Georg-August-Universität
Göttingen

Ruprecht-Karls-Universität
Heidelberg

Modulverzeichnis

Joint consecutive Master's degree programme "Matter to Life" - referring to: Prüfungs- und Studienordnung für den gemeinsamen konsekutiven Joint Degree-Masterstudiengang "Matter to Life" der Georg-August-Universität Göttingen und der Ruprecht-Karls-Universität Heidelberg (Amtliche Mitteilungen I 29/2023 S. 1051, Mitteilungsblatt des Rektors 17/2023 S. 1541)

Motivation

Living beings, whether they are cells, organs or even whole humans and animals, consist of a system of finely tuned interacting components. In terms of size and complexity, they range from molecules to organs, tissues, bones and nervous systems. An organism is a complex machine that burns fuel (generating free energy) to escape thermodynamic equilibrium, where no driving forces exist and energy and entropy conditions are balanced. Chemistry, physics and biology work in close interaction to create living matter.

But how could you replicate such a system without a blueprint?

To do so, you would have to take the whole system apart, step by step, down to the smallest component, to understand the function of the parts and their material composition - in other words, reverse engineer it. Once the blueprint and function of each component is understood, the original can be replicated or even improved.

This same "reverse engineering" approach is routinely applied to cells, tissues, organs, bones, and the nervous system: Biomedical research seeks to understand the function of the components of a living organism in order to develop strategies to repair them so that the entire system does not break down just because one component fails. To understand functions and mechanisms from an engineer's point of view, the system must be analyzed quantitatively at all relevant length scales - from the macroscopic to the mesoscopic to the molecular level - and described using theory and modeling. Such a "top-down" approach is necessary for elucidating and quantifying the complex interactions to eventually obtain an engineering design plan.

In doing so, the Max Planck School ***MATTER to LIFE*** and this degree programme aim to do more than identify and analyze the building blocks for constructing life. They promote free thinking and multidisciplinary collaboration and will educate a new generation of scientists, enabling them to explain the following questions:

- **What exactly is life?**
- **How can life be described quantitatively?**
- **How can life-like systems be built?**

To this end, students will receive intensive mentoring from an exceptional group of scientists and faculty and will have access to the most advanced tools in the field of reverse engineering. Students learn how to operate them, how to interpret the data, and how to extract the information needed to build a blueprint for life.

The curriculum is therefore designed to overcome conventional historically established demarcations between disciplines. It addresses the roots of life in chemistry and physics, which provide the foundation for understanding life and the tools for developing life-like processes.

Qualification objectives, profile, and particularities of the degree programme

Preamble – Qualification objectives

The programme pursues subject-specific, interdisciplinary and professional field-related goals in the comprehensive academic education for a later professional activity of its students. The resulting competence profile is included in this module directory as a qualification profile valid for all disciplines and implemented in the specific qualification objectives as well as the curricula and modules of the individual study programmes:

- Development of subject-specific competencies with a pronounced research orientation;
- Development of interdisciplinary competence;
- Development of personal and social competencies;
- Promotion of readiness to assume social responsibility on the basis of the acquired competencies.

Subject-specific und generic qualification objectives

The Master's programme is strongly research-oriented and encourages students to think and learn independently. It builds on the diverse experiences in the students' bachelor's programmes and addresses interdisciplinary scientific issues.

Graduates will have an in-depth knowledge of the chemical-physical basis of life and be able to scientifically describe, analyze, evaluate and successfully solve challenging problems and tasks in this interdisciplinary field. They will be able to construct and to theoretically describe life-like molecular systems and materials and have the ability to use chemical and physical principles to describe the behavior of complex materials. They will further be able to plan experimental or theoretical investigations, carry them out independently and convincingly document, interpret and present their scientific results.

The graduates of the Master's programme Matter to Life will have achieved the necessary qualifications for research-related professional work in interdisciplinary and innovative scientific fields. They will be able to contribute scientific approaches to the formulation and solution of complex problems and tasks in academia as well as in industry and have experience in communicating their expertise in a multidisciplinary environment. They will be able to expand their knowledge and skills to new subject areas and to use modern scientific equipment.

They will have an in-depth knowledge of the potential of a “bottom-up” understanding of life and of the synthesis of life-like systems and materials, while also being aware of limitations and hazards that arise. They will apply their knowledge responsibly, taking into account safety, environmental, ethical, and economic requirements. They will be equipped to actively shape the opinion-forming process in society with regard to scientific issues.

Graduates who have completed the Master's programme Matter to Life with a grade of 2.0 or better possess the scientific qualification for further PhD studies within the Max Planck School Matter to Life.

Graduates of the degree programme may enter any of the following professions

After graduation, students can work in research institutions, universities, interdisciplinary laboratories as well as in other fields as pharmaceutical, chemical or biotechnological industries among others.

Particularities of the degree programme

Students in this programme are integrated into the Max Planck School Matter to Life. This unites internationally established scientists across locations to focus on a common scientific topic and offers students a research-oriented study programme with individual mentoring, diverse laboratory places in an interdisciplinary community.

The small number of students (20 per cohort) ensures an optimal student-to-faculty ratio and allows for individualized and personalized support tailored to students' interests and needs.

In the Matter to Life programme, classical teaching is supported with digital models: Here, in addition to normal lectures, students work out the lecture content themselves based on the teaching materials provided on an interactive online platform. This is done individually, independent of location and self-paced.

Multidisciplinary teaching

In the Matter to Life programme, all students attend courses on biophysics and physical chemistry of life, synthetic chemistry, bioengineering and complex systems and get practical training in research in the field “Matter to Life” in the labs associated with the Max Planck School Matter to life.

Students can chose one of two focus areas: a focus on "Molecular Systems Chemistry and Engineering" (based at Heidelberg University), which provides additional training in the fields of physics and physical chemistry of life, quantitative analysis, and hierarchical assemblies of molecular and nanoscopic units as the basis of life-like materials; and a focus on “Complex Systems and Biological Physics” (based at the University of Göttingen), which provides additional training in biophysics and the dynamics of complex systems, including the physical principles of life and state-of-the art experimental and theoretical methods to study living and life-like systems. To ensure this interdisciplinarity, the Matter to Life Master's programme will focus on the following scientific topics:

- Understanding the chemistry and physics of life and of the components of living systems
- Quantitative analysis of life
- Engineering of molecular and nanoscopic entities as the basis of life-like materials.

Joint degree programme

The Matter to Life Master's degree programme is a joint degree programme by the University of Göttingen and Heidelberg University. The curriculum is offered jointly by both universities and location-independent participation is ensured as far as possible. The two universities involve all members of the faculty (Fellows) of the Max Planck School "Matter to Life" in its teaching programmes, including those fellows not affiliated to either of the two universities, especially in the context of laboratory rotations and master's theses.

The two universities each make their own contributions to the integrated curriculum and the associated course and examination work, thus ensuring the quality of the studies.

Reason for cumulative examinations:

Some modules in Matter to Life include multiple lectures that approach a core topic in Matter to Life from different directions. The advantage of this for students is that the very structure of the module presents a common core of content, making it easier for students to see the goals of each lecture from a macroscopic perspective. In addition, each lecture is concluded with a written exam, which allows students to better assess the learning load and creates a more homogeneously distributed exam load. The exact examination modalities are laid down in the individual module descriptions (cf. below); where more than one alternative is given, students shall be informed at the start of the respective semester.

In the Master's programme Matter to Life, the following teaching and learning forms are predominantly used in the various courses:

Lecture: Lecture by the lecturer, preparation and follow-up by self-study.

Lectures in the inverted classroom:

Self-study and guided consolidation and application of the material by the lecturer in the classroom.

Exercise/tutorial: self-study, processing of exercise sheets, active questions and discussions.

Practical course: Execution and evaluation of laboratory experiments, writing of experimental protocols.

Reason for modules with fewer than 5 credits

During the specialization phase, students have the free choice to attend interdisciplinary relevant lectures, seminars and practical courses that are closely related to the chosen specialization. The module serves to think outside the box within the subject of Matter to Life and is intended to provide a broadly based education.

Repeat exams

Module examinations that have not been passed or are considered failed can typically be repeated twice. (Failed attempts at other universities are to be counted towards this.) Some Göttingen modules usually offered in other programmes but open to Matter to Life students (module abbreviation other than M.MtL.*) may offer a different number of repetition attempts as stated in the specific module description.

Mobility window

Students have the opportunity to participate in modules and internships at other universities in Germany and abroad, especially in Modules from the 2nd and 3rd term. This requires prior arrangement with the study coordinator.

Model study plans / Model course of studies

Credits

A certain number of credits is awarded for each successfully completed module based on student workload and according to the rules of the European Credit Transfer and Accumulation System (ECTS).

The number of credits (C) to be earned per module reflects the average student workload; 1 C corresponds to approximately 30 hours of student work. This includes both the participation in the courses and the time required for preparation and follow-up of the course material (self-study). A minimum of 120 C is required for the two-year Master's programme Matter to Life.

How many credits are assigned to each module is specified in the respective module description. Students receive the credits as soon as the modules have been successfully completed (i.e. passed), regardless of the grading of the performance. These credits thus reflect the quantity of the performance rendered, whereas grades are assigned for qualitative assessment.

Exemplary Study plan

<table>
<tr><th>1. Semester</th><th>2. Semester</th><th>3. Semester</th><th>4. Semester</th></tr>
<tr><td>M.MtL.1002 (6 C)</td><td rowspan="3">M.MtL_SPEC (19 C)</td><td rowspan="5">M.MtL.1107
(30 C)</td><td rowspan="5">M.MtL_MA
(30 C)</td></tr>
<tr><td>M.MtL.1010 (6 C)</td></tr>
<tr><td>M.MtL.1011 (5 C)</td></tr>
<tr><td>M.MtL.1012 (8 C)</td><td>M.MtL.1301 (10 C)</td></tr>
<tr><td colspan="2">M.MtL.1201 & 1202 (6 C)</td></tr>
<tr><td colspan="2">60 C</td><td>30 C</td><td>30 C</td></tr>
</table>

Table 1: M.MtL.1002: Introduction to Physics of Complex Systems; M.MtL.1010: Quantitative Analysis of the Chemistry of Life; M.MtL.1011: Bioengineering/Synthetic Biology; M.MtL.1012: Biophysics and Physical Chemistry of Life; M.MtL.1201 & 1202: Ethics in Synthetic Biology and Professional Skills in Science MtL_SPEC: Specialization in Matter to Life; M.MtL.1301: Methods and topics from Matter to Life; M.MtL.1107: Lab Rotation; MtL_MA: Master's Thesis.

Module

Übersicht nach Modulgruppen

I. Joint Master’s degree program "Matter to Life"

Following the regulations below, at least 120 C must be successfully completed.

The joint Master's degree program "Matter to Life" comprises the scientific fields of biophysics, physical chemistry of life, quantitative analysis of the chemistry of life, bioengineering and complex systems and get practical training in research in the field “Matter to Life”.

1. Block I (Term 1-3)

Modules worth overall at least 90 C must be successfully completed within the following regulations.

a. Introductory Courses (Term 1-2)

The following introductory courses worth overall 35 C must be successfully completed:

b. Advanced Courses (Term 2-3)

Here you can find courses recommended for either the specialization **Complex Systems and Biological Physics** based at University of Göttingen or the specialization **Molecular Systems Chemistry and Engineering** based at Heidelberg University. The courses can be individually selected and combined. A total of at least 19 C must be achieved.

aa. Advanced courses - Molecular Systems Chemistry and Engineering

The following courses are recommendations for the specialization Molecular Systems Chemistry and Engineering based at Heidelberg University. The courses can be individually selected and combined with courses from Complex Systems and Biological Physics or from the additional elective modules.

bb. Advanced courses - Complex Systems and Biological Physics

The following courses are recommendations for the specialization Complex Systems and Biological Physics based at University of Göttingen. The courses can be individually selected and combined with courses from Molecular Systems Chemistry and Engineering or from the additional elective modules.

Shared courses with the Physics department in Göttingen are generally taught in person in Göttingen. Hybrid participation can be considered after consultation with the respective lecturer and if the format of the course is allowing the possibility.

cc. Advanced courses - Additional elective modules

The following courses are additional elective modules which can be combined with modules from Molecular Systems Chemistry and Engineering and/or Complex Systems and Biological Physics.

c. Laboratory Rotations (Term 3)

The following module/research internships worth overall 30 C must be successfully completed:

d. Key Competencies

The following modules worth overall 6 C must be successfully completed:

2. Block II (Term 4)

Completion of the Master's thesis is worth 30 Credits.

Georg-August-Universität Göttingen **Module B.Phy.5405: Active Matter**	3 C 2 WLH

Learning outcome, core skills: **Learning objectives**: The students will learn about the basic principles of the physics of active matter as characterized via nonequilibrium statistical physics. Topics will include: physics of micro-swimming, hydrodynamic coordination, continuum description of scalar active matter and motility-induced phase separation, polar active matter and flocking, active liquid crystals (e.g. nematics) and defects, phoretic active matter, activity in enzyme suspensions, and active membranes. **Competences**: This course will give the students a good theoretical understanding of active matter and enable them to follow the state-of-the-art research in the area of active matter.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Active Matter (Lecture)	
Examination: written examination (60 Min.) or oral examination (approx. 30 Min.)	3 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in statistical physics and hydrodynamics
Language: English	**Person responsible for module:** Prof. Dr. Ramin Golestanian
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Georg-August-Universität Göttingen **Module B.Phy.5608: Micro- and Nanofluidics**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Students will learn the fundamentals of fluid dynamics, hydrodynamics on the micro- and nanoscale, wetting and capillarity and "life" at low Reynolds numbers. Students will also learn the how these topics are studied/applied in experiments, learn about device fabrication using soft lithography and the use of fluidics in biology and biophysics including "lab-on-a-chip" applications. After successfully completing this course, students will be familiar with basic hydrodynamics and their applications at scales applicable to biology, biophysics, material sciences and biotechnology.	Attendance time: 28 h Self-study time: 62 h

Course: Micro- and Nanofluidics (Lecture)	

Von den folgenden Prüfungen ist genau eine erfolgreich zu absolvieren:	
Examination: Written examination (60 minutes)	3 C
Examination: Oral examination (approx. 30 minutes)	3 C

Admission requirements: none	**Recommended previous knowledge:** Introduction to Biophysics and/or Physics of Complex Systems
Language: English	**Person responsible for module:** Prof. Dr. Sarah Köster
Course frequency: every 4th semester; summerterm, in even years	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Georg-August-Universität Göttingen **Module B.Phy.5613: Soft Matter Physics**	3 C 2 WLH

Learning outcome, core skills:	**Workload:**
Learning objectives After successfully finishing this course, students will be familiar with fundamental concepts of soft condensed matter physics and their applications. Topics include: intermolecular interactions; phase transitions; interface physics; amphiphilic molecules; colloids; polymers; polymer networks; gels; fluid dynamics; self-organization. **Learning outcomes:** Students will be able to apply these fundamental concepts independently to specific questions. They will be able to use the knowledge learned to critically evaluate the current literature.	Attendance time: 28 h Self-study time: 62 h

Course: Soft Matter Physics (Lecture)	2 WLH

Von den folgenden Prüfungen ist genau eine erfolgreich zu absolvieren:	
Examination: Written examinationwritten exam (120 minutes)	3 C
Examination: Oral examinationoral exam (approx. 30 minutes)	3 C

Admission requirements: none	**Recommended previous knowledge:** Introduction to…Biophysics or/and Physics of complex systems or/and Solid State Physics or/and Materials Physics
Language: English	**Person responsible for module:** Prof. Dr. Sarah Köster
Course frequency: every 4th semester; summerterm, in odd years	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Georg-August-Universität Göttingen Module B.Phy.5625: X-ray physics	6 C 4 WLH
Learning outcome, core skills: Knowledge in: • Radiation-matter interaction • Dosimetry, radiobiology and radiation protection • Scattering experiments: photons, neutrons and electrons • Fundamental concepts in diffraction and Fourier theory • Structure analysis in crystalline and non-crystalline condensed matter • Generation of x-rays and synchrotron radiation • X-rays optics and detection • X-ray spectroscopy, microscopy and imaging After taking the course, students • will integrate fundamental concepts of matter-radiation interaction . • are able to apply quantitative scattering techniques with short wavelength radiation for structure analysis of condensed matter, including problems in solid state, materials, soft matter, and biomolecular physics • are able to plan and carry out x-ray laboratory experiments • are prepared to participate in beamtimes at synchrotron, neutron or free-electron radiation sources • can solve analytical problems in x-ray optics, diffraction and imaging	**Workload:** Attendance time: 56 h Self-study time: 124 h
Course: X-ray Physics	
Examination: Written examination (120 minutes) or oral examination (ca. 30 min.) or presentation (ca. 30 min.) **Examination prerequisites:** none **Examination requirements:** • solve problems of the topics mentioned above on a quantitative level, including calculations of structure factor, correlation functions, • applications of Fourier theory to structure analysis and basic solutions to the phase problem, • solve problems of wave optical propagation and diffraction • knowledge about interaction mechanisms and order -of-magnitude estimations, • knowledge about theoretical concepts and experimental implementations of different techniques, • knowledge of laboratory skills (x-ray sources, detection, dosimetry)	6 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English, German	**Person responsible for module:** Prof. Dr. Tim Salditt

Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 6; Master: 1 - 2
Maximum number of students: 15	

Georg-August-Universität Göttingen Module B.Phy.5648: Theoretical and Computational Biophysics	4 C 2 WLH
Learning outcome, core skills: This combined lecture and hands-on computer tutorial focuses on the basics of computational biophysics and deals with questions like "How can the particle dynamics of thousands of atoms be described precisely?" or "How does a sequence alignment algorithm function?" The aim of the lecture with exercises is to develop a physical understanding of those "nano maschines" by using modern concepts of non-equilibrium thermodynamics and computer simulations of the dynamics on an atomistic scale. Moreover, the lecture shows (by means of examples) how computers can be used in modern biophysics, e.g. to simulate the dynamics of biomolecular systems or to calculate or refine a protein structure. No cell could live without the highly specialized macromolecules. Proteins enable virtually all tasks in our bodies, e.g. photosynthesis, motion, signal transmission and information processing, transport, sensor system, and detection. The perfection of proteins had already been highly developed two billion years ago. During the exercises, the knowledge presented in the lecture will be applied to practical examples to further deepen and strengthen the understanding. By completing homework sets, which will be distributed after each lecture, additional aspects of the addressed topics during the lecture shall be worked out. The homework sets will be collected during the corresponding exercises.	**Workload:** Attendance time: 28 h Self-study time: 92 h
Course: Theoretical and Computational Biophysics (Lecture, Exercise)	
Examination: Oral examination (approx. 30 minutes) **Examination requirements:** Protein structure and function, physics of protein dynamics, relevant intermolecular interactions, principles of molecular dynamics simulations, numeric integration, influence of approximations, efficient algorithms, parallel programing, methods of electrostatics, protonation balances, influence of solvents, protein structure determination (NMR, X-ray), principal component analysis, normal mode analysis, functional mechanisms in proteins, bioinformatics: sequence comparison, protein structure prediction, homology modeling, and hands-on computer simulation.	4 C

Admission requirements: none	**Recommended previous knowledge:** • Introduction to Biophysics • Introduction to Physics of Complex Systems
Language: English, German	**Person responsible for module:** Hon.-Prof. Dr. Karl Helmut Grubmüller
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students:	

30	

Georg-August-Universität Göttingen **Module B.Phy.5649: Biomolecular Physics and Simulations**	4 C 2 WLH
Learning outcome, core skills: **Learning objectives:** This combined lecture and hands-on computer tutorial offers the possibility to deepen the knowledge about theory and computer simulations of biomolecular systems, particularly proteins, and can be understood as continuation of the lecture with exercises "Theoretical and Computational Biophysics" (usually taking place in the previous winter semester). During the exercises, the knowledge presented in the lecture will be applied to practical examples to further deepen and strengthen the understanding. By completing homework sets, which will be distributed after each lecture, additional aspects of the addressed topics during the lecture shall be worked out. The homework sets will be collected during the corresponding exercises. **Competencies:** Whereas the winter term lecture with exercises "Theoretical and Computational Biophysics" emphasized the principles of running and analysing simple atomistic force field-based simulations, this advanced course will broaden our view and introduce basic principles, concepts and methods in computational biophysics, particularly required to understand biomolecular function, namely thermodynamic quantities such as free energies and affinities. Further, inclusion of quantum mechanical simulation techniques will allow to also simulate chemical reactions, e.g., in enzymes.	**Workload:** Attendance time: 28 h Self-study time: 92 h
Course: Lecture with Exercises Biomolecular Physics and Simulations	
Examination: Oral examination (approx. 30 minutes) **Examination requirements:** Basic knowledge and understanding of the material covered in the course such as: Free energy calculations, Rate Theory, Non-equilibrium thermodynamics, Quantum mechanical methods (Hartree-Fock and Density Functional Theory), enzymatic catalysis; “handson” computational calculations and simulations	4 C

Admission requirements: none	**Recommended previous knowledge:** B.Phy.5648 Theoretical and Computational Biophysics
Language: English, German	**Person responsible for module:** Hon.-Prof. Dr. Karl Helmut Grubmüller
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module B.Phy.5658: Statistical Biophysics**	6 C 4 WLH

Learning outcome, core skills: **Objectives:** The students will learn basic concepts of statistical biophysics at the molecular, cellular and population level, as well as methods for the theoretical analysis of biophysical systems. **Competences:** After successful participation in the module, students should have working knowledge of basic concepts of statistical biophysics and be able to apply them to selected problems.	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Statistical Biophysics (Lecture with integrated problem sessions) *Course frequency:* each winter semester	WLH
Examination: written examination (120 Min.) or oral examination (approx. 30 Min.) **Examination requirements:** Physical principles of biological systems on the molecular, cellular and population level, application of methods from statistical physics to biological and biophysical problems.	6 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge in biophysics and statistical physics
Language: English, German	**Person responsible for module:** Prof. Dr. Stefan Klumpp
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 5 - 6; Master: 1 - 4
Maximum number of students: not limited	

Georg-August-Universität Göttingen **Module B.Phy.5660: Theoretical Biofluid Mechanics**	3 C 2 WLH

Learning outcome, core skills: The course will discuss the theoretical foundations of fluid mechanics used in the study of biological systems. Important concepts in the mathematical study of fluids will be introduced and employed to investigate blood flow and circulation, the propulsion of organisms and transport facilitated by fluid flow. Students will learn to set up theoretical models for a range of biological systems involving fluids employing the Navier-Stokes equation and appropriate boundary conditions. The course will prepare the students to simplify, assess and analyze models to investigate the intricate role of fluids in biological settings.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Theoretical Biofluid Mechanics (Lecture)	
Examination: Written exam (60 minutes) or oral exam (approx. 30 minutes) **Examination requirements:** Solving Navier-Stokes equation in simple geometry, derive simplified equations from models of fluid flow and transport, explore theoretical models in limiting parameter range and assess prediction in relation to modeled biological system. The exam will be oral, if max. 20 students take part at the first date of the course. Oherwise it will be a written exam.	3 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge of calculus and algebra
Language: English, German	**Person responsible for module:** Prof. Dr. Stefan Klumpp Contact: David Zwicker
Course frequency: every 4th semester; Every second Summerterm in Rotation to Microfluidic	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** Bachelor: 3 - 6; Master: 1 - 4
Maximum number of students: not limited	

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1002: Introduction to Physics of Complex Systems**	6 C 6 WLH
Learning outcome, core skills: This course is an introduction to the tools and techniques used to analyse dynamical systems. The fundamental theories are applied to real-world examples e.g. models relevant to climate change, ecology, and epidemics. Learning outcomes: On completion of this module students will have a sound knowledge of essential methods and concepts from Nonlinear Dynamics and Complex Systems Theory, including practical skills for analysis and simulation (using, for example, the programming language python) of dynamical systems.	**Workload:** Attendance time: 84 h Self-study time: 96 h
Course: Introduction to Physics of Complex Systems (Lecture)	4 WLH
Examination: written examination (120 Min.) or oral examination (approx. 30 Min.) **Examination prerequisites:** At least 50% of the homework exercises have to be solved successfully. **Examination requirements:** Knowledge of fundamental principles and methods of nonlinear physics, modern experimental techniques and theoretical models of complex systems theory.	6 C
Course: Introduction to Physics of Complex Systems (Exercise)	2 WLH

Admission requirements: none	**Recommended previous knowledge:** Basic programming skills (for the exercises)
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 1
Maximum number of students: 30	

Additional notes and regulations: Hybrid Learning - in-person in Göttingen with Live stream in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1006: Modern Experimental Methods**	6 C 6 WLH
Learning outcome, core skills: Knowledge about advanced applied optics, radiation-matter interaction, spectroscopy, microscopy and imaging techniques in biophysics After taking this course, students will have quantitative insight into modern experimental techniques for biophysics, in particular optical techniques from basic to advances microscopy including confocal, light sheet and nanoscopy, optical spectroscopy including time-resolved techniques (transient absorption), single molecule techniques (e.g. FCS), electron microscopy, neutron and x-ray diffraction (including protein crystallography), NMR spectroscopy, and X-ray imaging. Students have the competence to reduce the complexity to underlying physics of radiation-matter interaction, to use Fourier-based methods in signal theory, concepts of wave and quantum optics, as well as quantitative data analysis. Hand-on examples of experimental applications and data recording will be introduced by short teaching units in the laboratory along with the courses, and a deeper unit of a 3 days practical in one of the technquies.	**Workload:** Attendance time: 84 h Self-study time: 96 h
Course: Modern Experimental Methods (Lecture, Exercise)	6 WLH
Examination: Written examination (120 min.) or oral examination (approx. 30 min.) or presentation (approx. 30 min., 2 weeks preparation time) **Examination requirements:** Theoretical and practical knowledge of modern methods of experimental methods of biophysics.	6 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Tim Salditt
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 15	

Additional notes and regulations:
in-person in Göttingen

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1008: Advanced Topics in Matter to Life I**	6 C 6 WLH
Learning outcome, core skills: After successful completion of the module students will be able to understand and apply advanced concepts related to Matter to Life to current research topics. **Core skills:** Students will be able to describe and discuss state-of-the-art problems of relevant to Matter to Life	**Workload:** Attendance time: 84 h Self-study time: 96 h

Course: Advanced Topics in Matter to Life (Lecture) *Contents*: Theoretical or experimental topics relevant to Matter to Life	6 WLH
Examination: Written examination (120 minutes) or oral examination (approx.30 minutes) or presentation (approx. 30 minutes) **Examination requirements:** Advanced experimental techniques or theoretical models in Matter to Life	6 C

Admission requirements: Access must be authorized by the person responsible for the module. They may request the opinion of an authorized examiner in the related field.	**Recommended previous knowledge:** None
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: 30	

Additional notes and regulations: Only for Matter to Life Students - Topic dependend in-person in Göttingen with Live stream in Heidelberg or the other way around

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1009: Advanced Topics in Matter to Life II**	6 C 4 WLH

Learning outcome, core skills: After successful completion of the module students will be able to understand and apply advanced concepts related to Matter to Life to current research topics. **Core skills:** Students will be able to describe and discuss state-of-the-art problems of relevant to Matter to Life	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Course (3C) in the Field of Matter to Life (Lecture) *Contents*: Theoretical or experimental topics relevant to Matter to Life	2 WLH
Examination: Written examination (120 minutes) or oral examination (approx.30 minutes) or presentation (approx. 30 minutes) **Examination requirements:** Advanced experimental techniques or theoretical models in Matter to Life	3 C

Course: Course (3C) in the Field of Matter to Life (Lecture) *Contents*: Theoretical or experimental topics relevant to Matter to Life *Course frequency:* each semester	2 WLH
Examination: Written examination (120 minutes) or oral examination (approx.30 minutes) or presentation (approx. 30 minutes) **Examination requirements:** Advanced experimental techniques or theoretical models in Matter to Life	3 C

Admission requirements: Access must be authorized by the person responsible for the module. They may request the opinion of an authorized examiner in the related field.	**Recommended previous knowledge:** None
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 3
Maximum number of students: 30	

Additional notes and regulations:

Only for Matter to Life Students - Topic dependend in-person in Göttingen with Live stream in Heidelberg or the other way around

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1010: Quantitative Analysis of the Chemistry of Life**	6 C 4 WLH

Learning outcome, core skills: After successful completion of the module, students have a basic understanding of reaction mechanisms of classical synthetic chemistry. They are able to assess possible reactivities of individual chemical groups and thus set up reaction mechanisms of chemical transformations and have an idea of the experimental implementation of these reactions. They are able to assess and optimize stabilities, reactivities and selectivities.	**Workload:** Attendance time: 56 h Self-study time: 124 h

Course: Quantitative Analysis of the Chemistry of Life *Contents*: The course covers the fundamentals of organic and inorganic chemistry. In the inorganic-chemical part knowledge about metal ions in biological systems and therefore especially basic concepts of coordination chemistry with transition metals and lanthanides are taught, where thermodynamics and kinetics of complex formation play an important role. In the organic chemistry part, knowledge and mechanistic understanding of important organic reactions are taught. Not only basic organic reaction mechanisms but also bioinorganic topics are covered.	4 WLH
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination requirements:** basic understanding of structure and bonding, stability and reactivity and reaction mechanisms of organic and transition metal compounds.	6 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Franziska Thomas Peter Comba
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1
Maximum number of students: 30	

Additional notes and regulations: Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

Georg-August-Universität Göttingen Ruprecht-Karls-Universität Heidelberg Module M.MtL.1011: Bioengineering/Synthetic Biology	5 C 3 WLH
Learning outcome, core skills: Upon completion of the module, students will be able to analyze and design nucleic acid and protein structures, determine biophysical properties of such structures, estimate relevant scales, simulate the dynamic behavior of synthetic biological systems, and understand their function. Upon successful completion of the module, students have 1. a detailed understanding of quantitative aspects of gene expression and gene regulatory processes; 2. an overview of the main research directions within synthetic biology and the major related technologies; 3. the ability to apply their knowledge to design simple gene circuits themselves; 4. a very good understanding of nonlinear dynamics and dynamic systems in synthetic biological systems and the ability to independently analyze dynamical systems; 5. a good understanding of the role of stochastic processes in synthetic biology and key analytical methods. The students are able to analyze and simulate stochastic processes in the computer model; 6. the ability to assess and evaluate current developments in synthetic biology	**Workload:** Attendance time: 42 h Self-study time: 108 h
Course: Synthetic biology (Lecture) *Contents*: Areas of specialization in this course include biophysical and biochemical principles of synthetic biology, DNA nanotechnology, RNA and protein design, gene regulation and synthetic genetic circuits, description of biological dynamic systems, the use of cell-free systems, and the production of artificial cells. Students will have the opportunity to discuss and develop projects related to the application of nanotechnologies to living organisms and life-like systems. Students will be introduced to modeling biological systems and bioinformatics. The course also provides the foundation for describing and mastering bioengineering technologies for diagnosing and developing molecular systems with potential biomedical applications. Students will gain a focused overview of biomolecular principles and methods and computational design and analysis. Essential structural properties of biomolecules (proteins, peptides, nucleic acids) that underlie their wide structural and functional diversity in nature are discussed. Students will gain an overview of the fundamental concepts necessary to describe the effect of the structure and thermodynamics of these biomolecules on their stability, dynamics, and function. Students will also learn to analyze biological issues from the standpoint of systems theory and dynamical systems. They will gain insight into the fundamentals necessary to define and develop rational engineering strategies for bionanotechnology and synthetic biology.	2 WLH
Course: Synthetic Biology (Exercise)	1 WLH

Examination: Written Examination (120 minutes) or Oral Examination (approx. 25 minutes) **Examination requirements:** biomacromolecules, biological nanostructures, molecular machines and devices, chemical reaction networks, synthetic gene circuits, design of dynamic functions and behaviors, cell-free synthetic biology and artificial cells	5 C

Admission requirements: none	**Recommended previous knowledge:** Knowledge of molecular biology, biophysics, and mathematics is helpful.
Language: English	**Person responsible for module:** Prof. Dr. Eberhard Bodenschatz Prof. Dr. Friedrich Simmel (TU München)
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1
Maximum number of students: 30	

Additional notes and regulations: Distance Learning with live stream to Göttingen and Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1012: Biophysics and Physical Chemistry of Life**	8 C 6 WLH

Learning outcome, core skills: After successfully passing the module, students will have gained a basic understanding of advanced physical chemistry in the context of biological systems and will be able to describe the concepts of macromolecular structures and their interfacial chemistry. They will also be able to use concepts and methods of physical chemistry to propose possible research experiments to address cross-disciplinary research questions in the context of MtL.	**Workload:** Attendance time: 84 h Self-study time: 156 h

Course: Biophysics and Physical Chemistry of Life (Lecture) *Contents*: The course provides knowledge of physical chemistry as it relates to biological systems. It provides an introduction to advanced topics in the physical chemistry of life: biochemical thermodynamics, macromolecular structures, and interfacial chemistry. The course will include aspects of the physical chemistry of synthetic and natural macromolecules. Special attention will be given to the kinetics of synthetic polymerization reactions and biopolymer synthesis, and to inter- and intramolecular interactions between macromolecules, the molecular details and biological implications of which will be discussed. With respect to interfaces, a major aspect of this course is to illustrate the importance of interfacial processes in chemistry and in relation to chemical engineering, cell biology, materials science, and physics. Methods of surface modification, including specific functionalizations and strategies for patterning with emphasis on self-assembly processes will be presented. The characterization and role of possible intermolecular forces in interfacial interactions will also be addressed. All concepts already presented will be linked in a detailed discourse on exemplary biological interfaces, such as lipid vesicles with emphasis on their morphological complexity.	4 WLH
Examination: Written examination (120 min.) or oral examination (approx. 30 min.) **Examination requirements:** Basic understanding of physical and chemical principles governing biological systems at multiple scales. Ability to apply quantitative and theoretical methods for analyzing biomolecular structures, non-equilibrium processes, and self-organizing phenomena in living systems.	8 C

Course: Biophysics and Physical Chemistry of Life (Tutorial) in-person in Heidelberg and Göttingen	2 WLH

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Heike Böhm Tim Salditt
Course frequency:	**Duration:**

each winter semester	1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 4
Maximum number of students: 30	

Additional notes and regulations: Hybrid Learning - in-person and Live stream

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1013: Macromolecular Structures and Functions**	5 C 8 WLH
Learning outcome, core skills: Upon completion of the module, students will be able to describe diverse synthesis and analysis methods of natural and synthetic macromolecules and will have experience in the synthesis of macromolecules as well as microflow technology.	**Workload:** Attendance time: 112 h Self-study time: 38 h
Course: Macromolecular Structures and Functions (Lecture) *Contents*: The course focuses on the multiplicity and diversity of macromolecular structures and their respective functionalities. Technical knowledge of synthesis, structural characterization and construction of functional properties is provided. This bridges the research field of synthetic polymers and their structure-property relationships on the one hand, and the chemistry of biological macromolecules on the other. Biological macromolecules are considered as part of modern materials (for example, as a component of a hybrid material) and at the same time as a prime example of molecularly programmable, complex and adaptable superstructures. Structural entanglements are covered in detail, starting from monomer linkages, non-covalent bonds and couplings across a distance of multiple bonds (colloidal forces and entropic forces) to organization at the macromolecular and supramolecular level (spiral structures, globules and other nano-objects with a defined secondary, tertiary or quaternary structure). The course provides in-depth knowledge of the synthesis of macromolecules with emphasis on sequence control, molecular weight, and macromolecular sterochemistry: These include (i) controlled and living chain polymerization by various mechanisms (initiated by ions, group transfer, radicals, or a complex insertion as in metathesis, metallocene, and Ziegler polymerization reactions); (II) step-growth syntheses such as advanced polycondensation reactions (so-called low-band-gap polymers, chain-growth polycondensation, condensation or addition in water, fragment condensation), solid-phase synthesis, and cascade synthesis as in dendrimers. Specifically for biomacromolecules, enzymatic methods for protein and nucleic acid production (PCR, rolling circle amplification, expressed protein ligation) and biotechnological syntheses (recombinant protein expression) are covered. The course provides important knowledge on methods for microfluidic encapsulation of nucleic acids for in vivo applications. The focus will be on silencing RNA (siRNA) as an important tool of RNA interference as well as induction of protein expression by messenger RNA (mRNA). There will also be a focus on teaching methods that allow conjugation of biological with synthetic building blocks (click chemistry reactions). A second focus will be on structure-property relationships related to molecular self-assembly in aqueous solutions, such as helical structures, protein chain folding, and nucleic acid structures (A-, B-, Z-DNA). It also teaches the next higher level of organization, globule and micelle formation, as well as the formation of structured networks by covalent and reversible gelation processes, and the self-assembly of block copolymers from more	4 WLH

than two block polymers. In addition to thermodynamic control, other ways to regulate self-assembly will be shown, including kinetic control and control by non-covalent chemistry, such as the interplay between covalent and non-covalent chemistry through reversible grouping, hydrophobic interactions, and directed formation of reversible bonds. In addition, the course addresses physical characterization methods necessary for monitoring synthesis at all structural levels, starting from NMR methods, optical spectroscopy and vibrational spectroscopy, to fluorescence methods such as FRET, to characterization of particle size and shape by scattering techniques and advanced microscopy methods (cryo-SEM and -TEM, scanning probe microscopy and advanced optical microscopy).	
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination prerequisites:** Active participation in the lab course **Examination requirements:** Basic understanding of synthesis and analysis methods of natural and synthetic macromolecules and the synthesis of macromolecules.	5 C

Course: Macromolecular Structures and Functions (Internship)	4 WLH

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Andreas Herrmann
Course frequency: each summer semester1	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 15	

Additional notes and regulations:

Lecture: Live stream in Heidelberg and Göttingen

Internship: in-person in Aachen at DWI

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1014: Bioconjugation & Imaging Chemistry**	3 C 2 WLH
Learning outcome, core skills: Upon successful completion of the module, students will have a basic understanding of the preparation and characterization of bioconjugates and their application as sensors and activators in biological systems for quantitative analysis of biological processes.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: Bioconjugation & Imaging Chemistry (Lecture) *Contents*: The course deals with different types of molecular elements associated with biological vectors, where the biological vectors ensure that the elements are transported to specific cells (e.g. selective labeling of tumor cells for imaging or therapy; vectors: peptides, antibodies, antigens, nanoparticles). Molecular elements include optical, magnetic, and radiochemical probes. The synthesis of molecular elements and methods for binding the elements to biological vectors are outlined. Emphasis is placed on the fundamental principles of various probes (e.g., on/off optical sensors; paramagnetic probes in MRI imaging and structure determination of proteins in cells; radiopharmaceutical imaging and therapy). Many of these systems consist of ions of main group, transition, and rare earth metals. The basic principles of metal ion selectivity, prevention of transmetallation (chemical inertia under physiological conditions) are discussed, and emphasis is placed on the fundamental theory of metal-based systems with respect to sensors and activators.	2 WLH
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination requirements:** Basic understanding of the preparation and characterization of bioconjugates and their application as sensors and activators in biological systems for quantitative analysis of biological processes.	3 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Peter Comba
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations:
Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1015: Genome Engineering**	4 C 4 WLH
Learning outcome, core skills: After successful completion of the module, students will have a basic understanding of genome engineering and will be able to critically read and evaluate publications in this field. They are able to apply methods for genome engineering.	**Workload:** Attendance time: 56 h Self-study time: 64 h
Course: Genome Engineering (Lecture) *Contents*: The Genome Engineering course provides an overview of the background and application of genomic technologies for reading and writing genomes as the basis of synthetic biology. The course includes an introduction to basic nucleic acid chemistry and function of DNA, as well as structural and functional aspects of genes and genome biology. Additional topics include: How is information encoded in the genome, methods for genome sequencing, and recent findings that enable whole genome sequencing and assembly. Methods for manipulating DNA will be presented, including DNA synthesis and the use of enzymatic methods for genetic engineering of simple and complex genomes. The course covers and discusses recent method developments in genome engineering, the discovery and development of CRISPR/Cas, its technologically generated versions that allow knockout of genes in genomes, site-specific insertion of mutations, and replacement of whole genes or chromosome segments. Also covered will be the application of genome engineering in biotechnology, diagnostics, and therapeutics, as well as in cell and tissue engineering and future applications of synthetic genomes. Classic publications of important discoveries as well as recent developments in genome engineering will be discussed. Also discussed will be ethical, legal, and societal implications of genome engineering. The module consists of lectures by various faculty members, as well as inverted classroom sessions focusing on case studies that present examples from the most current literature and actual faculty research. Students will receive the case studies prior to class. Students study the materials and are encouraged to propose experimental or theoretical strategies to address the issues. Together and in tutorials, questions raised are discussed and answered. Students apply what they have learned in a capstone project in which they independently complete a research project.	2 WLH
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination prerequisites:** Regular participation in the lab course and report for the lab course (max. 20 pages) **Examination requirements:** Basic understanding of genome engineering and associated methods.	4 C
Course: Genome Engineering (Internship)	2 WLH

Admission requirements:	**Recommended previous knowledge:**

none	none
Language: English	**Person responsible for module:** Michael Boutros
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations:

Lecture: Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

Internship: in-person in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1016: Chemical Biology**	4 C 2 WLH

Learning outcome, core skills: Graduates of the module will be able to select and apply tools from chemistry, cell biology and biophysics to investigate issues at the molecular level.	**Workload:** Attendance time: 28 h Self-study time: 92 h

Course: Chemical Biology (Lecture) *Contents*: Chemical biology could also be described as the application of chemistry to the study of living systems in situ. Here, the goal is to develop tools to manipulate biological phenotypes and to visualize and quantify biochemical activities in vivo. Through discussion of a selection of important publications, the course provides an introduction to current chemical biology. The publications describe technologies or approaches that represent a conceptual advance, enabling the exploration of a biological question that could not be addressed using more traditional approaches. Since chemical biology is still a relatively young and dynamic field, the publications to be discussed will be adjusted from year to year. The following topics will be discussed in the course: (i) synthetic and genetically encoded probes; (ii) chemical biology of kinases; (iii) chemical labeling of proteins; (iv) semisynthesis of proteins; (v) genetic code expansion and artificial amino acids; (vi) chemical optogenetics; (vii) chemical genetics; (viii) targeted deconvolution of bioactive molecules; (ix) activity-based protein analysis; (x) fluorescent probes. The course requires that students read the underlying publications prior to class in order to participate in discussion.	2 WLH
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination requirements:** Basic knowledge of tools from chemistry, cell biology and biophysics to investigate issues at the molecular level.	4 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Kai Johnsson Richard Wombacher
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations:
In-person in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1017: GlycoSciences**	3 C 2 WLH
Learning outcome, core skills: Upon successful completion of the module, students will have a basic understanding of the importance of sugars for interdisciplinary research. They are able to pose scientific questions and describe their research interests, place them in the context of current literature and present them.	**Workload:** Attendance time: 28 h Self-study time: 62 h
Course: GlycoSciences (Seminar) *Contents*: This course is focused on the multidisciplinary field of sugar research. The course looks at the latest developments and cutting edge research on a specific topic in the field. In the first session, the group selects a specific research question to explore theoretically. The seminar provides students with the opportunity to work together to acquire literature knowledge, formulate research questions, and draft various parts of a research proposal.	2 WLH
Examination: Essays or oral presentation **Examination requirements:** Basic understanding of the importance of sugars for interdisciplinary research	3 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Heike Böhm
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations: interactive presentations, independent literature search. Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1018: Biofabrication & Tissue Engineering**	3 C 3 WLH
Learning outcome, core skills: After successfully passing the module, the students will have obtained a fundamental understanding of the principles of biofabrication in vitro and in situ with focus on tissue engineering applications, and will be knowledgeable on which materials and cell types are the most suitable for different medical applications. They will be able to apply biofabrication and 3D cell culture techniques.	**Workload:** Attendance time: 42 h Self-study time: 48 h

Course: Biofabrication & Tissue Engineering (Lecture) *Contents*: The *Biofabrication & Tissue Engineering* course will provide an overview of modern biofabrication technologies used to design and fabricate engineered tissues in vitro and in situ. The course will introduce nozzle-based biofabrication methods, such as extrusion and inkjet printing, as well as nozzle-free methods like volumetric printing. The course will cover the use of natural and synthetic materials as inks used in biofabrication, and discuss their advantages and disadvantages. The course will also cover the basics of 3D cell culture and its demands for different medical applications. The first 4 lectures of the course will provide the students with the basics on the topics of biofabrication and tissue engineering, whereas the lectures 5-8 will be given in the inverted classroom format. In the inverted classroom lecture, the students will have the opportunity to discuss state-of-the-art scientific articles of the most recent discoveries in the field of biofabrication. Practical training in the last part of the course (week 9 -12) will include handling of various hydrogels and printing using different techniques, as well as cell culture and bioprinting with cells.	2 WLH

Course: Biofabrication & Tissue Engineering (Internship)	1 WLH
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination prerequisites:** Regular participation in the lab course and report for the lab course (max. 20 pages) **Examination requirements:** Basic understanding of the principles of biofabrication in vitro and in situ with focus on tissue engineering applications, and knowledgeable on which materials and cell types are the most suitable for different medical applications.	3 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Daniela Duarte Campos
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted:	**Recommended semester:**

twice	2
Maximum number of students: 30	

Additional notes and regulations:

Lecture partially in the inverted classroom and Practical training. Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

Internship: in-person in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1019: Data Science & Simulations**	3 C 2 WLH

Learning outcome, core skills: Upon completion of the course, students will be able to select adequate computational techniques and apply appropriate computational models and algorithms to complex biological problems and assess the range of validity of each.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Data Science & Simulations (Lecture) *Contents*: The course covers computational methods for solving biological problems and designing synthetic life-like systems at various scales. The methods include physics-based approaches such as particle-based atomistic and mesoscopic simulations, as well as techniques in data-driven bioinformatics and machine learning. Physics-based approaches include recent advances in Monte Carlo, molecular dynamics, and Brownian dynamics simulations, as well as kinetic modeling. The course teaches data-driven techniques for analyzing next generation sequencing experiments, including transcriptome and single cell analysis. The overarching focus is on multi-scale approaches that bridge the molecular with the mesoscopic and ultimately the macroscopic scale. Topics are guided by examples from current research advances and challenges from recent literature or faculty research. For each case study topic dealing with a specific subset of computational techniques, the relevant physical, chemical, or mathematical principles are discussed. Explanatory material on the case study, relevant background, and a code or software example will be distributed prior to class. Practical applications in a computer laboratory complement the lectures. In the practical part, depending on the complexity of the computer-based method, (pseudo) code examples are developed in class or supplemented with critical components. Scientific software is also used in practical exercises to solve the case study problem. The range and possible pitfalls of the applied methods are critically examined.	1 WLH
Course: Data Science & Simulations (Exercise) Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen	1 WLH
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination requirements:** Basic understanding of adequate computational techniques and appropriate computational models and algorithms to complex biological problems.	3 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Michael Boutros Frauke Gräter

Course frequency: every 4th semester1	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 1 - 3
Maximum number of students: 30	

Additional notes and regulations: Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

<table>
<tr><td>Georg-August-Universität Göttingen
Ruprecht-Karls-Universität Heidelberg
Module M.MtL.1020: Methods of quantitative analysis</td><td>3 C
2 WLH</td></tr>
</table>

Learning outcome, core skills: After successful completion of the module, students have a basic understanding of analytical methods in the natural sciences. They are able to formulate scientific hypotheses and plan experiments to validate the results, taking into account reproducibility and statistical significance. They are able to critically read and evaluate analytical methods in publications.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Methods of quantitative analysis (Lecture) *Contents*: The course covers modern analytical methods for the study of molecular structures. The importance of combining methods to cover all size scales of the object of study (from the molecular level to the mesoscopic level) to validate research hypotheses will be illustrated with examples from recent literature. The need to create reproducible and statistically significant data sets will be highlighted and discussed in the context of previous and current relevant literature. Through discussions of the use of high-resolution optical microscopy (e.g., STED microscopy) and electron microscopy for the study of biological systems, students will gain a detailed understanding of the complementary uses, as well as the advantages and disadvantages, of using light and electrons to study biological systems. The analytical capabilities of tunable high-energy radiation sources (synchrotron radiation and X-ray lasers), which combine imaging techniques with spectroscopic methods for chemical composition analysis, will be presented. As physical phenomena, diffraction and scattering are the fundamental principles of physical optics and thus relevant to interactions between acoustic and electromagnetic waves with molecules and particles. The physical principles of these phenomena will be taught and knowledge of basic and modern diffraction and scattering technologies will be reinforced in practical experiments. The module will also cover the theoretical background and methods for measuring the dynamics and kinetics of biomolecular reactions and time-dependent processes in living systems. The operation of lasers and their special role in modern biological research will be introduced. Various laser spectroscopy and scattering technologies will be discussed theoretically and demonstrated practically, with a focus on time-dependent processes. The methods and underlying theory of measuring fast and slow kinetics in biomolecular reactions will be discussed using examples from the literature. We will cover the formal kinetic description of fast chemical and biomolecular reactions (enzyme kinetics), as well as the statistical tools for studying diffusion and convection experimental data and the experimental implementation of kinetic measurements from stopped-flow to pump-probe experiments. Again, the need to create reproducible and statistically significant data sets and discuss results in the context of the literature will be emphasized.	1 WLH
Course: Methods of quantitative analysis (Practical course)	1 WLH
Examination: Written examination (120 min) or oral examination (approx 30 min)	3 C

Examination prerequisites: Regular participation in the lab course and report for the lab course (max. 20 pages) **Examination requirements:** Basic understanding of analytical methods in the natural sciences.	

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Hans-Robert Volpp
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations:

Lecture: Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

Internship: in-person in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1021: Synthetic Cells & Virology**	4 C 4 WLH
Learning outcome, core skills: Upon successful completion of the module, students will have an understanding of the synthesis and analysis of synthetic viruses and viral substructures (e.g., capsid shells and/or viral replication systems); they will also have state-of-the-art knowledge of synthesis tools and technologies for the production of such materials. They are able to design experiments for hierarchical assemblies of molecular and nanoscopic entities as the basis of life-like materials.	**Workload:** Attendance time: 56 h Self-study time: 64 h
Course: Synthetic Cells & Virology (Lecture) *Contents*: The course covers physical and chemical methods from the field of modern synthetic biology for the design and construction of synthetic viruses with desired functions and for the development of synthetic cells and tissues with lifelike properties. Cutting-edge research topics serve as a guiding thread and discussion throughout the course. In particular, these include modern methods of biofunctionalization as well as methods from the fields of microfluidics and protein engineering for the fabrication of lifelike machines, cells, and tissues. The course deals with modern technologies based on light and microfluidics which regulate self-assembly processes in the construction of lifelike compartments. Immunology, virology, and especially new synthetic biology approaches in these disciplines are among the greatest challenges in biomedical research today. At the same time, viruses are among the smallest biological objects with the ability to self-replicate in a more complex environment. This makes the construction of viruses and viral vectors with desired properties particularly promising, a reason why these methods are now used in applied biomedical research. The fact that viruses are foreign to their host has been instrumental in the discovery of a number of cellular processes and appears to be an optimal property for the construction of artificial cell-like systems that support their replication. The study of viral interactions with host cells and the immune system provides a variety of examples of situations in which quantitative, interdisciplinary approaches with extensive involvement of physics, chemistry, and technology have led to breakthrough technical advances in biomedical and clinical applications. Our approach aims at intervening in the life cycle of cells using molecular or nanoscopic systems, or even artificially engineered cells and viruses. This module will provide an overview of the most challenging and current research examples and will provide the chemical, physical, molecular biological and biochemical basis to describe research examples in synthetic virology. Theoretical knowledge will be complemented by hands-on experience in laboratory practicals, for example in microfluidics, viral vector development, or DARPin technology. The module will consist of lectures based on the concept of the inverted classroom teaching/learning method and will focus on "case studies" - in the sense of examples from the current literature or examples from the teacher's own research. Students	2 WLH

will engage with teaching materials, which will be handed out to them well in advance of the course in preparation for discussion, and will be encouraged to develop and present experimental and/or theoretical approaches to the problem. Subsequent course meetings and exercises will be used to discuss issues, deepen expertise, and develop research strategies, which can in turn be tested in exercises and laboratory practicals. Furthermore, the relationship between living and non-living matter will be part of the course material. In addition, students will be instructed in the design and construction of chimeric antigen receptors (CARs, also known as chimeric immunoreceptors) for use as engineered receptors to graft any specificity onto immune cells (T cells). These types of receptors are currently being tested in clinical trials for use against specific diseases.	
Examination: Written examination (120 min) or oral examination (approx 30 min) **Examination prerequisites:** Regular participation in the lab course and report for the lab course (max. 20 pages) **Examination requirements:** Basic understanding of the synthesis and analysis of synthetic viruses and viral substructures as well as state-of-the-art knowledge of synthesis tools and technologies for the production of such materials. Ability to design experiments for hierarchical assemblies of molecular and nanoscopic entities as the basis of life-like materials.	4 C

Course: Synthetic Cells & Virology (Internship)	2 WLH

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Heike Böhm Joachim Spatz
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations: Lecture: Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen Internship: in-person in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1022: Supramolecular Chemistry**	5 C 4 WLH
Learning outcome, core skills: After successful participation in this course, the student will be able to: - Recall and understand the non-covalent interactions between molecules. - Recall and understand the thermodynamic driving force involved in assembly of supramolecular structures. - Molecularly design an amphiphile - Molecular design a self-assembly peptides - Molecularly design liquid crystals - Recall functions of self-assembled structures - Recall mechanisms involved in molecular machines.	**Workload:** Attendance time: 56 h Self-study time: 94 h
Course: Supramolecular Structure (Lecture) *Contents*: This course gives an overview of supramolecular chemistry, self- assembly of molecules, supramolecular materials and molecular machines. It is divided into 12 regular lectures (listed below) and three slots where students present their case studies. The lectures: 1. An introduction to Supramolecular Chemistry, Self-assembly, Supramolecular Materials and Molecular Machines. 2. Molecular non-covalent interactions 3. The thermodynamics of self-assembly 4. Catenanes, rotaxanes and knots 5. An introduction into the self-assembly of molecules 6. The self-assembly of amphiphiles 7. The self-assembly of peptides and proteins 8. The self-assembly of liquid crystals 9. Non-equilibrium self-assembly: energy landscapes of self-assembly 10. Supramolecular Materials: self-assembly into structures with function 11. Supramolecular Materials: self-assembled hydrogels 12. Supramolecular materials: liquid crystals. Teaching and learning methods: The module consists of a lecture and an exercise. After teaching the basics of supramolecular, non covalent interactions the topics are deepened on specific examples such as Amphiphiles, Peptides and Liquid Crystals. Thematic blocks on Non- Equilibrium self-assembly, self-assembly hydrogels and molecular machines complete the topics. The gradual structure should consolidate the learning experience. The contents of the lecture are conveyed through presentations. In addition, the students should work through relevant textbook chapters, which may	4 WLH

also be supplemented by further literature, e.g. selected journal articles. As part of the exercises, specific questions are answered and selected examples are worked on. This allows the students to deepen and work on topics and facts from the preliminary lecture.	
Examination: Written examination at the end of the course (70%; 90 min); Oral presentation during the course (30%) **Examination requirements:** In this exam, students should be able to show that they can distinguish between supramolecular polymers and classical polymers. They are able to name the unique properties of a supramolecular polymer and compare the advantages and disadvantages of these polymers. Students can describe possible polymerization mechanisms using examples. They are able to give examples of non-equilibrium self-assemblies, self-assembly hydrogels and molecular machines and to distinguish between them. Tasks are set that have to be answered using self-formulated texts, as well as multiple-choice tasks.	5 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Job Boekhoven
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 20	

Additional notes and regulations:
Distance Learning with live stream to Göttingen and Heidelberg. Depending on number of participants lecturer will come on site for 1-2 lectures.

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1023: Theoretical Biophysics**	6 C 6 WLH
Learning outcome, core skills: After successful finishing of the module • the students will have advanced knowledge of theoretical biophysics, • the students will have practical experience with theoretical calculations of bio-systems.	**Workload:** Attendance time: 84 h Self-study time: 96 h
Course: Theoretical Biophysics (Lecture) *Contents*: • Macromolecules - General properties of macromolecules: Freely jointed chain, the Gaussian chain model, elastic rod model, self avoiding chains, conformations and energy landscapes, macromolecules in solution, macromolecules at a surface - Intermolecular interactions and electrostatic screening - Helix-Coil transition - DNA melting -Polyelectrolytes: The Poisson-Boltzmann equation - Proteins: Protein folding numerical approaches, folding as a spin glass problem, protein-protein interactions - Chromatin: Chromatin models, force-extension behaviour of folded macromolecules - Genes: Gene expression and genetic code • Membranes - Self–assembly of micelles - Surface behaviour of lipids: differential geometry of surfaces, membrane elasticity and bending energy, membrane fluctuations - Structure of Lipids -Cell Membranes • Transport - Diffusion - Polymer dynamics: Rouse Model, hydrodynamic interactions • Networks - Gels - Metabolic Networks: Boolean networks, scale-free networks, robustness of networks • Molecular Motors - Polymerization of cell filaments - Brownian ratchet - A basic model of a molecular motor	4 WLH

• Statistical Analysis - Bayesian Analysis - Monte Carlo Methods - Hidden Markov Models	
Examination: Oral exam (approx. 30 min) **Examination requirements:** Basic understanding of general properties of macromolecules, intermolecular interactions, protein approaches and Chromatin models, polymer dynamics, metabolic networks, molecular motors and statistical analysis.	6 C

Course: Theoretical Biophysics Exercise (Exercise) *Contents*: Practical experience with theoretical calculations of bio-systems. Exercises with homework.	2 WLH

Admission requirements: none	**Recommended previous knowledge:** • basics of classical mechanics, electrodynamics and statistical mechanics
Language: English	**Person responsible for module:** Ulrich Schwarz
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 20	

Additional notes and regulations: Hybrid Learning - in-person in Heidelberg with Live stream in Göttingen

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1025: Spectroscopy of Biomolecules**	6 C 7 WLH
Learning outcome, core skills: Molecular Biochemistry and Biophysics of different classes of biomolecules, modern biophysical methods for analysis of biomolecules. Work with state of the art equipment, critical review of current topics in biochemistry, detailed analysis of experiments and corresponding presentation, independent acquisition of expert knowhow from publications.	**Workload:** Attendance time: 98 h Self-study time: 82 h
Course: Spectroscopy of Biomolecules (Lecture) *Contents*: Spectroscopy of biomolecules (fluorescence, FT-IR, CD, UV/Vis), modern microscopic methods (optical microscopy, scanning probe microscopy), functional analysis of different classes of biomolecules.	1,5 WLH
Course: Spectroscopy of Biomolecules (Tutorial)	0,5 WLH
Course: Methods course: Spectroscopy of Biomolecules (Internship)	5 WLH
Examination: Oral examination (approx. 30 minutes) **Examination prerequisites:** Regular participation in the lab course and report for the lab course (max. 20 pages) **Examination requirements:** Basics in modern analysis methods used for biomolecules	6 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: German, English	**Person responsible for module:** Prof. Dr. Claudia Steinem
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations: in-person in Göttingen

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1103: Remote Laboratory Work**	3 C 1 WLH
Learning outcome, core skills: An introduction to laboratory experiments performed remotely. Students will collaborate to operate a research microscope in person and remotely. They will collect data, analyse the resultant images and report their results. By the end of the module students will: Be familiar with the workings of a research microscope Understand and be compentent in using video particle tracking and image analysis Develop a data analysis pipeline Be able to collaborate in remote teams	**Workload:** Attendance time: 14 h Self-study time: 76 h
Course: Remote Laboratory Work (Practical course)	
Examination: Written Report (max. 10 pages) **Examination requirements:** A written report demonstrating the successful use of advanced experimental methods to analyse systems relevant to Matter to Life.	3 C

Admission requirements: none	**Recommended previous knowledge:**
Language: English	**Person responsible for module:** Prof. Dr. Sarah Köster
Course frequency: each semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 2
Maximum number of students: 10	

Additional notes and regulations: Hybrid Learning - in-person in Göttingen and remote in Heidelberg

Georg-August-Universität Göttingen Ruprecht-Karls-Universität Heidelberg Module M.MtL.1106: Matter to Life Internship	6 C 6 WLH
Learning outcome, core skills: After successful completion of the module, students should be competant to work within a research group on a topic related to matter to life. The students should independently familiarise themselves with the group's research topic and be able to perform research under supervision and as part of a team. The results of this work should be presented as a talk or poster.	**Workload:** Attendance time: 84 h Self-study time: 96 h
Course: Matter to Life Internship (Internship)	6 WLH
Examination: Poster presentation or oral presentation (30 minutes) **Examination prerequisites:** Regular participation in the lab course and report for the lab course (max. 20 pages) **Examination requirements:** Familiarity with and ability to apply advanced techniques to address research questions related to matter to life.	6 C

Admission requirements: This module can be selected only on the recommendation of a lecturer.	**Recommended previous knowledge:** None
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp
Course frequency: each semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 2
Maximum number of students: not limited	

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1107: Lab Rotation**	30 C 40 WLH
Learning outcome, core skills: Students will work on two connected scientific research projects and be familiarized with advanced topics in the field of Matter to Life. They will learn to successfully perform a sub-task within larger research projects and finally present the results to a professional audience. Students will be able to organize, conduct, evaluate and present small, manageable projects in the field of Matter to Life, obeying the rules of good scientific practice.	**Workload:** Attendance time: 560 h Self-study time: 340 h
Course: Lab Rotation (Practical course)	38 WLH
Examination: Written report (max. 20 pages) **Examination requirements:** Methods for in-depth familiarization in a scientific field of work, critical review of literature, scientific presentation, good scientific practice.	28 C
Course: Results of the Research Projects (Key competence) *Contents*: The specific skills practiced in the seminar include efficient and concise presentation of own scientific results in English, development of a differentiated scientific vocabulary, and the critical discussion of the scientific data in the broader context of their relevance for current research.	2 WLH
Examination: Oral presentation (approx. 20 min), not graded **Examination requirements:** Demonstration of adequate oral presentation skills including the critical discussion and evaluation of the data presented.	2 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 3
Maximum number of students: 30	

Additional notes and regulations: Only for Matter to Life Students

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1201: Ethics in Synthetic Biology**	3 C 2 WLH

Learning outcome, core skills: Upon successful completion of the module, students will have a basic understanding of relevant ethical issues in Synthetic Biology. They will be able to explain and discuss ethical difficulties within the discipline as well as to interested laypersons and contribute to the social discourse on these topics.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Ethics in Synthetic Biology (Key competence)	2 WLH
Examination: Written examination (120 minutes) **Examination requirements:** biosafety; dual-use research; cultural concepts of natural and artificial, living and non-living; economic aspects of synthetic biology, patentability; mechanisms of participation and societal decision-making related to synthetic biology	3 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Thorsten Moos Nils Schütz
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 1
Maximum number of students: 30	

Additional notes and regulations: Distance Learning or in-person in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1202: Professional Skills in Science**	3 C 2 WLH

Learning outcome, core skills: The students will be trained in scientific writing and oral presentation skills which will enable them to adequately structure and compose scientific texts, particularly for written and oral reports on experimental and theoretical findings in the field of their studies. They will be introduced to the principles of good scientific practice and measures required to secure ethical standards in science. In addition, the students will gain an understanding of laboratory safety principles and knowledge of measures and procedures to work safely in a research laboratory.. Other topics covered include intellectual property, commercialisation of ideas and critical evaluation of the scientific literature.	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Professional skills in science (Key competence)	2 WLH
Examination: Oral presentation (approx. 30 min.), not graded **Examination requirements:** Demonstration of writing competence, oral presentation skills, lab safety rules and regulations in a scientific context in the English language at an advanced level.	3 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp Köster, Sarah, Prof. Dr.
Course frequency: once a year	**Duration:** 2 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** Master: 1 - 2
Maximum number of students: 30	

Additional notes and regulations: Distance Learning

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1301: Methods and Topics from Matter to Life**	10 C 4 WLH
Learning outcome, core skills: Learning outcomes Students will extend their knowledge in the physics of complex systems and biophysics through the study of selected advanced topics. The emphasis is on connecting textbook-level knowledge with current research though a combination of introductory presentations by the lecturer(s), student presentations, self-study and scientific group discussions. Students will learn and practise applying the concepts from the introductory lectures on biophysics and physics of complex systems to specific problems in the physics of living systems and to critically assess current scientific literature. Core skills: Critical evaluation of the scientific literature, scientific discussion and debate, presentation and communication skills, application of previous knowledge in unfamiliar contexts.	**Workload:** Attendance time: 56 h Self-study time: 244 h
Course: Methods and Topics from Matter to Life (Lecture, Seminar)	4 WLH
Examination: Oral examination (approx. 45 minutes) **Examination prerequisites:** Presentation (approx. 20 min.) **Examination requirements:** In the final oral examination, the students demonstrate their broad knowledge of biophysics and the physics of complex systems. They should show that they recognize the interrelationships between these areas and that they can place specific scientific questions within the context of these relationships.	10 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp Prof. Dr. Eberhard Bodenschatz
Course frequency: each summer semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 2
Maximum number of students: 30	

Additional notes and regulations: Hybrid Learning - in-person in Göttingen with Live stream in Heidelberg

Georg-August-Universität Göttingen **Ruprecht-Karls-Universität Heidelberg** **Module M.MtL.1406: Research seminar Matter to Life**	4 C 2 WLH
Learning outcome, core skills: After successful completion of the module, students should present complex lines of reasoning and evaluate own and others' presentations in critical discussion.	**Workload:** Attendance time: 28 h Self-study time: 92 h
Course: Research seminar Matter to Life (Seminar)	2 WLH
Examination: Oral Presentation (approx. 60 minutes) **Examination prerequisites:** regular participation **Examination requirements:** Preparation of complex topics for presentation and scientific discussions.	4 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English	**Person responsible for module:** Prof. Dr. Stefan Klumpp
Course frequency: every 4th semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: twice	**Recommended semester:** 1 - 3
Maximum number of students: 15	

Additional notes and regulations:
Only for Matter to Life Students - Topic dependend in-person in Göttingen with Live stream in Heidelberg or the other way around

Georg-August-Universität Göttingen **Module M.Phy.1401: Advanced Lab Course I**	6 C 6 WLH
Learning outcome, core skills: After successful completion of the module, students have • familiarised themselves independently with complex issues, • performed experimental tasks under guidance in a team, • and have written scientific protocols within good scientific practice.	**Workload:** Attendance time: 84 h Self-study time: 96 h

Course: Advanced Lab Course I	
Examination: Oral examination (approx. 30 minutes) **Examination prerequisites:** 4 successful performed experiments. **Examination requirements:** Advanced experimental methods for solving physical problems.	6 C

Admission requirements: none	**Recommended previous knowledge:** none
Language: English, German	**Person responsible for module:** StudiendekanIn der Fakultät für Physik
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** 1
Maximum number of students: not limited	

Georg-August-Universität Göttingen **Module M.Phy.1404: Methods of Computational Physics**	6 C 6 WLH

Learning outcome, core skills: After successful completion of the module students will be familiar with the key methods and algorithms of computational physics. Students will be able to select and deploy appropriate computational approaches in order to model and analyse a range of classical and quantum systems.	**Workload:** Attendance time: 84 h Self-study time: 96 h

Course: Computational lab course	2 WLH

Course: Methods of Computational Physics (Lecture)	4 WLH
Examination: written (120 min.) or oral exam (approx. 30 min.) **Examination prerequisites:** Successful completion of 5 computational projects **Examination requirements:** Projects may include: Monte Carlo for phase transitions, rare event simulations, exact numerics for quantum systems, quantum Monte Carlo, simulations of disordered/glassy systems.	6 C

Admission requirements: none	**Recommended previous knowledge:** Basic knowledge of equilibrium statistical mechanics and 1-particle quantum mechanics.
Language: English, German	**Person responsible for module:** Prof. Dr. Fabian Heidrich-Meisner
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** 1 - 3
Maximum number of students: 30	

Georg-August-Universität Göttingen Module M.Phy.1405: Advanced Computational Physics	6 C 6 WLH
Learning outcome, core skills: After successful completion of the module students should be familiar with the complete project cycle of advanced computational physics work. Students will be able to build and refine appropriate models for solutions of specific physical problems, select and implement advanced computational approaches using both existing software and own codes, and analyse the resulting data.	**Workload:** Attendance time: 84 h Self-study time: 96 h
Course: Computational lab course	
Examination: Oral examination (approx. 30 minutes) **Examination prerequisites:** Successful completion of 3 problem-driven computational projects (50% of the achievable score in each project) **Examination requirements:** Projects may include: Monte Carlo for phase transitions, rare event simulations, exact numerics for quantum systems, quantum Monte Carlo, simulations of disordered/glassy systems.	6 C

Admission requirements: none	**Recommended previous knowledge:** • *Methods of Computational Physics* • *Advanced Statistical Physics* • *Advanced Quantum Mechanics*
Language: English, German	**Person responsible for module:** Prof. Dr. Marcus Müller
Course frequency: each semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** 2
Maximum number of students: 30	

Georg-August-Universität Göttingen **Module M.Phy.5610: X-ray Tomography for Students of Physics and Mathematics**	3 C 2 WLH

Learning outcome, core skills: Knowledge in: • Principles of Radiography and Tomography • Radiation Safety / Reconstruction Algorithms and practical Implementation of algorithms, testing of algorithms, cone beam reconstruction • phase retrieval and phase contrast • treatment of artefacts, filters • quantitative assessment of image quality • image segmentation Taking the course students will be able to : • operate laboratory equipment, perform tomographic alignment and to setup tomographic scans • to reconstruct data based on Matlab toolbox (Salditt Group) • to analyse data, perform segmentation	**Workload:** Attendance time: 28 h Self-study time: 62 h

Course: Course: X-ray Tomography *Contents*: • one week self-study in preparation based on tutorials and the textbook by Salditt/ Aspelmeier /Aeffner (De Gruyter 2017), a full one week course with • morning lectures including Matlab tutorials • afternoon tomography practice in the laboratory using three different instruments (liquid metal jet, rotating anode, high energy), • overnight scans • Matlab-based reconstruction (Server IRP, Toolbox Salditt Group)	
Examination: Oral examination (approx. 45 minutes) **Examination requirements:** • Presentation of a successful scan and reconstruction, • oral discussion of the data and analysis	3 C

Admission requirements: none	**Recommended previous knowledge:** Electrodynamics, Matlab/Python
Language: English	**Person responsible for module:** Prof. Dr. Tim Salditt
Course frequency: each winter semester	**Duration:** 1 semester[s]
Number of repeat examinations permitted: three times	**Recommended semester:** 1 - 4
Maximum number of students:	

15	

Additional notes and regulations:

1 week in October before start of lectures.

Partial overlap with Physicists’ tomography course.