientific data in the form of a comprehensive results presentation

Indicative Literature

- Alberts, B., et al., Molecular Biology of the Cell, 7th Edition, W.W. Norton & Company, Inc., 2022
- Pollard, T.D., Earnshaw, W.C., et al., Cell Biology, 4th Edition, Elsevier, 2022
- Milo, R., Phillips, R., Cell Biology by the Numbers, Garland Science, Taylor & Francis Group, LLC, 2016
- CellProfiler™, Free open-source software for measuring and analyzing cell images. Download from cellprofiler.org

Recommendations for Preparation

- Make yourself familiar with the different cell types and tissues of the human body
- Read about common and rare diseases mentioned in the cell biological textbook and in recent literature (follow recommendations given during seminars; search: https://pubmed.ncbi.nlm.nih.gov/; https://medlineplus.gov/) focus on cancer or endocrinological disorders
- Familiarize yourself with image analysis tools (e.g. https://cellprofiler.org/; https://tutorials.cellprofiler.org/)
- Familiarize yourself with experimental "cell-painting" tools and molecular probes used as markers of cellular structures and compartments (Thermofisher-Invitrogen; Broad Institute)
- Visit journal clubs or lab meetings of the research groups with partial cell biological orientation
- Visit the Molecular Life Sciences seminar series where researchers from other institutions present

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic knowledge of cell biology methods and concepts; ability to read and understand scientific articles; critical discussion skills;
Module Prerequisites	
Module Co-requisites	Guided Self-study Data Tools for the Life Sciences

Usability and Relationships to other Modules

Examination Type: Module Component Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Quantitative Cell Biology seminar	Written Examination	60 min	50%	1,2,3
Quantitative Cell Biology tutorial	Presentation	20 min	50%	4,5,6

Module completion: To pass this module, both module component examinations must be passed with at least 45%.

4.4.2 Supramolecular Chemistry

Module Name:	**Supramolecular Chemistry**
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	Year 1 or 2
Semester:	1 or 3
4C-Model Reference:	n/a
Mandatory Status:	mandatory elective for QLS and AdvMat
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Tevyashova Anna
Student Workload	
Asynchronous Self Study:	
Interactive Learning (lectures):	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	Number	Type	CP
Supramolecular Chemistry	xxxx	Lecture	5

Module Description

The course aims to offer a comprehensive overview and foundational knowledge of supramolecular chemistry, focusing on non-covalent interactions. It covers a wide variety of these interactions, including hydrogen bonding, van der Waals forces, ionic interactions, and π-π stacking. Emphasis is placed on the principles governing these interactions and their roles in different chemical contexts. In drug design and discovery, understanding non-covalent interactions is essential for the rational design of drugs and inhibitors, which depend on specific binding to biological targets. In biomolecular engineering, the ability to manipulate and design supramolecular assemblies facilitates the creation of novel biomaterials and bio-inspired systems. Insights from supramolecular chemistry are also valuable in systems biology for modelling complex biological networks and understanding the emergent properties of biological systems. The principles of self-assembly and molecular recognition are fundamental in nanotechnology for developing nanoscale devices and materials. Furthermore, knowledge of non-covalent interactions enhances the development and application of advanced analytical techniques, such as spectroscopy and chromatography, which are crucial for probing molecular structures and dynamics. Supramolecular chemistry also provides the molecular framework for the quantitative methods essential for analyzing and modelling complex systems

Intended Learning Outcomes

By the end of the module, students will be able to:

- Account for fundamental concepts, methods and theories within supramolecular chemistry.
- Identify, analyze, and apply non-covalent interactions in diverse chemical contexts.
- Assess the current problems and research in the field.
- Anticipate the importance of supramolecular association within the life sciences and
- Interpret, analyze and evaluate experimental data of supramolecular interaction.

Indicative Literature

- Jonathan W Steed, Jerry L Atwood, Supramolecular Chemistry, 2nd Ed Wiley-Blackwell, 2009, ISBN-13: 978-0470512340

Recommendations for Preparation
To prepare for this course, it is recommended that students have a solid background in basic chemistry, particularly in physical and organic chemistry. Reviewing foundational concepts in these areas will help students grasp the more advanced topics covered in the course. Additionally, reading introductory materials on supramolecular chemistry can provide a useful head start, ensuring that students are well-prepared to engage with the course content.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Knowledge of Organic Chemistry, Inorganic Chemistry, Physical Chemistry and Biochemistry is required.
Module Prerequisites	None
Module Co-requisites	None

Usability and Relationships to other Modules

The course plays a foundational role in understanding complex biological and chemical systems. Its focus on non-covalent interactions provides essential insights into the mechanisms underlying molecular recognition, self-assembly, and catalysts. These principles are critical for successful completion of Computational Life Science, Modelling and Simulation, Advanced Molecular Simulations, as well as Quantitative Experiments in Life Science modules. The principles of supramolecular chemistry are integral to the development of advanced materials.

Examination Type: Module Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Supramolecular Chemistry	Written Examination	120 min	100%	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.4.3 Biochemical Engineering - From Cells to Processes

Module Name:	Biochemical Engineering - From Cells to Processes
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	1
Semester:	1
4C-Model Reference:	NA
Mandatory Status:	Mandatory elective for QLS
Module Components:	2
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Katrin Rosenthal, Prof Dr Elke Nevoigt
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	35 h
Independent Study:	55 h
Hours Total:	125 h

Module Components	Number	Type	CP
Microbial Engineering	xxxx	Lecture	2.5
Advanced Bioprocess Engineering and Digitalization	xxxx	Lecture	2.5

Module Description

Many valuable products such as enzymes, pharmaceutical proteins, small-molecule pharmaceuticals, biofuels, commodities and fine chemicals can be produced from renewable raw materials using living cells or their ingredients. This course combines strategies on how to design and optimize bioprocesses by engineering either i) the cellular factory or ii) the reaction. With regard to cell factory engineering, cutting-edge methods of synthetic biology that support metabolic engineering will be the main focus.

The second module component explores the fundamental concepts and distinctions between in vitro and in vivo biotransformations, emphasizing their implications and applications in bioprocessing. Students will analyze and evaluate integrated process development approaches for both upstream and downstream operations, gaining insights into the optimization of bioprocess efficiency through digital twins. Additionally, the module covers the application of computational tools and digitalization techniques, including computer-aided design software to enhance bioreactor and bioprocess design.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Examine how genetic engineering and synthetic biology has changed our opportunities to create microbial cells that can be exploited for the production of a target molecule
2. Understand the necessity of the ‘design-build-test-learn cycles’ in targeted microbial strain development
3. Discuss the possibilities to establish novel metabolic pathways in a microbial cell and evaluate different methods of DNA assembly to obtain expression cassettes for both single enzymes and entire metabolic pathways
4. Understand and differentiate between in vitro and in vivo biotransformations, including their implications and applications
5. Analyze and evaluate integrated process development approaches for upstream and downstream bioprocesses
6. Apply computational tools and digitalization techniques in bioreactor and bioprocess design, including computer-aided design software and approaches towards SMART biolabs
7. Analyze cutting-edge research articles

Indicative Literature

- Wilson, D.B., Sahm, H., Stahmann, K.-P., and Koffas, M. Industrial Microbiology, Wiley-VCH, 2013
- Li, M. and Borodina, I. (2015) Application of synthetic biology for production of chemicals in yeast *Saccharomyces cerevisiae*. *FEMS Yeast Research* 15: 1–12
- Liu, Z., Zhang, Y. and Nielsen, J. (2019) Synthetic Biology of Yeast. *Biochemistry*: 58, 1511−1520
- Liese, A., Seelbach K., and Wandrey, C. Industrial Biotransformations, Wiley-VCH, 2006

Recommendations for Preparation

Previous exposure to the specified course material is helpful but not essential.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Fundamentals of Molecular Biology and Genetic Engineering, Microbiology, Metabolic Pathways, Enzymes
Module Prerequisites	None
Module Co-requisites	None

Usability and Relationships to other Modules

- This module is for students who want to extend their studies in Metabolic Engineering, Biotechnology, and Biochemical Engineering.

Examination Type: Module Component Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Microbial Engineering	Written Examination	60 min	50%	1,2,3,4
Advanced Bioprocess Engineering and Digitalization	Written Examination	60 min	50%	5,6,7

Module completion: To pass this module, the assessment of each module component have to be passed with at least 45%.

4.4.4 Structure Elucidation

Module Name:	**Structure Elucidation**
Module Code:	-
CP:	5 ECTS
Frequency:	Annually (Spring)
Year:	1
Semester:	2
4C-Model Reference:	N/A
Mandatory Status:	Mandatory Elective for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Nikolai Kuhnert, Prof Dr Ulrich Kortz
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	35 h
Seminar:	
Lab:	
Tutorial:	
Exam Preparation:	20 h
Independent Study:	70 h
Hours Total:	125 h

Module Components	Number	Type	CP
Structure Elucidation	xxxx	Lecture	5 ECTS

Module Description

Modern Life Science and Material Science operate at the molecular level. The individual chemical structure defines the properties of biomolecules and materials and interactions. Hence it forms the basis of life and of material science. A thorough understanding of instrumental methods used for chemical structure elucidation in solution, in the solid state and in the gas phase, and their application to "known" and novel "unknown" substances is therefore an essential part of both MSc programs.

The module builds on previous knowledge at the Bachelor level and gives an intermediate level introduction and actual exposure to key experimental techniques such as nuclear magnetic resonance (NMR) spectroscopy, single crystal X-ray diffraction, infrared (IR) spectroscopy, mass spectrometry, Mössbauer spectroscopy and electron paramagnetic resonance (EPR) spectroscopy. Typically, a chemical structure elucidation process requires the use of a combination of several experimental techniques, which will be presented to the students along with applied exercises. The module will further introduce more advanced techniques such as multidimensional NMR spectroscopy (homonuclear and heteronuclear) of organic and inorganic compounds, materials, metabolites and proteins, high resolution tandem mass spectrometry, and single crystal as well as powder X-ray diffraction combined with data treatment and molecular visualization using state of the art software.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Appreciate information content of spectroscopic and diffraction data
2. Predict and propose chemical structures from spectroscopic and diffraction data
3. Predict and deduce spectral data from chemical structures
4. Interpret spectral data and assign signals to molecular features
5. Recommend and rate spectroscopic experiments with a view of solving ambiguous chemical structure problems

Indicative Literature

- Sternhill and Kalman 2D NMR spectroscopy
- Sternhill and Kalmann Solving organic spectroscopic problems
- David W. H. Rankin, Norbert W. Mitzel, Carole A. Morrison: Structural Methods In Molecular Inorganic Chemistry, 2nd edition, Wiley, 2013.

Recommendations for Preparation

Background literature for preparation provided by individual faculty.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic knowledge on chemical bonding and spectroscopic techniques (BSc level Analytical Methods and Inorganic Chemistry) Understanding of chemical structure and bonding
Module Prerequisites	Guided self-study
Module Co-requisites	Experimental Techniques

Usability and Relationships to other Modules

NA

Examination Type: Module Examination

Components	Assessment Type	Duration	Weight	Scope (ILOs)
Structure Elucidation	Written examination	120 minutes	100 %	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.4.5 Molecular Simulations

Module Name:	**Molecular Simulations**
Module Code:	-
CP:	5
Frequency:	Annually (Spring)
Year:	2
Semester:	3
Mandatory Status:	Mandatory Elective for QLS
Number of Module Components:	2
Program Affiliation:	Msc Quantitative Life Science
Module Coordinator(s):	Prof Dr Ulrich Kleinekathöfer
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	17.5 h
Seminar:	
Lab:	17.5 h
Tutorial:	
Exam Preparation:	30 h
Independent Study:	60 h
Hours Total:	125 h

Module Components	Number	Type	CP
Molecular Simulations Lecture	xxxx	Lecture	2.5
Molecular Simulations Lab	xxxx	Lab	2.5

Module Description

This course will provide the students with an introductory level understanding of the concepts and techniques for the modelling and simulations of biological systems on the molecular scale. Both fundamentals and applications of the most popular molecular simulation methods especially Molecular Dynamics (MD) approaches will be discussed, through examples distilled from the frontier of computational molecular life sciences. Integrated practical work in the computer lab will closely follow the theoretical discussion during the lecture. Computational hands-on problems using state-of-the-art scientific software packages are done partially in supervised sessions and partially as self-study.

Intended Learning Outcomes

By the end of this module, students will be able to:

1. Explain the theory and computational techniques of (bio)molecular dynamics simulations in the realm of (bio)molecular systems
2. Students will be familiar with software for molecular dynamics simulations,
3. Apply modern molecular simulation techniques to practical problems with a focus on Life Sciences
4. Analyze, visualize and present results obtained from molecular simulations.

Indicative Literature

- Alavi, S., P, Molecular Simulations: Fundamentals and Practice, Wiley-VCH, Weinheim, 2020
- Frenkel, D., and Smit, B., Understanding Molecular Simulation, 3rd Edition, Academic Press, 2023

Recommendations for Preparation

Students taking this course should have some general knowledge of basics physics and chemistry.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Basic knowledge of math, physics and chemistry.
Module Prerequisites	Data Tools for the Life Sciences Guided self-study
Module Co-requisites	

Usability and Relationships to other Modules

None

Examination Type: Module Component Examination

Components	Assessment Type	Duration/length	Weight	Scope (ILOs)
Molecular Simulations Lecture	Written examination	90 min	50 %	1,4
Molecular Simulations Tutorial	Laboratory report	5-10 pages	50 %	2-4

Module completion: To pass this module, both module component examinations have to be passed with at least 45%.

4.4.6 Machine Learning in Cheminformatics

Module Name	Machine Learning in Cheminformatics
Module Code:	-
CP:	5
Frequency:	Annually (Fall)
Year:	2
Semester:	3
4C-Model Reference:	N/A
Mandatory Status:	Mandatory elective for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	Prof Dr Petr Popov
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	17.5 h
Seminar:	17.5 h
Lab:	
Tutorial:	
Exam Preparation:	
Independent Study:	90 h
Hours Total:	125 h

Module Components	Number	Type	CP
Machine Learning in Cheminformatics	xxxx	Seminar	5

Module Description

Deep learning achieves remarkable results in many fields, including life sciences. This course is made for students that are ready to apply their skills to scientific applications, such as molecular design and drug discovery. Molecules play vital roles in our organism, constantly interacting with each other and performing all its functions.

Prediction of a biomolecule's properties, as well as design of molecules with target properties, are highly important yet unsolved problems and at the core of cheminformatics. The complex and rich nature of biomolecules can be represented as sequences, graphs, 3D objects, or high- dimensional descriptors, enabling the application of numerical methods in order to define their quantitative structure-activity relationship (QSAR).

The rapid accumulation of molecular data opened the gates for machine learning to be applied for such representations, and to derive powerful prediction models that outperform classical empirical methods. During this course students will be introduced to the open problems in chemoinformatics and the state-of- the-art machine learning methods attempt to solve these problems. The course concludes with a final project aimed to solve chemoinformatics problem of choice using machine learning.

Intended Learning Outcomes

1. Recall key concepts in cheminformatics
2. Explain the steps involved in the QSAR pipelines
3. Apply cheminformatics tools to analyze chemical compounds
4. Design a machine learning-based QSAR pipeline

Indicative Literature

- Deep Learning for the Life Sciences, by Vijay Pande, Patrick Walters, Peter Eastman, Bharath Ramsundar Publisher: O'Reilly Media, Inc.
- Faulon, Jean-Loup, and Andreas Bender. Handbook of chemoinformatics algorithms. CRC press, 2010.

Recommendations for Preparation

Students will practice deep learning for drug discovery and molecular design problems. The course includes theoretical lectures, that cover basics of molecular structures, such that no prior knowledge of structural chemistry or biology is required. Seminars are python coding sessions, so python programming skills are required. Prior understanding of machine learning is an asset.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Python, Machine Learning, Chemistry, Molecular Biology
Module Prerequisites	Data tools for the Life Science
Module Co-requisites	

Usability and Relationships to other Modules
The course will be useful for computational chemists, computational biologists, data scientists as well as software engineers, who want to apply their skills for the cheminformatics.

Examination Type: Module Examination

Module Components	Assessment Type	Duration	Weight	Scope (ILOs)
Machine Learning in Cheminformatics	Project assessment	n/a	100%	All

Module completion: To pass this module, the module examination has to be passed with at least 45%.

4.5 Master Thesis QLS (30 CP)

Module Name	**Master Thesis QLS**
Module Code:	-
CP:	30
Frequency:	Annually (Spring)
Year:	2
Semester:	4
4C-Model Reference:	N/A
Mandatory Status:	Mandatory for QLS
Number of Module Components:	1
Program Affiliation:	MSc Quantitative Life Science
Module Coordinator(s):	
Student Workload	
Asynchronous Self Study:	
Interactive Learning:	
Lecture:	
Seminar:	
Lab:	560 h
Tutorial:	
Exam Preparation:	20 h
Independent Study:	170 h
Hours Total:	750 h

Module Components	**Number**	**Type**	**CP**
Master Thesis QLS	-	Thesis	30

Module Description

The aim of this module is to train students to motivate, design, carry out and document a research project in one of the research groups of the faculty of Quantitative Life Science. Some familiarity with the requisite experimental techniques and analytical skills will typically have been acquired in one of the preceding Lab Rotations (I, II and III). The thesis topic is determined in mutual agreement with the laboratory head. They may arise from the ongoing research in the instructor's own research group, but it is also possible for a student to adopt a topic of his/her own choice provided the instructor agrees to supervise it. The project selected should be a topical piece of novel science with a view of being published in a peer-reviewed scientific journal. The thesis work comprises the full cycle of a scientific research endeavor: (i) identifying a relevant open research question, (ii) carrying out a literature survey to put the planned work in its context and relate it to the state of the art (SoA), (iii) formulate a concrete research objective, (iv) design a research plan including a statement of criteria to evaluate the success of the project, (v) carry out the plan (with the possibility to change the original plan when necessary), (vi) document the results, (vii) analyze the results with respect to the SoA, the original objective, and the success criteria, and (viii) and summarize all of this work in the thesis document. Moreover, the student is expected to actively participate in the meetings of and engage with the respective research group. All of this work should be done with as much self-guidance as can be reasonably expected. The laboratory head will likely give substantial guidance for (i), (iii) and (iv), whereas the other aspects will be addressed with larger degrees of self-guidance and with the support of the research group.

Practical laboratory and instrument training will be provided by members of the relevant research groups (Postdocs, technicians and experienced PhD students). A research proposal document summarizing (i) – (iv) is expected as an interim result and milestone (target size: 5 pages). At the end of the course, there will be a conference-style meeting where all students present their work.

The project concludes with a thesis, and an oral defense thereof.

Intended Learning Outcomes

At the end of this course the student will be able to:

1. Discuss, at a professional level, a circumscribed segment of the hosting group's research area.
2. Compare and select experimental methods, as required for the project, at a professional level.
3. Design and implement the full cycle of a novel scientific research project in a professional manner.
4. Formulate a research proposal such that that it could serve as a funding proposal;
5. Author a Master Thesis at the level expected from a scientific publication.
6. Examine and defend his own research in the wider scientific context.
7. Demonstrate general professional skills like communication, presentation and time management.

Indicative Literature

- N.A.

Recommendations for Preparation

Study indicative research literature and methods in the selected research group.

Entry Requirements

Recommended Knowledge, Abilities or Skills	Proficiency in the area of the chosen thesis topic.
Module Prerequisites	Lab Rotation I, II, and III
Module Co-requisites	None

Usability and Relationships to other Modules

The master thesis can build on the Lab Rotation I, II or III, but students are free to choose a different topic and a different supervisor for the master thesis.

Examination Type: Module Examination

Module Components	Assessment Type	Duration	Weight	Scope
Master Thesis	Thesis	30-60 pages	80%	All
Master Thesis	Oral Examination	30 min	20%	All

Module completion: To pass this module, both examinations have to be passed with at least 45%.

5 Appendix

5.1 Intended Learning Outcome Matrix MSc Quantitative Life Science

MSc Quantitative Life Science					Guided self-study	Data Tools for Life Sciences	Experimental Techniques	Omics I - Genomics and Transcriptomics	Computational Life Sciences - Modelling and Simulations	Omics II - Microbiomics and Metabolomics	Molecular Simulations	Machine Learning in Cheminformatics	Supramolecular Chemistry	Structure Elucidation	Biochemical Engineering; From Cells to Processes	Quantitative Cell Biology	Lab RotationQLS I	Lab Rotation QLS II	Lab Rotation QLS III	Scientific Presentations	Scientific Writing	Intellectual Property and Commercialization	Master Thesis
Semester					1	1	2	2	3	3	3	3	1 or 3	2	1 or 3	3	1	2	3	1	2	3	4
Mandatory/ Mandatory elective					m	m	m	m	m	m	me	me	me	me	me	me	m	m	m	m	m	m	m
ECTS Credits					5	5	5	5	5	5	5	5	5	5	5	5	10	10	10	5	5	5	30
	Competencies*																						
Program Learning Outcomes	**A**	**E**	**P**	**S**																			
Describe complex technical and conceptional advances in the Life Sciences in depth and with specific focus on omics techniques, like genomics, transcriptomics, proteomics, and metabolomics.	x							x	x	x	x	x	x	x	x	x				x	x		
Understand common computational tools, algorithms, and databases for data processing, analysis and visualization used in the life sciences.	x					x		x	x	(x)	x				(x)	(x)							
Critically examine and creatively apply intricate techniques to perform quantitative experiments, obtain reliable data, and answer complex scientific questions in the life sciences at high scientific and ethical standards.	x				x		x	x	x	x			x	x	x	x	x	x	x	x			x
Scrutinize and implement innovative bioinformatics approaches to obtain, examine, and compare Life Science data.	x					x		x	x		x	x			x		(x)	(x)	(x)	x			
Construct comprehensive mathematical models and detailed computational simulations to generate and test hypothesis in the field of biology or chemistry.	x				x				x		x	x					(x)	(x)	(x)				
Scrutinize and critique scientific results, experimental approaches, and research hypothesis from all fields of quantitative life science.	x					x	x	x	x	x										x			x
Construct original and innovative research hypothesis and design experiments to test them individually or as a team in actual research projects and a master thesis.	x	x		x				x		x	x	x	x	x	x	x					x		x
Apply professional writing, communication, and presentation techniques, combined with state-of-the-art visualization tools to effectively communicate with scientific and non-scientific audiences.	x	x		x																x	x	x	
Understand the chances, risks, and approaches of applying scientific research in modern society considering ethical and commercial aspects while following and defending ethical, scientific, and professional standards.		x	x	x																	x	x	
Take responsibility for their own learning, personal and professional development and role in diverse teams, evaluating critical feedback and self-analysis.		x	x	x	x																		x
Assessment Type																							
Written examination					x	x	x	x	x	x	x		x	x	x	x							
Term paper																					x		
Essay																							
Project report						x																	
Poster presentation																							
Laboratory report											x						x	x	x				
Program Code																							
Oral examination																						x	x
Presentation																x	x	x	x				
Practical Assessments																							
Project Assessments												x											
Portfolio Assessments																				x			
Master Thesis																							x
Module Achievements								x															

*Competencies: A-scientific/academic proficiency; E-competence for qualified employment; P-development of personality; S-competence for engagement in society