Modulhandbuch Studiengang Master Biochemie

Studienplan für den Master-Studiengang Biochemie

Der folgende Studienplan gilt in Verbindung mit der Prüfungsordnung des Master-Studiengangs Biochemie der Fakultät für Chemie und Biochemie.

1. Die Gliederung des Studienplans beruht auf dem Studienjahr mit Studienbeginn im Wintersemester.
2. Es wird empfohlen, die Lehrveranstaltungen in der angegebenen Reihenfolge zu besuchen. Für einzelne Praktika ist die erfolgreiche Teilnahme an vorhergehenden Lehrveranstaltungen entsprechend Abs. 3 erforderlich.
3. Die Zulassung zu den nachstehend genannten Praktika ist abhängig vom Vorliegen eines Leistungsnachweises für im Ausbildungsgang vorhergehende Lehrveranstaltungen (Vorleistungen) gemäß folgender Zusammenstellung:

Lehrveranstaltung	Vorleistung
Strahlenschutz im Radionuklid-Labor	Praktische Erfahrungen im Umgang mit Radioisotopen in einem vorangegangenen Praktikum
Spezialisierung	Modulpraktika Biochemie und Schwerpunktpraktikum
Master-Arbeit	Spezialisierung

4. Kennzeichnung der Lehrveranstaltungen

Pf	=	Pflichtveranstaltung
W	=	Wahlpflichtveranstaltung
CP	=	Kreditpunkte für den jeweiligen Leistungsnachweis

5. Schwerpunktprogramme

- Biochemie des Nervensystems,
- Biomolekulare Chemie,
- Proteine: Struktur und biologische Funktion,
- Molekulare Biologie und Biotechnologie der Pflanzen und Mikroorganismen,
- Molekulare Medizin
- Molekulare Biochemie der Stammzellen

6. Die Spezialvorlesungen aus dem Themenbereich der Schwerpunktausbildung müssen sich von denen aus dem Bachelor-Studiengang unterscheiden.

7. Wahlfreiheit

   Wahlpflichtveranstaltungen können frei aus dem gesamten Lehrangebot bzw. den Schwerpunktprogrammen für den Master-Studiengang der beteiligten Fakultäten gewählt werden.

Sem.	Modul	V	Ü/S	Pr	Typ	CP
1. (WS)	Biochemisches Seminar	-	2	-	Pf	3
	Bioinformatik	2	1	-	Pf	5
	Strahlenschutz im Radionuklid-Labor	2	1	-	Pf	5
	Modulpraktika Biochemie der Schwerpunkte	-	3	18	W	4 x 4
29 SWS	Summe: 1. Semester	4	7	18		29
2. (SS)	Biochemie IV	2	-	-	Pf	6
	Spezialvorlesung aus dem Themenbereich der Schwerpunktausbildung	2	1	-	W	5
	Ringvorlesung zum Schwerpunktprogramm	2	-	-	Pf	5
	Schwerpunktpraktika (2 x 4.5 Wochen)	-	2	16	W	2 x 8
25 SWS	Summe: 2. Semester	6	3	16		32
3. (WS)	Master-Wahlvorlesung Chemie	2	1	-	W	5
	Ausbildung in Versuchstierkunde (20 h V + 20 h Pr)	2	-	1,5	Pf	5
	Spezialvorlesung aus dem Themenbereich der Schwerpunktausbildung	2	1	-	W	5
	Spezialisierung (1 Semester)	-	1	13	W	14
23,5 SWS	Summe: 3. Semester	6	3	14,5		29
4.(SS)	Masterarbeit (6 Monate)					30
77,5 SWS	Summe:	16	13	48,5		120

Modulliste Masterstudiengang Biochemie

Pflichtveranstaltungen

<table>
<tr><td colspan="6">Biochemical Seminar</td></tr>
<tr><td>Module 1.1</td><td>Credits
3 CP</td><td>Workload
90 h</td><td>Term
1st semester</td><td>Frequency
only winter term</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Courses
Biochemical Seminar (185720)</td><td>Contact hours
28 h</td><td>Self-Study
62 h</td><td>Group size
45 students</td></tr>
<tr><td colspan="6">Prerequisites
None</td></tr>
<tr><td colspan="6">Learning outcomes

The students practice preparing and delivering a 20-minute oral presentation based on a scientific paper provided by the seminar supervisor. The presentation typically is set up as a PowerPoint presentation, but in principle open for every presentation technique.
Following the presentation the students practice defending their presentation in a 10-minute discussion period with the two supervisors and their fellow students of the audience. All students present in the audience at the seminar are called upon to critically evaluate the performance of the presenters.</td></tr>
<tr><td colspan="6">Content
The seminar offers a variety of general themes around which the topics of the individual presentations are grouped. In general, the topics are related to the research interests of the supervisors that share the teaching load of this seminar. Current general themes are:
• Proteome
• Ion Channels and Exocytosis
• Membrane Transporters
• Membrane receptors
• Apoptosis
• Biosensors</td></tr>
<tr><td colspan="6">Teaching methods
Seminar</td></tr>
<tr><td colspan="6">Mode of assessment
Seminar presentation with discussion</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
A 20-minute seminar presentation with a 10-minute discussion in front of two supervisors and the student's peers</td></tr>
<tr><td colspan="6">Module applicability (in other studies courses)</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted by CP</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
T. Günther-Pomorski, S. Neumann, D. Wolters, I. Dietzel-Meyer, B. Justesen, S. Kruss, R. Stoll, H. Kirschner, M. Hollmann, D. Tapken</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Introduction to Bioinformatics

Modul 1.2	Credits 5 CP	Workload 150 h	**Term** 1st semester	**Frequency** only winter term	Duration 1 semester
Course a) Lecture: Introduction to Bioinformatics b) Computer Practical: Introduction to Bioinformatics			**Contact hours** 28 h	**Self-study** 122 h	**Group size** a) unlimited b) maximum 40 students in parallel sessions

Prerequisites:
Knowledge of basic concepts of Biochemistry, Genetics and Molecular Biology lectures

Learning outcomes
In this combined lecture/practical module the students are introducted to the basic concepts of Bioinformatics. The topics covered range from basic sequence analysis to the visualization and interpretation of 3D structures of proteins. Strong emphasis is given to classical structure prediction methods for RNA and proteins, being also complemented to novel artifical intelligence techniques. The algorithmic principles are teached as necessary for a basic understanding. A strong focus lies on the extension of theoretical knowledge to development of practical skills, enabling the student to become familiar with tools available free of charge from the internet, and to make use of them for the theoretical planning and experimental interpretation of their own laboratory work. These subjects are further engrossed by the exercises and computer practicals.

Content

a) Lecture

- Introduction and Overview of Bioinformatics
- Genomes and Genome Analysis – Next Generation Sequencing
- Databases I – Literature Search - Virtual Cloning
- Binary Sequence Comparison
- Local AlignmentsLocal and Global Alignments - Motifs and Profiles
- Global Multiple Sequence Alignments
- Molecular Dynamics Simulation I - Visualization of proteins
- Molecular Dynamics Simulation II – Structure Prediction of Proteins using AI
- Databases II - Protein Structure Base - Visualization of Biomolecules
- Validation of ProteinStructures
- Phylogeny
- Structure Prediction and Gene Finding
- RNA analysis -Transcriptome Analysis
- Machine Learning in Bioinformatics

b) Exercise and Computer Practical

- Databases
- Virtual Cloning
- Phylogenetic Analysis
- Transcriptome Analysis
- Validation of Protein Structures
- Structure Prediction
- Molecular Dynamics Simulation

Teaching methods

a) Lecture

b) Exercises and Computer Practical. Home work on selected assignments and supervision of script-based practical work at the computer pool of the university
Mode of assessment Written exam
Requirement for the award of credit points Passing the exam
Module applicability Master of Science Biochemistry, also open to M. Sc. students of Stem Cell Biology, Applied Informatics, Physics, Medical Physics, and to B. Sc. students of Biology
Weight of the mark for the final score Weighted by CP
Module coordinator and lecturer(s) M. Lübben, R. Stoll, T. Rudack, A. Mosig
Further information

Basic course in radiation protection according to Fachkundegruppe S4.1

Modul 1.3	Credits 5 CP	Workload 150 h	**Term** 1st semester	**Frequency**	Duration 1 week
Courses a) Lecture (461859) b) Practical and exercises (461860)			**Contact hours** 50 h	**Self-study** 100 h	**Group size** max. 24 students

Prerequisites:
None

Learning outcomes
Students acquire the theoretical background necessary to meet the German legal requirements for obtaining the state certificate "Fachkunde im Strahlenschutz", which is necessary for a promotion to the position of a radiation safety officer under German law ("Strahlenschutzbeauftragter").

Content

- Physics of radiation: types, origin and generation of radiation, radioactive decay, interaction of radiation with matter
- Basics of radiochemistry, radiation dose: legal dosage limits, exposure of humans to radiation, radiation exposure at the workplace, biological effects, risks
- Measurement of radiation, radiation protection and safety, legal basics and requirements: radiation safety code, permits, guidelines, norms
- Tasks and duties of a radiation safety officer

Teaching methods
a) Lecture
b) Practical and exercises

Mode of assessment
Written exam on the last day of the course

Requirement for the award of credit points
Passing the exam

Module applicability
Master of Science Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
M. Lübben, D. Meyer, B. Schalwat, D. Rogalla, V. Foteinou, A. Haak, H. Leßlich, M. Siewert, T. Lenders, S. Spöllmann

Further information
The state certificate necessary for obtaining the "Fachkunde im Strahlenschutz" is intended to be obtained in the course, therefore the lectures are legally required to be given in German.
Students who do not speak German can instead participate in the radiation safety course that is part of the module "Molecular tracing methods" (LV No. 203100/203050) in the master studies course "International Stem Cell Biology". However, successful participation in this course that is taught in English will not lead to the official state certificate which allows to work as a Radiation Protection Agent.

Biochemistry IV - Biochemistry of Membrane Receptors					
Module 1.4	Credits 7 CP	Workload 210 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Courses Biochemistry IV – Biochemistry of Membrane Receptors (185820)			**Contact hours** 28 h	**Self-Study** 182 h	**Group size** 45 students

Prerequisites
Familiarity with the contents of the Bachelor studies course lectures Biochemistry 0, I, II, and III.

Learning outcomes
Students will gain an overview of the various membrane receptors and ion channels, their structure-function relationships, and the intracellular signal transduction pathways these receptors are connected to. A further focus will be on understanding the interplay between different signal transduction pathways as well as the regulatory principles governing them. Students are supposed to grasp the wide-ranging implications that signal transduction pathways have for cell physiology and the organism as a whole. Furthermore, students are expected to learn and understand basic concepts in biochemistry. In the context of the specific topics listed below, reference will be made to those basic concepts of previous lectures (Biochemistry I-III) that are considered crucial for an in-depth understanding of the principles of biochemistry.

Content

- **Cell-cell contacts:** Structure of tight junctions, anchoring junctions, gap junctions; function of gap junctions.
- **Cell-cell adhesion:** Cell migration, N-CAMs, cadherins, selectins, integrins, activation of endothelial cells, extracellular matrix proteins: FGF, chondroitin sulfate, laminin, fibronectin, tenascin. Integrin receptors: MIDAS motif, I-domain, signal transduction; integrin regulation from within the cell, regulation of the cytoskeleton, focal adhesion kinase, function during fertilization.
- **Voltage-activated ion channels:** Resting membrane potential, signal propagation, sodium currents, potassium currents, action potential; single channel conductivity, patch clamp technique.
- **Presynaptic function and vesicle release:** Life cycle of a vesicle, vesicular proteins, SNARE complex formation, fusion pore formation, NSF and SNARE complex dissolution.
- **Ligand-activated ion channels:** Glutamate receptors (NMDA, kainate, AMPA receptors), post-transcriptional modifications, structure-function relationship, ligand binding site, receptor modulation, molecular correlates of memory formation, LTP. Acetylcholine receptors: structure, acetylcholine release, pore opening. GABA and glycine receptors: structure and function.
- **Structure of the synapse:** Presynaptic terminal, vesicle release, postsynaptic organization, structure of the nerve-muscle synapse, chemical vs. electrical synapses, EPSPs, miniature postsynaptic potentials
- **Signal transduction pathways:** Introduction, protein kinase A, structure-function relationship in the catalytic center.
- **Receptor protein tyrosine kinases**: Subclasses. Insulin receptor and FGF receptor: extra- and intracellular domains, heparin, EGF-receptor, PDGF receptor. Signaling modules SH2 domain, SH3 domain, TRK and GDNF receptors. Protein-protein interaction domains: SHC-GRB2, IRS-1, protein tyrosine phosphate binding domain (PTB), pleckstrin homology domain (PH), phospholipase C-g.
- **Signal transduction of cellular survival:** PI-3 kinase: P85 subunits, a, b, g, d subunits, catalytic subunits; Bcl-2 protein family: Bcl-xl, Bak; Ras protein, MAP kinase; serine-threonine kinases: TGF-b receptors, structure of the cytoplasmic domain, comparison to PKA, SMAD.

- **Phosphotyrosine phosphatases:** Mechanism, PTP-BL,PDZ domains, catalytic center
- **Non-receptor tyrosine kinases**: Src kinase family, structure-function relationship.
- **Cytokines:** Families I through IV of cytokine receptors. Class I: growth hormone, erythropoietin, and prolactin receptors, janus kinases (JAKs), STATs, IL-6 receptor family: signal transduction, II-2 receptor family, gene therapy. Class II: Interferon alpha (ligand), signal transduction of the interferon alpha receptor. Class III: Tumor necrosis factor receptor family (p55), TRAFs, TRADD, FAAD, RIP, death domain (Fas, TNFR1, p75NTR), caspases (9.3.1), and their inhibition. Class IV: Interleukin-1 receptor, IRAP.
- **Seven-transmembrane receptors/G proteins:** (GPCRs): Classification, GTP-ase cycle, transducin, regulation of GDP/GTP exchange activity, rhodopsin, regulation of guanylate cyclase, calcium-dependent proteins, Ca/calmodulin, arrestin, photo transduction, G proteins

Teaching methods
Lecture

Mode of assessment
Written exam

Requirement for the award of credit points
Passing the exam

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
M. Hollmann, T. Günther-Pomorski, S. Neumann

Further information
The PowerPoint slides shown are available on disc and/or deposited in the corresponding Moodle course. Note-taking during lectures is encouraged. Independent post-preparation of module contents as well as independent consultation of course material is recommended to prepare for the exam.

<table>
<tr><td colspan="6">Instruction in Laboratory Animal Science</td></tr>
<tr><td>Modul 1.5</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Term
3rd semester</td><td>Frequency
only summer term</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Courses
a) Lecture (185902)
b) Practical (185903)</td><td>Contact hours
a) 35 h
b) 21 h</td><td>Self-study
94 h</td><td>Group size</td></tr>
<tr><td colspan="6">Prerequisites:
None</td></tr>
<tr><td colspan="6">Learning outcomes
Students acquire a basic knowledge in animal experimentation.</td></tr>
<tr><td colspan="6">Content
a)
• Introduction, Ethics, 3R principle
• Legal regulations
• Rodent biology
• Pain – Suffering – Harm
• Analgesia and anesthesia
• Animal experiment conduction
• Application and collection techniques
• Basic surgical techniques
b)
• Laboratory animal handling
• Application and blood collection
• Survival surgery</td></tr>
<tr><td colspan="6">Teaching methods
c) Lecture
d) Practical</td></tr>
<tr><td colspan="6">Mode of assessment
Written exam</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Passing the exam
Active participation in the practical</td></tr>
<tr><td colspan="6">Module applicability
Master of Science Biochemistry</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted by CP</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
M. Schmidt</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Master-Wahlmodul Chemie

<table>
<tr><td colspan="6">Concepts of Molecular Chemistry I: Physical Organic Chemistry</td></tr>
<tr><td>Module 2.1</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Term
1., 3. Sem.</td><td>Frequency
WS</td><td>Duration
1 Semester</td></tr>
<tr><td colspan="3">Courses
a) Lecture
b) Exercises</td><td>Contact hours
a)2 SWS / 30 h
b)1 SWS / 14 h</td><td>Self-Study
105 h</td><td>Group size
30 Students</td></tr>
<tr><td colspan="6">Prerequisites</td></tr>
<tr><td colspan="6">Learning outcomes
• Students acquire advanced knowledge on the theory and techniques of the basic concepts of physical organic chemistry such as bond models, thermochemistry, and the theoretical evaluation of properties of experimental interest, in particular the theory of potential energy reaction surfaces. The main focus lies on the interplay between theoretical and experimental methods.
• Students learn to read and understand advanced selected scientific publications in the topic of physical organic chemistry, how to summarize the publication in an abstract, and to present the essentials of the publication in an oral presentation using presentation software (15 min + 5 min discussion).</td></tr>
<tr><td colspan="6">Content
- The covalent chemical bond (properties, experimental methods)
- The non-covalent chemical bond (van der Waals complexes, hydrogen bonds, supramolecular chemistry, peptides)
- Thermochemistry (properties, Benson’s additivity rules)
- Potential energy surfaces (internal coordinates, Born Oppenheimer approximation, stationary points, reaction coordinates, Marcus theory, Curtin Hammett principle, More O’Ferral-Jencks diagrams, reactivity and selectivity, tunneling)
- Force field calculations (MM2)
- Linear free energy relations
- Experimental techniques (matrix isolation)</td></tr>
<tr><td colspan="6">Teaching methods
Lecture, seminar based teaching with active participation of the student</td></tr>
<tr><td colspan="6">Mode of assessment
30 min end-of-term oral exam or 2-hour end-of-term written exam</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Successful oral presentation, passing the exam</td></tr>
<tr><td colspan="6">Module applicability</td></tr>
<tr><td colspan="6">Weight of the mark for the final score</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s): W. Sander</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Theoretical Chemistry II: Dynamics and Simulation (Chemistry)					
Module 2.2	Credits 5 CP	Workload 150 h	**Term** 1. or 3. Sem.	**Frequency** Each WiSe	Duration 1 Semester
Courses a) Lectures b) Exercises			**Contact hours** a)+b) 2+1 SWS	**Self-Study** a) 30 h b) 75 h	**Group size** 10 – 20 Students

Prerequisites

Undergraduate level knowledge in classical mechanics, statistical mechanics and time-independent non-relativistic quantum mechanics

Learning outcomes

Students acquire advanced knowledge of the theory and computational techniques of statistical mechanics and (bio)molecular dynamics simulations in the realm of (bio)molecular systems such as (bio)molecules, clusters, liquids, solids and surfaces. In addition, analysis methods to extract observables of experimental interest, such as various spectroscopic, scattering, and diffraction techniques, are presented such that the students can judge both their strengths and weaknesses with the focus on topical problems in Theoretical Chemistry with a focus on Solvation Science.

Content

Essentials of classical and statistical mechanics: Formulations according to Newton, Lagrange and Hamilton, corresponding equations of motion, conservation laws/conserved quantities, Noether theorem, Liouville theorem, ensembles, distribution functions, first and second moments of distributions, connection to averages and fluctuations of observables, correlation functions in space and time, van Hove correlation function, pair and radial correlation function with connection to x-ray diffraction and neutron scattering experiments, dynamic and static structure factors.

Potential energy surfaces: Valence force fields, pair potentials, many-body effects, empirical versus ab initio parameterizations, characterization of stationary points, connection between properties of hypersurfaces and chemical concepts, adiabatic chemical reactions.

Molecular dynamics: Basic idea of classical molecular dynamics, deriving integrators via "pedestrian approach" and via Liouville formalism, ergodicity, extended phase space/Lagrangian methods for thermostatting and barostatting, finite system size effects, boundary conditions, convergence criteria for dynamical computer simulations, realizing various ensembles in terms of simulation algorithms, holonomic constraints, deriving molecular dynamics from the time-dependent Schroedinger equation, time-dependent self-consistent field dynamics, ab initio molecular dynamics equations of motion according to Ehrenfest, Born-Oppenheimer and Car-Parrinello, including nuclear quantum effects via path integral simulations.

Teaching methods

Lecture and exercises with problems for self-studying, Q&A and discussion sessions with presentations given by the participants, digital material provided via TheoChem Cloud.

Mode of assessment

Written or oral end-of-semester exam

Requirement for the award of credit points

Passing the end-of-semester exam

Module applicability

M.Sc. Chemistry and M.Sc. Biochemistry (Focal Point Program “Biomolecular Chemistry”)

Weight of the mark for the final score

According to CP

Module coordinator and lecturer(s)

D. Marx

Further information

Module can be integrated CP-relevant in M.Sc. Biochemistry within the Focal Point Programme “Biomolecular Chemistry”

<table>
<tr><td colspan="6">Metabolomics for the discovery of new natural products and biomarkers</td></tr>
<tr><td>Module 2.3</td><td>Credits
5 CP</td><td>Workload
120 h</td><td>Term
semester 1-3</td><td>Frequency
1/year</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Courses
Metabolomics for the discovery of new natural products and biomarkers</td><td>Contact hours
3 SWS</td><td>Self-Study
100 h</td><td>Group size
20 students</td></tr>
<tr><td colspan="6">Prerequisites
Knowledge of basic analytical and organic chemistry, basic biochemistry</td></tr>
<tr><td colspan="6">Learning outcomes
Students acquire a broad overview upon instrumental analytics for the identification of natural products and biomarkers for various diseases.</td></tr>
<tr><td colspan="6">Teaching methods
Offered as hybrid lecture (lecture hall / Zoom) with supporting materials provided via moodle.</td></tr>
<tr><td colspan="6">Mode of assessment
Oral exam</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Passing the oral exam</td></tr>
<tr><td colspan="6">Module applicability
Elective Lecture I-VI</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted according to CPs</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
Frank Schulz</td></tr>
<tr><td colspan="6">Further information
The lecture will be based on review articles, selected book chapter and current primary research publications.</td></tr>
</table>

Biomolecular Simulation: Understanding Experiments at the Molecular Level					
Module 2.4	Workload 150 h	Credit points 5 CP	Available in semester 1	Frequency Each WiSe	Course duration 1 Semester

1	**Teaching methods**	**Hours per week**	**Contact time**	**Self-study**
	a) Lecture b) Exercises	a) 2 h b) 1 h	45 h	105 h

2	**Learning objectives** Students acquire advanced knowledge of both experimental techniques as well as molecular simulation methods for studying biomolecular systems, ranging from the solvation of small solutes to proteins to biological interfaces. The focus will be on structure-dynamics-function relationships and the underlying thermodynamic properties and principles. A number of selected techniques will be introduced and it will be discussed how simulations can be used to interpret the experiments at the molecular or even atomic level. A particular objective is to provide insights into the merits and limitations of the respective methods.
3	**Soft skills** interactive presentation in front of an audience, identification and recording of principal lecture contents, independent revision of module contents, independent consultation of the relevant literature
4	**Prerequisite(s)** Admission to the Master Course Program
5	**Evaluation of the learning process** active participation during lectures, interactive presentation of homework during exercises
6	**Mode of examination** 30-45 min end-of-term oral exam or 2-hour end-of-term written exam
7	**Requirements for acquiring credit points** Passing the end-of-term exam
8	**Significance for overall grade** Weighted according to CPs
9	**Module contents** **Fundamentals**: Energy landscape, Boltzmann ensemble, hierarchy of timescales (Frauenfelder), energy density, thermal energy, soft vs. hard degrees of freedom, fluctuations, entropy. **Biological (macro)molecules**: Structure and relevant interactions, H-bonds, electrostatics, van-der-Waals, hydrophobic effect. Dielectric properties of water, polarizability. **Molecular models**: Degrees of freedom, sampling (Molecular Dynamics, Monte Carlo), spatial boundary conditions, ingredients and parameterization of force fields. Water models. **Förster resonance energy transfer**: Basic principles of fluorescence (Einstein coefficients, spontaneous vs. induced emission, transition dipole moments, radiative lifetimes, Jablonsky diagrams, quantum yields), FRET (energy transfer efficiency, Förster radius, distance measurements), orientation of transition dipoles, FRET from MD simulations.

	Binding: Isothermal titration calorimetry (basic principle, description of the apparatus, binding isotherm), statistical mechanics (canonical/grand-canonical/isobaric-isothermal ensemble, partition function, free energy, phase space integrals), potential of mean force, thermodynamic integration. Applications to ligand-receptor binding, protein folding. Enthalpy-entropy compensation. **Protein dynamics**: Dimensionality reduction, principal component analysis, normal mode analysis, harmonic vs. quasiharmonic approximation, entropy estimation.
10	**Person in charge / Lecturer(s)** L. Schäfer

From top-level science to top-level business

Module 2.5	Credits 5 CP	Workload 125 h	**Term** x. Sem.	**Frequency** Only WS	Duration 1 Semester
Courses a) Seminar b) **Lecture**			**Contact hours** 3 SWS	**Self-Study** 90 h	**Group size** 30 Students

Prerequisites
The module is intended for students from the 5th semester onwards in the Bachelor's and Master's degree in addition to doctoral students, but without exclusion criteria. Previous knowledge, especially in business administration or corporate law, is explicitly not required.

Learning outcomes
After successful completion of the module

- students develop business ideas using different creativity techniques
- design their ideas using different prototyping methods
- understand how to define target groups
- select appropriate methods for customer interviews
- students master the presentation technique of pitching

Content
The module pursues the overarching goal of sensitising students and doctoral students of chemistry and related, similarly basic science degree programmes to a possible business start-up. To this end, the students are not only provided with basic knowledge on how to start a business, but also with tools to first develop an idea of a business model that suits their specific professional and/or methodological skills and to identify ways to master the transfer from science to practice. Personal experience reports by successful founders, who all have a strong background in basic research at the RUB, additionally provide vivid practical reports as "role models" in personal contributions. In addition to these practical reports, the participants benefit from the involvement of experts from different disciplines, such as customer interviews or pitching, who convey content in an application-oriented manner and enable the students to apply it independently. International external experts also help the participants to broaden their horizons.

Teaching methods
Seminar-based teaching, group work, digital teaching formats.

Mode of assessment
On the last day of the course, there is a 10-minute presentation of an individual business idea in group work using the creative techniques learned for business model generation. In addition, students are required to submit an individual guideline-based short reflection on the learned content one week later.

Requirement for the award of credit points
Successful final presentation as well as timely submission of the guideline-based reflection.

Module applicability

Weight of the mark for the final score
The decisive assessment criterion is the group presentation of the business idea. The guiding question-based reflection has an individual effect with tendencies of one mark level.

Module coordinator and lecturer(s)
Kristina Tschulik; Annabelle Beyer;Frederik Lehmann

Further information

Spezialmodule aus dem Themenbereich der Schwerpunktausbildung

Focal Point Programme: Biomolecular Chemistry

<table>
<tr><td colspan="6">Biophysical Chemistry I</td></tr>
<tr><td>Module 3.1</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Term
2. Semester</td><td>Frequency
SS</td><td>Duration
1 Semester</td></tr>
<tr><td colspan="3">Courses
a) Biophysical Chemistry I</td><td>Contact hours
4 SWS, 60 h</td><td>Self-Study
90 h</td><td>Group size
30 Students</td></tr>
<tr><td colspan="6">Prerequisites
Knowledge in basic Physical Chemistry.</td></tr>
<tr><td colspan="6">Learning outcomes
After successful completion of the module/course, students will be able to:
Acquire advanced knowledge in experimental techniques in biophysical chemistry with a focus on structure determining methods.
Understand their applications, advantages, and disadvantages of the methods
Analyze and screen relevant literatures independently
Develop presentation skills in front of an audience
Utilize digital techniques to prepare and conduct a presentation</td></tr>
<tr><td colspan="6">Content
Advanced Biophysical techniques:
Protein structures
Molecular interactions
Computational approaches
X-ray diffraction
Calorimetry techniques
Fluorescence theory, FRET
Super-resolution microscopy</td></tr>
<tr><td colspan="6">Teaching methods
Lecture (2 SWS, 30 h), Exercise (1 SWS, 15 h), Seminar (1 SWS, 15 h).</td></tr>
<tr><td colspan="6">Mode of assessment
Participation in all seminars and presentation about an assigned publication.
Written exam of 60 mins.</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Pass both parts: presentation (50%) and written exam (50%).</td></tr>
<tr><td colspan="6">Module applicability
M.Sc. Chemistry, M.Sc. Biochemistry.</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted according to CPs.</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
Lecturers from Physical Chemistry departments.</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Biophysical Chemistry II					
Module 7.2	Credits 5 CP	Workload 150 h	Term 3. Semester	Frequency WS	Duration 1 Semester
Courses a) Biophysical Chemistry II			**Contact hours** 4 SWS, 60 h	**Self-Study** 90 h	**Group size** 30 Students

Prerequisites

Knowledge in basic Physical Chemistry.

Learning outcomes

After successful completion of the module/course, students will be able to:

- Acquire advanced knowledge in experimental methods in the investigation of dynamics and thermodynamics of proteins and membranes, and on protein reaction and function based on selected examples
- Understand their applications, advantages, and disadvantages of the methods
- Analyze and screen relevant literatures independently
- Develop presentation skills in front of an audience
- Utilize digital techniques to prepare and conduct a presentation

Content

Advanced Biophysical techniques:

- Microcalorimetry in protein characterization
- Fluorescence-based methods in protein interactions
- Advanced fluorescence microscopy
- Fourier transform spectroscopy
- Attenuated total reflection (ATR) spectroscopy
- Vibrational spectroscopy in biomolecular solvation
- Scanning probe microscopy (SPM) in biochemistry

Teaching methods

Lecture (2 SWS, 30 h), Exercise (1 SWS, 15 h), Seminar (1 SWS, 15 h).

Mode of assessment

Participation in all seminars and presentation about an assigned publication.
Written exam of 60 mins.

Requirement for the award of credit points

Pass both parts: presentation (50%) and written exam (50%).

Module applicability

M.Sc. Chemistry, M.Sc. Biochemistry.

Weight of the mark for the final score

Weighted according to CPs.

Module coordinator and lecturer(s)

Lecturers from Physical Chemistry departments.

Further information

Concepts of Spectroscopy 1					
Module 3.2	Credits 5 CP	Workload 150 h	**Term** 1. Semester	**Frequency** Each WS	Duration 1 Semester
Courses a) Lectures b) Exercises			**Contact hours** a) 2 SWS b) 1 SWS	**Self-Study** 105 h	**Group size** a+b) 20 - 50

Prerequisites
Basic knowledge in quantum chemistry, quantum mechanics, spectroscopic techniques and the necessary mathematical formalism

Learning outcomes
After successful completion of the module/course, students will be able to:

- Obtain theoretical and practical knowledge of modern linear and nonlinear spectroscopic methods (time- and frequency-domain) which allow for the elucidation of molecular structure and dynamics in different environments
- Understand applications of laser spectroscopic techniques from the THz to the VUV wavelength region to the study of molecules and their interactions

Content

1. Electromagnetic radiation, molecular structure, light-matter interaction
2. Optical and spectroscopic elements
3. Line broadening mechanisms, spectral bandwidth, Fourier transformation
4. Molecular symmetry, point groups, molecular symmetry groups
5. Rotational spectroscopy: linear, symmetric, spherical, and asymmetric rigid rotor molecules, rotational infrared, millimeter, microwave and Raman spectra
6. Vibrational spectroscopy: diatomic and polyatomic molecules, infrared and Raman spectra, vibrational selection rules, normal mode analysis
7. Electronic spectroscopy: diatomic and polyatomic molecules, electronic and vibronic selection rules, Franck-Condon transitions, intramolecular nonradiative processes (internal conversion, intersystem crossing), curve crossings and conical intersections
8. Laser basics, population inversion and gain mediums, cavity modes, properties of coherent radiation, specific laser systems
9. Introduction to nonlinear spectroscopy

Teaching methods
Active participation during lectures and exercises with problems for self-studying, Q&A and discussion sessions with presentations given by the participants, Moodle course with online material

Mode of assessment
2-hour end-of-term written exam on the content of the lectures

Requirement for the award of credit points
Passing the written examination

Module applicability
M.Sc. Chemistry; M.Sc. iMOS; M.Sc. Lasers and Photonics

Weight of the mark for the final score
Weighted according to CPs

Module coordinator and lecturer(s)
P. Petersen
Lecturers from Physical Chemistry departments

Further information

Organofluorine Chemistry

Module 3.3	Credits 5 CP	Workload 120 h	**Term** 2. Sem.	**Frequency** each SoS	Duration 1 Semester
Courses a) Lecture b) Exercises			**Contact hours** 2 + 1 SWS	**Self-Study** 75 h	**Group size** 20 Students

Prerequisites

None. Ideally: knowledge of basic methods for organic transformations.

Learning outcomes

Students will acquire a broad overview of organofluorine chemistry. After completion of the course, students will know all fundamental approches toward the synthesis of organofluorine compounds and will be able to independently devise synthetic routes and solve corresponding problems. Students will also be able to interpret the sometimes unusual reactivity of organofluorine components and to analyze the influence of fluorine substituents in organic molecules. In addition to textbook knowledge, current publications in the field will also repeatedly be included in the lecture.

Content

History of organofluorine chemistry
Sources of fluorine

Synthesis of organofluorine compounds

- fundamental fluorine reagents
- direct (per)fluorination, electrochemical fluorination
- nucleophilic and “electrophilic” fluorination
- synthesis of fluoroarenes
- conversion of functional groups

Properties and structures of organofluorine compounds

- C-F bond: fundamentals
- steric effects
- physic-chemical properties
- Bent’s rule and special fluorine effect
- dipol interactions
- intramolecular interactions
- analytics: 19F-NMR
- acidities
- fluorine substituents as pi-donors

Reactivity of organofluorine compounds

- fundamental considerations
- perfluorocarbons and substituted perfluorocarbons, fluorinated alkanes
- per- and polyfluoroolefins
- fluoroarenes: SNAr and ortho metalation
- C-F activation and polyfluoroarenes in cross-coupling reactions (C-H activation)
- fluorinated enol ethers and analogues

Applications

- fluorous biphase catalysis
- pharmaceuticals

Teaching methods

Blackboard and Powerpoint, online videos, discussion of recent research papers

Mode of assessment	*Written exam (90 min)*
Requirement for the award of credit points	*Passing of final written examination*
Module applicability	*Master of Science Chemistry*
Weight of the mark for the final score	*according to credit points*
Module coordinator and lecturer(s)	S. Huber
Further information	

Theoretical Chemistry III: Electronic and Molecular Structure Theory (Chemistry)					
Module 3.4	Credits 5 CP	Workload 150 h	**Term** 2. or 4. Sem.	**Frequency** Each SoSe	Duration 1 Semester
Courses a) Lectures b) Exercises			**Contact hours** a+b) 3 SWS	**Self-Study** a) 30 h b) 75 h	**Group size** 10-20 Students

Prerequisites

Learning outcomes

After completing this course students will basic knowledge of modern wavefunction-based computational electronic and molecular structure methods and how these methods can be applied to solve typical problems in structure determination, spectroscopy, and the investigation of mechanisms and energetics of chemical reactions. Futhermore they will know how to judge the accuracy and reliability of such methods.

Content

a+b) The course starts with basic principles for quantum mechanical many-particle systems and how their wavefunctions can be described in compact ways and then discusses a variety of modern wavefunction methods and their application:

- Pauli princple and Slater determinants
- Particle number representation (second quantization)
- Hartree-Fock and Multiconfigurational Self-Consistent Field methods
- Single- and Multiconfigurational Configuration Interaction methods
- Single- and Multireference Perturbation Theory
- Coupled-Cluster Methods
- Explicitly Correlated F12 Methods
- Response Theory approach to excitation energies and spectra
- Basis set convergence and basis set extrapolation
- Thermochemistry protocols

Teaching methods

Lecture and exercises with problems for self-studying,Q&A and discussion sessions with presentations given by the participants, Moodle course with online material.

Mode of assessment

submission and grading of the solution sheets for the hands-on problems and a final oral end-of-semester exam

Requirements for the award of credit points

Passing the oral end-of-semester exam

Module applicability

M.Sc. Chemistry

Weight of the mark for the final score

According to CP

Module coordinator and lecturer(s)

C. Haettig

Further information

Theoretical Spectroscopy (Chemistry)					
Module 3.5	Credits 5 CP	Workload 150 h	**Term** 2. or 4. Sem.	**Frequency** Each SoSe	Duration 1 Semester
Courses a) Lectures b) Exercises			**Contact hours** a+b) 2+1 SWS	**Self-Study** 105 h	**Group size** 10 – 20 Students

Prerequisites
Undergraduate level knowledge in classical mechanics, statistical mechanics and time-independent non-relativistic quantum mechanics as well as advanced knowledge at the level of the "Dynamics and Simulation" M.Sc. lecture

Learning outcomes
Students understand and are able to explain theoretical approaches relying on time-dependent methods to compute observables which are obtained experimentally using spectroscopic, scattering, and diffraction techniques. They are able to assess the scope and limitations of such methods in the context of Solvation Science with a focus on (bio)molecular condensed phase systems, in particular aqueous solutions and soft matter.

Content
Review of standard molecular spectroscopy: Approximate decoupling of time-independent Schrödinger equation in terms of translational, rotational, vibrational and electronic contributions, ro-vibrational spectroscopy of diatomics based on rigid rotor/harmonic oscillator approximation, selection rules, vibronic effects in the Frank-Condon approximation, Frank-Condon principle applied to the solvation of chromophores, normal mode analysis of vibrations of polyatomic molecules
Time-dependence in quantum mechanics: Time-dependent Schrödinger equation and its wavepacket solutions, properties of free particle and Gaussian wavepackets, quantum/classical correspondence and Ehrenfest theorem, time-evolution operator formalism and Dyson equation, Schrödinger versus Heisenberg versus Dirac pictures of quantum dynamics, time-dependent variational principle (Dirac-Frenkel TDVP), linear TDVP, essentials of the time-dependent Hartree (TDH) method and its multiconfiguration (MCTDH) extension, Gaussian wavepacket propagation methods (Heller, Singer)
Time-dependent perturbation theory for spectroscopy: Formalism and applications to important schematic models, linear TDVP in Dirac picture, first- and second-order diagrams, virtual states and transitions, Fermi's Golden Rule
Molecular systems in the radiation field for spectroscopy: Transition probability, absorption cross section, dipole approximation, transition dipole, semiclassical approach to molecule-radiation field coupling, basics of the quantization of the radiation/electromagnetic field for spontaneous emission, multi-photon processes and non-linear spectroscopy, Raman scattering process, transformation of spectroscopy formulated in the static Schrödinger picture to the dynamic Heisenberg picture (Kubo-Gordon formalism to compute spectra), time-autocorrelation functions and spectral line shape function, time-domain versus frequency-domain spectroscopy
Neutron scattering and x-ray diffraction: van Hove formalism, first Born approximation, dynamic and static structure factor, scattering length and form factors, coherent and incoherent scattering, van Hove correlation function and the structural dynamics of liquids, pair correlation functions, radial distribution functions

Teaching methods
Lecture and exercises with problems for self-studying, Q&A and discussion sessions with presentations given by the participants, digital material provided via TheoChem Cloud.

Mode of assessment	Written or oral end-of-semester exam
Requirement for the award of credit points	Passing the end-of-semester exam

Module applicability
M.Sc. Chemistry and M.Sc. Biochemistry (Focal Point Program "Biomolecular Chemistry")

Weight of the mark for the final score	According to CP
Module coordinator and lecturer(s)	D. Marx

Further information
Module can be integrated CP-relevant in M.Sc. Biochemistry within the Focal Point Program "Biomolecular Chemistry"

Bioinorganic Chemistry I					
Module 3.6	Credits 5 CP	Workload 150 h	Term 1st or 3rd Sem.	Frequency Only WS	Duration 1 Semester
Courses a) Bioinorganic Chemistry I (Lecture and Seminar)			**Contact hours** 3 SWS	**Self-Study** 105 h	**Group size**
Prerequisites Basic Understanding of general chemistry, coordination chemistry and biochemistry					
Learning outcomes After successful completion of this module, the students have - A basic understanding of the role of metals in a biological environment - Knowledge about the structure, function and properties of metalloenzymes The students are able to - Identify, solve, and discuss problems related to the role of metal centers in biomolecules - Find, read, and critically comment on pertinent literature in the field of Bioinorganic Chemistry					
Content The lecture covers classical bioinorganic chemistry topics, including but not restricted to the following: Occurrence of metal ions and compounds in the environment, metal ion uptake and homeostasis, metals as active sites in metalloenzymes, spectroscopic characterization of metal centers in biomolecules, reaction mechanisms of metalloenzymes, model compounds for metalloenzymes, activation and metabolism of small molecules by metal centers and metalloenzymes (e.g. H_2, O_2, N_2, CH_4, etc.).					
Teaching methods Lecture and Seminar with student contributions (e.g. presentation, video, written contribution such as project draft or grant application)					
Mode of assessment Written exam and grading of student contributions					
Requirement for the award of credit points Active participation in student contribution, successful completion of written exam					
Module applicability Master Chemistry, Master Biochemistry, Master Biology					
Weight of the mark for the final score Weighted according to CP					
Module coordinator and lecturer(s) Nils Metzler-Nolte, Ulf-Peter Apfel and Members of Inorganic Chemistry I					
Further information					

Supramolecular Chemistry

Module 3.7	Credits 5 CP	Workload 120 h	**Term** 1./3. Sem.	**Frequency** each WS	Duration 1 Semester
Courses a) Lecture b) Exercises			**Contact hours** 2 + 1 SWS	**Self-Study** 75 h	**Group size** 20 Students

Prerequisites

None. Ideally: knowledge of basic methods for organic transformations.

Learning outcomes

Students will acquire a broad overview of supramolecular chemistry. After completion of the course, students will be aware of all relevant concepts in supramolecular chemistry and will be able to identify them independently. Participants will also study all relevant noncovalent interactions, including their electronic origin, their manipulation and their limitations. On the basis of the most common structural motifs, cation binders, anion binders and neutral molecule binders will be discussed. Students will be aware of the fundamentals of self-assembly as well as of its most important applications. Finally, participants will be able to interpret the use of non-covalent interactions in organocatalysis. In addition to textbook knowledge, current publications in the field will also repeatedly be included in the lecture.

Content

Definition, history

Concepts
- Lock & key, induced fit
- binding constants
- cooperativity / chelate effect
- preorganization / complementarity, selectivity

Noncovalent Interactions
- ion pairing, ion-dipole, dipole-dipole
- hydrogen bonding, halogen bonding, further closed-shell interactions
- cation-π, π/ π , anion- π interactions
- van-der-Waals interactions, solvation and hydrophobic effect, entropy

Fundamental Techniques
- high-dilution synthesis
- template synthesis

Cation Binding
- crown ethers, lariat ethers
- cryptands, spherands
- calixarenes

Anion Binding
- recognition by electrostatics
- recognition by electrostatics and hydrogen bonding
- recognition by hydrogen bonding
- recognition by Lewis acids, core motifs

Neutral Guest Binding
- recognition by hydrogen bonding
- recognition by hydrophobic effect

Self-Assembly
- rotaxanes
- catenanes, knots
- capsules

Applications in Catalysis
- reactions in confined space (capsules)
- noncovalent organocatalysis
- self-replication, noncovalent catalyst assembly, “classical” supramolecular catalysis

Teaching methods

Blackboard and Powerpoint, online videos, discussion of recent research papers

Mode of assessment

Written exam (90 min)
Requirement for the award of credit points *Passing of final written examination*
Module applicability *Master of Science Chemistry*
Weight of the mark for the final score *according to credit points*
Module coordinator and lecturer(s) S. Huber
Further information

Focal Point Programme: Membrane and Nervous System Biochemistry

<table>
<tr><td colspan="6">Lecture Series in the Focal Point: Biochemistry of Membranes and Nervous Systems</td></tr>
<tr><td>Module 3.8</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Term
2nd semester</td><td>Frequency
only summer term</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Courses
Lecture Series in the Focal Point: Membrane and Nervous System Biochemistry (185830)</td><td>Contact hours
28 h</td><td>Self-Study
122 h</td><td>Group size
~ 5–20 students</td></tr>
<tr><td colspan="6">Prerequisites
Knowledge of basic concepts of Biochemistry lectures.</td></tr>
<tr><td colspan="6">Learning outcomes
After completion of the course, students will have acquired an overview of current research of the working groups and departments, which are assigned to this focal point. This lecture series is organized in such a way that a different principal investigator presents her or his research on each date.</td></tr>
<tr><td colspan="6">Content
• Oxidative stress and antioxidant defence in neurodegenerative diseases
• Optical control of glutamate receptors
• Functional significance of and mechanisms underlying hippocampal synaptic plasticity
• Intra- and extracellular analysis of action potentials, analysis of transmembrane ion currents using voltage-clamp techniques
• Glutamate receptor assembly and transport to the plasma membrane
• Functional plasticity of neurons – modulation of voltage-activated Na^+-currents
• Neurotrophic signalling by RasGTPase in neuronal brain cells
• Neurons with a migratory background and brain lamination
• Imaging of neurotransmitter dynamics
• Investigating affective disorders in animal models
• Optogenetics</td></tr>
<tr><td colspan="6">Teaching methods
Lecture</td></tr>
<tr><td colspan="6">Mode of assessment
Written exam</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Passing the exam</td></tr>
<tr><td colspan="6">Module applicability (in other studies courses)</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted by CP</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
T. Günther-Pomorski, I. Dietzel-Meyer, M. Hollmann, C. Theiss, A. Faissner, D. Wolters, D. Manahan-Vaughan, O. Güntürkün, E. Förster, S. Kruss, N. Freund, S. Herlitze</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Special Lecture in the Focal Point: Biochemistry of Membranes and Nervous Systems					
Module 3.9	Credits 5 CP	Workload 150 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Courses Special Lecture: Biochemistry of Membranes and Nervous Systems (184631)			**Contact hours** 28 h	**Self-Study** 122 h	**Group size** ~ 5–20 students
Prerequisites Knowledge of basic concepts of Biochemistry lectures.					
Learning outcomes After completion of the course, students will have acquired in-depth knowledge on topics such as membranes and the nervous system together with an outlook on current research.					
Content *The special lecture deals with:* • *Cells of the nervous system* • *Structure and function of neuronal synapses* • *Electrical properties of neurons* • *Formation and recycling of presynaptic vesicles* • *Motor proteins and vesicular transport* • *Neurodegenerative diseases – Parkinson's disease* • *Lipid signaling in neuronal cells* • *Glucose metabolism in neuronal cells* • *Development of the nervous system* • *Learning and memory* • *Advanced light microscopy for neuroscience*					
Teaching methods Lecture					
Mode of assessment Written exam					
Requirement for the award of credit points Passing the exam					
Module applicability (in other studies courses)					
Weight of the mark for the final score Weighted by CP					
Module coordinator and lecturer(s) T. Günther-Pomorski, S. Neumann					
Further information					

Special Lecture in the Focal Point: Biochemistry of Membranes and Nervous Systems

Module 3.10	Credits 5 CP	Workload 150 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Courses Special Lecture: Ion Channels in Excitable Membranes (184632)			**Contact hours** 28 h lecture 1 h seminar	**Self-Study** 121 h	**Group size** ~ 5–20 students

Prerequisites

Knowledge of basic concepts of physics, physical chemistry and biochemistry.

Learning outcomes

After completion of the course, students will have acquired a basic understanding of the molecular mechanisms governing information processing and regulation of fast reactions in biosystems. Students will have been introduced into structure, function and regulation of the most essential membrane proteins involved in generation and processing of electrical signals in receptor- nerve and muscle cells as well as their synaptic connections.

Content

- Role of bioelectricity/ electrochemical potentials in living systems
- Proteins, essential for generation of the resting membrane potential:
  - structure and function of different isoforms of the Na^+/K^+-ATPases
  - structure, subunit composition and selectivity filter of the KCSA-K^+-channel
- Propagation of local potential changes, length- and time constants
- Intra- and extracellular analysis of action potentials, analysis of transmembrane ion currents using voltage-clamp techniques
- Protein structure of voltage-gated Na^+-channels, analysis of current/voltage relationship and inactivation of Na^+ currents using patch-clamp techniques
- Structure of delayed rectifying K^+- channels, structure and position of the voltage sensor, current/voltage relationship of the delayed rectifying K^+- channel, reconstruction of the action potential from the ion currents using the Hodgkin-Huxley-model
- Cell type specific action potential kinetics as consequence of the expression of different K^+-channel subunits, ion channel blockers
- Structure, function, activation- and inactivation kinetics of voltage-activated Ca^{2+}-channels,
- Connexins, Pannexins, Innexins, rectifying and double-rectifying electrical junctions, mechanisms of vesicle fusion at chemical synapses
- Structures, subunit compositions, ion conductances and current/voltage relationships of ionotropic receptors for acetylcholine, glutamate and glycine
- G-protein coupled receptors for acetylcholine, glutamate and adrenaline and their action in the sympathetic nervous system.
- Structure of mechanoreceptors and transmission of mechanical and acoustic signals into the central nervous system
- Structure of photoreceptors and transmission of visual information into the central nervous system
- Regulation of extracellular electrolyte concentrations, aquaporins

Teaching methods Lecture

Mode of assessment Written exam

Requirement for the award of credit points

Passing the exam

Module applicability (in other studies courses)

Weight of the mark for the final score

Weighted by CP

Module coordinator and lecturer(s)

I. Dietzel-Meyer

Further information

Special Lecture in the Focal Point: Biochemistry of Membranes and Nervous Systems					
Module 3.11	Credits 5 CP	Workload 150 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Courses Special Lecture: Structure, Function and Physiology of Nicotinic Acetylcholine Receptors (184633)			**Contact hours** 28 h	**Self-Study** 122 h	**Group size** ~ 5–20 students

Prerequisites
Knowledge of basic concepts of Biochemistry lectures.

Learning outcomes
After completion of the course, students will have acquired an understanding about the structure, function and physiology of nicotinic acetylcholine receptors from basic research to industrial drug development.

Content

- History of acetylcholine receptor research
- Acetylcholine receptors from Torpedo's electrical organ
- Functional properties of nicotinic acetylcholine receptors on the neuromuscular junction and electrophysiological methods for their investigation
- Cloning and sequence analysis of nicotinic acetylcholine receptors
- Expression of cloned nicotinic acetylcholine receptors in heterologous systems, especially in *Xenopus* oocysts.
- Nicotinic acetylcholine receptors in the central and peripheral nervous system
- Pharmacology of nicotinic acetylcholine receptors
- Structure of nicotinic acetylcholine receptors, especially the agonist binding site, binding of competitive ligands
- Ligands of nicotinic acetylcholine receptors as drugs and in crop protection - an example of modern aspects of drug development
- Mutations and knockout of nicotinic acetylcholine receptors

Teaching methods
Lecture

Mode of assessment
Written exam

Requirement for the award of credit points
Passing the exam

Module applicability
Master of Science Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
C. Methfessel

Further information

Focal Point Programme: Biochemistry of Stem Cells

<table>
<tr><td colspan="6">Lecture Series in the Focal Point: Biochemistry of Stem Cells</td></tr>
<tr><td>Module 3.12</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Term
2nd semester</td><td>Frequency
only summer term</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Courses
Stem Cells (185890)</td><td>Contact hours
28 h</td><td>Self-Study
122 h</td><td>Group size
~ 5–20 students</td></tr>
<tr><td colspan="6">Prerequisites
Knowledge of basic concepts of Molecular and Cell Biology</td></tr>
<tr><td colspan="6">Learning outcomes
Knowledge:
Students have acquired an overview about views, problems and current research topics and know research fields and research groups related to stem cell biology
Skills:
Students are capable of understanding original research work and relate current research to basic knowledge
Competencies:
Students have learned to
a) Relate current original research results to a theoretical background
b) Follow-up recent achievements in the field
c) Put relevant problems into a scientific context
They are capable of communicating in a scientific context in front of an international audience.</td></tr>
<tr><td colspan="6">Content
• Muscle Stem Cells and Myogenesis
• Cancer stem cells
• Embryonic and Induced Pluripotent Stem Cells
• Use of stem cells in transgenic and knock out technologies
• Induction of pluripotent stem cells
• Novel sources of adult human stem cells with multipotency
• Intracellular signalling in stem cells
• Neonatal stem cells in clinic and research
• Fat-derived human mesenchymal stem cells and dental follicle cells
• Molecular structure and functions of the stem cell niche
• Limbal Stem Cells - from bedside back to bench
• Advances in neonatal stem cells research and application
• Cell Biology of Neural Stem Cells during CNS Development</td></tr>
<tr><td colspan="6">Teaching methods
Lecture</td></tr>
<tr><td colspan="6">Mode of assessment
Multiple choice exam</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Passing the exam</td></tr>
<tr><td colspan="6">Module applicability
Master of Science Biochemistry</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted by CP</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
H. Zähres (Coordinator), Brand-Saberi, Bühler, Dehmelt, Dittmer, Faissner, Giebel, Heumann,, Kaltschmidt, Pfannkuche, Thakur, Wiese, Zähres</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Special Lecture in the Focal Point: Biochemistry of Stem Cells					
Module 3.13	Credits 5 CP	Workload 150 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Courses Special Lecture: Molecular Genetic Methods (203002)			**Contact hours** 28 h	**Self-Study** 122 h	**Group size** ~ 5–20 students
Prerequisites Knowledge of basic concepts of Molecular and Cell Biology					
Learning outcomes *Knowledge:* *Students have learnt: Cloning (Enzymes, Prokaryotic vector systems, cDNA, Ligation / Recombination techniques), Gene expression / Protein analysis, Sequencing / Epigenetic analysis, Gene transfer and expression (Eukaryotic vector systems), Gene targeting, Genome editing, Transgenic animals* *Skills:* *Students have acquired skills in gene and genome analysis, skills in cloning of gene constructs, cell and animal manipulation, protein expression* *Competencies:* *Students have acquired concepts and strategies for gene and genome analysis and manipulation according to experimental requirements*					
Content • Essentials of cloning in prokaryotic vector systems: DNA restriction by natural and by artificial, custom-made enzymes, modification systems • Prokaryotic vector systems, selection modes, cDNA synthesis, ligation, recombination site associated exchange of gene cassettes • Gene expression in *E. coli*, protein analysis • State of the art sequencing techniques, epigenetic genome analysis • In vitro, in vivo mutagenesis • Gene transfer and expression (eukaryotic vector systems, viral, non-viral, episomal expression vectors) • Gene targeting, RNA interference (HR, shRNAs, nucleases), genome editing (CRISPR/Cas9) • Transgenic animals (constitutive, conditional, inducible mice) • RNA methods (modification, mRNA transfer, miRNAs)					
Teaching methods Lecture					
Mode of assessment Free text exam					
Requirement for the award of credit points Passing the exam					
Module applicability Master of Science Biochemistry					
Weight of the mark for the final score Weighted by CP					
Module coordinator and lecturer(s) H. Zähres					
Further information					

Special Lecture in the Focal Point: Biochemistry of Stem Cells					
Module 3.14	Credits 5 CP	Workload 150 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Courses Special Lecture: Tissue Engineering (203003)			**Contact hours** 28 h	**Self-Study** 122 h	**Group size** ~ 5–20 students

Prerequisites

Knowledge of basic concepts of Molecular and Cell Biology

Learning outcomes

Knowledge:

Students have learned the macroscopic and microscopic anatomy and function of organ systems, cell-based therapies and gene therapies for tissue-specific replacement.

Skills:

Students can apply principles of tissue culture and of "Good manufacturing practice" (GMP), which will be taught theoretically as a general preparation for practical modules.

Competencies:

Students are capable of developing approaches for solving tissue-specific problems of tissue reconstitution and have the ability to integrate different disciplines to this purpose.

Content

- Morphogenesis and Tissue Engineering
- Biomaterials in Tissue Engineering
- Stem cells for toxicological and pharmacological assays
- Gene Transfer and Gene Therapy
- Generation of iPS
- Tissue Engineering using Adult Stem Cells (HSC/MSC/NSC)
- Tissue Engineering using Pluripotent Stem Cells (ES/iPS)
- Cardiovascular Cell Engineering
- Hematopoietic Cell Engineering
- Isolation of mesenchymal stem cells from bone marrow aspirate/adipose tissue
- Musculoskeletal Cell Engineering
- Neural Cell Engineering

Teaching methods
Lecture

Mode of assessment
Oral exam with two examiners (B.Brand-Saberi, H. Zähres)

Requirement for the award of credit points
Passing the exam

Module applicability
Master of Science Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
H. Zähres (coordinator) Behr, Böing, Börger, Giebel, Ott, Jacobsen, Kindler, Klump, Zähres

Further information

Special Lecture in the Focal Point: Biochemistry of Stem Cells

Module 3.15	Credits 5 CP	Workload 150 h	**Term** 1st semester	**Frequency** only winter term	Duration 1 semester
Courses Stem Cell Physiology (203010)			**Contact hours** 28 h	**Self-Study** 122 h	**Group size** ~ 5–20 students

Prerequisites
Knowledge of basic concepts of Molecular and Cell Biology

Learning outcomes
Knowledge:
Students can describe the principles and chronology of vertebrate development and stem cell types
Skills:
Students have understood and are able to explain basic processes of development. They can summarize and interpret developmental and stem cell related primary literature. Students can interpret basic and advanced problems in stem cell biology and relate morphological data.
Competencies:
Students can integrate and evaluate relevant stem cell-related textbook knowledge and research data at the morphological, developmental and molecular level.
They can design and adequately present advanced level Power-Point based talks, relate them to background knowledge and critically discuss new data. They are capable of communicating in a scientific context in front of an international audience.

Content

- Cell cycle control and its implications for stem cell biology
- Principles of vertebrate development
- Gametogenesis and fertilization
- Early development: cleavage, blastocyst, gastrulation
- The three germ layers: ectoderm, mesoderm, endoderm and their derivatives
- Species-specific aspects of development
- Stem cell classification:
  - Hematopoietic stem cells
  - Mesenchymal stem cells, mesangioblasts
  - Embryonic stem cells
  - Fetal stem cells
  - Adult stem cells
  - Induced pluripotent stem cells
  - Stem cells in invertebrates
- Reproductive medicine

Teaching methods
Lecture

Mode of assessment
Written exam

Requirement for the award of credit points
Passing the exam

Module applicability
Master of Science Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
B. Brand-Saberi (Coordinator), Böing, Fragale

Further information

Focal Point Programme: Proteins in Biomedicine

<table>
<tr><td colspan="6">Lecture Series in the Focal Point: Proteins in Biomedicine – “Lab days”</td></tr>
<tr><td>Module 3.16</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Term
2nd semester</td><td>Frequency
only summer term</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Courses
Lecture Series in the Focal Point: Proteins in Biomedicine – Lab days (185851)</td><td>Contact hours
20 h</td><td>Self-Study
130 h</td><td>Group size
~ 5–20 students</td></tr>
<tr><td colspan="6">Prerequisites
Knowledge of basic concepts of Biochemistry lectures. Student should be member of the focal point: Proteins in Biomedicine</td></tr>
<tr><td colspan="6">Learning outcomes
After completion of the course, students will have acquired an overview of current research of the working groups and departments, which are assigned to this focal point. This lecture series is organized in such a way that a different principal investigator presents her or his research on two sessions. In addition, each student has to present a poster containing methodological information and a powerpoint presentation on the subject and outcomes of a current research paper selected by the supervisors.</td></tr>
<tr><td colspan="6">Contents
• Mass spectrometry, protein biomarkers of cancer
• Label-free detection of diseases by infrared imaging
• Genomics and transcriptomics of cancer
• Imaging Analysis
• Modeling of proteins
• Molecular mechanisms of G protein-coupled receptors
• Use of NMR for detection of pathogenetic mechanisms
• Molecular mechanisms of small G proteins
• Spectroscopic investigation of optogenetic tools
• Diagnosis of neurodegenerative diseases using vibrational spectroscopy
• Medically relevant ABC transporters
• P-type ATPases in health and disease
• Structural analysis of proteasome</td></tr>
<tr><td colspan="6">Teaching methods
Lectures by supervisors, Poster presentation and Powerpoint presentation by students</td></tr>
<tr><td colspan="6">Mode of assessment
Successful presentations and defense in critical discussion with fellow students and supervisors</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Successful presentations and defense in critical discussion; grade ascertained by supervisor group</td></tr>
<tr><td colspan="6">Module applicability
Master of Science Biochemistry</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted by CP</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
M. Lübben, R. Stoll, K. Gerwert, C. Kötting, T. Rudack, K. Barkovits, K. Marcus, M. Eisenacher, E. Hofmann, A. Mosig</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Special Lecture in the Focal Point: Proteins in Biomedicine					
Modul 3.17	Credits 5 CP	Workload 150 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Courses Special Lecture: Current Methods of Protein Biochemistry and Structural Biology – Expression, Purification and Structural Analysis of Proteins (184651)			**Contact hours** 28 h	**Self-study** 122 h	**Group size** ca. 10

Prerequisites:
Knowledge of basic concepts of Biochemistry lectures. Students should be members of the focal point "Proteins in Biomedicine".

Learning outcomes
In the special lecture "Current Methods of Protein Biochemistry and Structural Biology – Expression, Purification and Structural Analysis of Proteins" the basics of important subjects of structural biology, biospectroscopy, and mass spectrometry are deepened.

Content
The contents of the special lecture are:

- Cloning and Cell Biological Methods
- Protein Expression in *Escherichia coli* and *Pichia pastoris*
- Protein Folding
- Separation of Proteins and Peptides
- Protein Purification and Quantification
- Bioinformatic Methods of ProteinModelling - Use of Artifical Intelligence
- Introduction to Protein StructureDetermination I – NMR
- Introduction to Protein StructureDetermination II – X-ray
- Mass Spectrometry of Proteins
- Bioinformatic Methods in Proteomics
- Introduction to UV/Vis-, Raman- and FTIR-Spectroscopy
- Spatio-temporally Resolved FluorescenceSpectroscopy
- Biophotonics and Spectral Histopathology
- Bioinformatic Analysis of Spacially Resolved Spectral Data

Teaching methods
Lecture

Mode of assessment
Written exam

Requirement for the award of credit points
Passing the exam

Module applicability
Master of Science Biochemistry, also applicable for Bachelor of Science Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
M. Lübben / E. Hofmann, I. Vetter, R. Stoll, T. Rudack, K. Barkovits, S. Rozanova, K. Gerwert, C. Kötting, A. Mosig, F. Großerüschkamp, K. Marcus

Further information

Special Lecture in the Focal Point: Proteins in Biomedicine

Modul 3.18	Credits 5 CP	Workload 150 h	**Term** 2nd semester	**Frequency** only summer term	Duration 1 semester
Course Special Lecture: Proteins in Signal Transduction and Energy Conversion (185850)			**Contact hours** 28 h	**Self-study** 122 h	**Group size** ca. 10

Prerequisites:
Knowledge of basic concepts of Biochemistry lectures

Learning outcomes
In the special lecture "Proteins in Signal Transduction and Energy Conversion" current topics from the field of structural biology and of molecular physiology of medically related proteins is discussed. With the theoretical knowledge the students should be enabled to continue with specializing practicals and/or to start with their master thesis in one of the fields covered by the lecturers.

Content

- Introduction to Signal Transduction
- Domains in Signal Transduction
- Architecture of Membranes und Membranes
- Proteins –Transporters and Channels I
- The Role of Membrane Transporters II
- Receptors and Ion Channels in the Context of Neurological Diseases
- Principles of GTP Binding Proteins- The Superfamily of Ras Proteins
- Kinases and Phosphatases: Structure - Function - Relationships
- Structure and Function of the Proteasome
- Structure and Function of ATP Synthase
- Diabetes mellitus
- Signal Transduction in Cancer
- Basics of Immunology
- Immunological Strategies to Fight Cancer

Teaching methods
Lecture

Mode of assessment
Written exam

Requirement for the award of credit points
Passing the exam

Module applicability
Master of Science Biochemistry, also applicable for Bachelor of Science Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
M. Lübben / E. Hofmann, I. Vetter, R. Stoll, T. Rudack, K. Barkovits, S. Rozanova, K. Gerwert, C. Kötting, K. Marcus, F. Großerüschkamp

Further information

Focal Point Programme: Molecular Biology and Biotechnology of Plants and Microorganisms

<table>
<tr><td colspan="6">Special Lecture in the Focal Point: Molecular Biology and Biotechnology of Plants and Microorganisms</td></tr>
<tr><td>Modul 3.19</td><td>Credits
5 CP</td><td>Workload
150 h</td><td>Term
3rd semester</td><td>Frequency
only winter term</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Course
Special Lecture: Microbial Biotechnology (190515)</td><td>Contact hours
28 h</td><td>Self-study
122 h</td><td>Group size
ca. 10</td></tr>
<tr><td colspan="6">Prerequisites:
Knowledge of basic concepts of biochemistry and molecular biology</td></tr>
<tr><td colspan="6">Learning outcomes
Students develop an understanding of the application of biotechnological production processes and their realisation. They get to know current applications in white biotechnology. In short seminar papers they deal with limitations and challenges for research based on current results.</td></tr>
<tr><td colspan="6">Content
• Definition of biotechnology
• Basics of biotechnology
• Renewable resources and metabolism
• Fermentation
• Models of biotechnological processes (vitamins, polymers, ...)</td></tr>
<tr><td colspan="6">Teaching methods
Lecture</td></tr>
<tr><td colspan="6">Mode of assessment
Seminar paper, written exam</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
Regular attendance, seminar paper, passing the exam</td></tr>
<tr><td colspan="6">Module applicability
Master of Science Biochemistry, also applicable for Bachelor of Science Biochemistry, Bachelor of Science Biology, Master of Science Biology</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Weighted by CP</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
D. Tischler</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Modular Advanced Practicals in the Focal Point Programme

<table>
<tr><td colspan="6">Four modular practicals from four different focal points.</td></tr>
<tr><td>Module 3.20</td><td>Credits
16 CP</td><td>Workload
480 h</td><td>Term
1st semester</td><td>Frequency
only WS</td><td>Duration
1 semester</td></tr>
<tr><td colspan="3">Courses
The individual courses offered are listed on the following pages.</td><td>Contact hours
256 h</td><td>Self-Study
224 h</td><td>Group size
1–4 students</td></tr>
<tr><td colspan="6">Prerequisites
none</td></tr>
<tr><td colspan="6">Learning outcomes
Students learn advanced techniques applied in research labs of the different focal points involved in the studies course as well as theoretical aspects of the topics investigated in these labs.
Details on the learning outcomes of the individual courses can be found on the following pages.</td></tr>
<tr><td colspan="6">Content
See individual course descriptions.</td></tr>
<tr><td colspan="6">Teaching methods
Practical</td></tr>
<tr><td colspan="6">Mode of assessment
Varies between courses, usually active and successful participation in the practical and either a written project report, a presentation or a poster to present the results of the practical. Details for each individual course can be found on the following pages.</td></tr>
<tr><td colspan="6">Requirement for the award of credit points
See individual course descriptions.</td></tr>
<tr><td colspan="6">Module applicability (in other studies courses)</td></tr>
<tr><td colspan="6">Weight of the mark for the final score
Each of the four courses weighted by its CPs (4 CP for each course)</td></tr>
<tr><td colspan="6">Module coordinator and lecturer(s)
Module coordinator: I. Dietzel-Meyer
Lecturers: See individual course descriptions.</td></tr>
<tr><td colspan="6">Further information</td></tr>
</table>

Practical for Partial Fulfilment (1/4) of the Requirements for the Modular Advanced Practical in the Focal Point Programme

Heterologous expression of neurotransmitter receptors in frog oocytes					
Module 3.21	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses Heterologous expression of neurotransmitter receptors in frog oocytes (Focal Point Biochemistry of Membranes and the Nervous System)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 1–4 students
Prerequisites none					
Learning outcomes Students learn the electrophysiological techniques to functionally analyze ionotropic glutamate receptors in frog oocytes. They will use these techniques to characterize various functional and pharmacological features of ionotropic glutamate receptors. After the practical the students will be able to conduct basic electrophysiological experiments in the *Xenopus* oocyte expression system and to analyze and present the results of such experiments. They will have a basic understanding of the structure, function and pharmacology of ligand-gated ion channels, particularly ionotropic glutamate receptors.					
Content • Surgery to remove oocytes from *Xenopus laevis* frogs. • Injection of RNA into oocytes. • Recording ligand-gated ion channels with the two-electrode voltage clamp method. • Analysis of current-voltage relationships of ion channels. • Desensitization and inactivation of ion channels. • Pharmacology and modulation of ionotropic glutamate receptors.					
Teaching methods Practical					
Mode of assessment Assessment of active and successful participation in the practical (50%) and a written project report (50%)					
Requirement for the award of credit points Active and successful participation in the practical and a written project report.					
Module applicability (in other studies courses)					
Weight of the mark for the final score Weighted by CP					
Module coordinator and lecturer(s) D. Tapken					
Further information					

Neurotransmitter binding and pharmacology					
Module 3.22	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Biochemistry of Membranes and the Nervous System)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–3 students

Prerequisites
none

Learning outcomes
Communication in the central nervous system relies on chemical synapses, which release neurotransmitters that are then sensed by their corresponding target receptors. A key goal is to understand the dynamics of neurotransmitter release, diffusion, and uptake *in situ* as well as the molecular action of neurotransmitters at their membrane receptors. The development of genetically encoded fluorescent biosensors for glutamate (e.g. iGluSnFR), serotonin, dopamine and many other neurotransmitters and modulators has enabled to visualize neurotransmitter dynamics in real-time and opened new avenues for drug screening. After completion of the course the students will have (i) learned the design principles of fluorescent sensors for neurotransmitters, (ii) performed real-time imaging with one of these sensors in cultured cells, and (iii) obtained binding data of endogenous ligands as well as pharmacological compounds. Understanding the principles behind these approaches will allow students to work within the fields of receptor biochemistry, neuroscience and molecular pharmacology.

Content
This practical course is dedicated to modern methods in live cell imaging with fluorescent biosensors. It covers molecular engineering, cell culture and genetic delivery methods, wide-field fluorescence imaging and advanced data analysis. The following methods will be used:

- Work with eukaryotic expression plasmids, site-directed mutagenesis and sequences
- Eukaryotic cell culture and transfection
- Wide-field fluorescence imaging in combination with ligand perfusion
- Design and implementation of a fluorescent binding assay using a plate-reader

Teaching methods
A two-week all-day practical lab course

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (40%), and an oral presentation (10%).

Requirement for the award of credit points
Active and successful participation in the practical and a written project report.

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
A. Reiner

Further information

Watching sterol transporters at work: a synthetic biology approach					
Module 3.23	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Biochemistry of Membranes and the Nervous System)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2 students

Prerequisites
none

Learning outcomes
Sterols constitute an essential lipid class in eukaryotic membranes with intracellular levels and distribution being highly regulated. Disorders related to sterol transport cause severe diseases. Members of the ATP-binding cassette (ABC) transporter family are involved in sterol transport, but the underlying mechanisms are poorly understood. After completion of the course the students will be able to (i) grow and induce yeast cells in order to heterologously express membrane transporters, (ii) purify the detergent solubilized membrane protein through a Flag-tag affinity column, (iii) detect and quantify the amount of protein, (iv) reconstitute the trasporter into small vesicles of defined lipid composition; and (v) monitor its sterol transfer activity using a FRET-based assay.

Content
This practical course is dedicated to modern methods in sample preparation and characterization of membrane proteins for functional studies. It covers overexpression in yeast, membrane solubilization, affinity tag purification of the transporter, sample quality control, sample optimization and functional assays. The participants will study the yeast plasma membrane sterol transporter Aus1. The following methods will be employed:

- Grow and induce yeast cells transformed with plasmids containing the genes of interest.
- Preform membrane solubilization and affinity tag purification.
- Confirm presence and quantify the purified protein through SDS-PAGE and Western Blot
- Reconstitute the pump into small vesicles of defined lipid composition
- Adjust the settings of a FRET-based assay for the vesicle sample with reconstituted protein
- Monitor its activity using a FRET-based sterol transfer assay

Teaching methods
Practical

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (40%), and an oral presentation (10%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
S. Veit

Further information

Preparation and characterization of proteoliposomes with the main focus on single-vesicle microscopy					
Module 3.24	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Biochemistry of Membranes and the Nervous System)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2 students
Prerequisites none					
Learning outcomes After completion of the course students will have acquired basic practical skills in handling lipids, model membranes and membrane proteins. Students will get insight into the preparation and characterization of large unilamellar vesicles (LUVs) and the reconstitution of membrane transporters. Students will increase their knowledge concerning the characterization of membrane transporters in model membrane systems, regarding reconstitution efficiency, lamellarity, protein orientation and protein activity.					
Content Due to the amphipathic nature of membrane proteins, their reconstitution into model membranes is an essential approach for the investigation of individual features and activities of specific cell membrane components under both native like and chemically defined conditions. Established model-membrane systems used in ensemble average measurements are limited by sample heterogeneity and insufficient knowledge of lipid and protein content, which prevents quantitative analysis of vesicle properties, substrate transport, and their correlation with protein activity. The use of microscopy-based techniques reveals the connection between such properties on a single-vesicle level, thereby overcoming these drawbacks. The following methods will be employed: (i) Preparation of LUVs with defined lipid composition, (ii) detergent-mediated reconstitution of membrane transporters to obtain proteoliposomes, (iii) single vesicles containing fluorescent membrane proteins and lipid markers will be immobilized, imaged by confocal microscopy, and quantified by image analysis. Application of membrane-impermeant quenchers will allow for the determination of vesicle lamellarity, protein orientation, and reconstitution efficiency in the immobilized proteoliposomes. Techniques to characterize the proteoliposomes e.g. SDS-PAGE analysis, and fluorescence spectroscopy will be used.					
Teaching methods Practical					
Mode of assessment Assessment of active and successful participation in the practical (50%), a written project report (40%), and an oral presentation (10%)					
Requirement for the award of credit points Achievement of at least the mark “sufficient” regarding the above modes of examination					
Module applicability (in other studies courses)					
Weight of the mark for the final score Weighted by CP					
Module coordinator and lecturer(s) S. Veit, L. Paweletz					
Further Information					

Catch the Flippase

Module 3.25	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Biochemistry of Membranes and the Nervous System)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 3 students

Prerequisites
none

Learning outcomes
The eukaryotic plasma membrane is equipped with special proteins that actively translocate lipids from one leaflet to the other and thereby help generate membrane lipid asymmetry. Among these ATP-driven transporters, the P4 subfamily of P-type ATPases (P4-ATPases) comprises lipid flippases that catalyze the translocation of phospholipids from the exoplasmic to the cytosolic leaflet of cell membranes. However, despite their importance, their lipid specifity and their regulation remains poorly understood. After completion of the course the students will be able to (i) purify the detergent solubilized membrane protein through a FLAG-tag affinity column, (ii) detect and quantify the amount of protein, (iii) verify the activity of the purified protein using an ATPase assay. Understanding the principles behind the procedure and techniques in this course will allow students to work within the fields of membrane biology and membrane biochemistry.

Content
This practical course is dedicated to modern methods in sample preparation and characterization of membrane proteins for functional studies. It covers membrane solubilization, affinity tag purification of the transporter, sample quality control and sample optimization. The participants will study the plant flippase. The following methods will be employed:

- Perform membrane solubilization using different detergent and ratio
- Purify the protein using FLAG-tag affinity column.
- Confirm presence and quantify the purified protein through SDS-PAGE and Western blot.

Verify the activity of the purified protein using an ATPase assay.

Teaching methods
Practical

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (40%), and an oral presentation (10%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
H. D. Uzun

Further information

Membrane mimics: Where isolated membrane proteins dwell					
Module 3.26	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Biochemistry of Membranes and the Nervous System)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 1–2 students

Prerequisites
none

Learning outcomes
The characterization of membrane proteins presents its own challenges when compared to the study of water-soluble proteins. Localized in the lipid bilayer of cellular membranes, membrane proteins require hydrophobic regions to stay within the bilayer. These hydrophobic regions also render them less soluble in water and they therefore depend on amphiphilic membrane-like systems to mask hydrophobic protein regions in water-based assays. Students will familiarize themselves with multiple membrane mimics (detergents, co-polymer nanodiscs, liposomes) and experience their advantages and drawbacks.
A P-type ATPase will be solubilized (detergents, co-polymers) from isolated membranes and afterwards purified via affinity chromatography. Solubilized protein will be re-inserted into artificial liposomes and protein activity assays will give insight into the impact of the respective membrane mimic on protein function.

Content
- solubilization of membranes via detergents or co-polymers
- affinity purification via tagged protein constructs
- reconstitution of target protein from nanodiscs or detergent micelles into artificial liposomes
- protein activity assays for solubilized and compartmentalized systems
- SDS-PAGE and Western Blotting to track the target protein
- comparison between different membrane-like systems for the characterization of membrane proteins

Teaching methods
Practical

Mode of assessment
Assessment of active and successful participation in the practical (50%) and a written project report (50%)

Requirement for the award of credit points
Active and successful participation in the practical and a written project report.

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
T. Günther-Pomorski, E. Malysenko

Further information

Raman spectroscopy of biochemical molecules in response to temperature and pH changes					
Module 3.27	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Biomolecular Chemistry)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 1–3 students
Prerequisites Knowledge of basic laboratory techniques and basic laser spectroscopy methods					
Learning outcomes Students acquire practical skills in operating a Raman microscope/spectroscope and in preparing biochemical samples. The aim is to track pH/temperature-induced changes using Raman spectroscopy and the correct scientific analysis of the data.					
Content • Safety instruction briefing including laser safety regulations • Seminar – Correct operation of the instruments in the practical course – Principles of lasers – Microscopy (contrast methods, transmission, reflection, interference, diffraction, light and dark-field, phase contrast, resolution, confocality, optical elements, focusing laser beams, optical imaging) – Basic concepts of quantitative analysis using optical systems (concentration-dependent absorbance, absorption measurements, molar extinction coefficient) – Raman spectroscopy of biomolecules in combination with a thermal module – Influence of pH and temperature changes on biomolecules, e.g. glycine or AMP • Practical Course – Microscopic/spectroscopic data of calibration samples (determination of resolution, determination of sharpness using gratings) – Preparation of nucleotide and amino acid solutions – pH/temperature-induced changes in biochemical samples by Raman spectroscopy – The intensive three-day introduction to the laser microscope and measurement of calibration samples enables the students to carry out the experiments themselves. The supervisors are available to answer questions. – Introduction to the correct analysis of spectroscopic data using Mathematica. – The content of this practical will be discussed with the participants beforehand.					
Teaching methods full-time two-week practical lab course in a research group with compulsory seminar presentation of the obtained results or a written project report					
Mode of assessment Assessment of active and successful participation in the practical (50%) and a written project report or oral presentation of the results (50%)					
Requirement for the award of credit points Achievement of the minimum grade of “sufficient” in the above examinations					
Module applicability (in other studies courses)					
Weight of the mark for the final score Weighted by CP					
Module coordinator and lecturer(s) S. Henkel, M. Havenith-Newen and coworkers from Physical Chemistry II					
Further information					

Bioinorganic Chemistry

Module 3.28	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Course (Focal Point Biomolecular Chemistry)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2 students

Prerequisites
none

Learning outcomes
After successful completion of the course, students have
- An understanding of the synthetic challenges in making metal bioconjugates
- Practical experience in their synthesis and characterization
- Performed basic biological and / or cell culture experiments

Students are able
- To analyze spectroscopic data on metal complexes and their bioconjugates
- Critically analyze the outcome of biological experiments on metal complexes
- Find, read, and critically comment on pertinent literature on the subject

Content
The course combines chemical synthesis of bioactive metal complexes and/or their bioconjugates with biological investigation of their properties. A variety of experiments are offered that all include the following elements:
- Synthesis of metal complexes (e.g. derivatives of $Ru(bipyridine)_3$, Cisplatin or Carboplatin, $Re(CO)_3L_3$, $Mn(CO)_3L_3$, etc.) and/or bioconjugates thereof (e.g. with cell penetrating or intracellular signaling peptides, proteins, PNA)
- Characterization of the metal complexes and bioconjugates with modern analytical methods (e.g. HPLC, MS, NMR, IR, UV-vis, fluorescence)
- Study of their biological behavior (e.g. cytotoxicity on cancerous and normal cell lines, DNA binding and cleavage, CO release, intracellular localization and fluorescence) as applicable to the properties of the metal complexes.

Teaching methods
Lab Practical

Mode of assessment
Assessment of active and successful participation in the practical (50%) and a written project report (50%)

Requirement for the award of credit points
Assessment of active and successful participation in the practical (50%), submission of a written project report that meets the requirements (50%)

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
N. Metzler-Nolte and coworkers from Inorganic Chemistry I – Bioinorganic Chemistry

Further information

Biophysical Chemistry					
Module 3.29	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Course (Focal Point Biomolecular Chemistry)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2 students

Prerequisites
none

Learning outcomes
After successful completion of the course, students have
- Purified and characterized a recombinant protein
- Quantified the affinity with binding partners and substrates
- Obtained rate constants of binding and enzymatic turn-over

Students are able
- To purify recombinant proteins from bacterial lysates by chromatographic techniques
- To critically analyze biomolecular interactions and enzymatic activity
- To judge the experimental results obtained in the practical course in the context of scientific literature in related fields of research.

Content
The course combines bacterial synthesis of proteins, their purification and basic biochemical characterization in the first week. The second week is devoted to the application of one or two biophysical techniques to address thermodynamic and kinetic characteristics of protein interactions and enzymatic activity. A variety of experiments can be selected for this purpose:
- Purification of proteins from bacterial cell lysates with the help of affinity chromatography, ion exchange chromatography and size exclusion chromatography
- Quantification of binding affinity through fluorescence spectroscopy and isothermal titration calorimetry.
- Investigation of binding kinetics by stopped flow and temperature jump experiments with the help of fluorescence detection.

Teaching methods
Lab Practical

Mode of assessment
Assessment of active and successful participation in the practical (50%) and a written project report (50%)

Requirement for the award of credit points
Assessment of active and successful participation in the practical, submission of a written report that meets the requirements

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
C. Herrmann and coworkers from Physical Chemistry I

Further information

Expression and spectral characterization of microbial retinal proteins

Module 3.30	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–3 students

Prerequisites
none

Learning outcomes
Students will acquire an overview on advanced applications to adress issues in an ongoing research project. They will be introduced to independent laboratory work and gain insights to recent research topics in biochemical and biophysical analysis of the function of a selected microbial retinal protein. Expression host of proteins will be either the eubacterium *Escherichia coli* or the eukaryote *Pichia pastoris*. Depending on the expression system, the students will learn the molecular biological handling of the respective organism, and the isolation and biophysical characterization of membrane proteins which are applied in optogenetics.

Content
Safety instructions
Practical course

- Preparation of fermentation media
- Plasmid amplification and transformation of the *Pichia pastoris* or *Escherichia coli* expression strain
- Expression of microbial rhodopsin in *Pichia pastoris* or *Escherichia coli*
- Membrane preparation and detergent solubilization
- Chromatographic purification using affinity and gel filtration techniques
- Identification of the purified protein by Western blotting
- Measurement of light-driven proton pumping of *E. coli* expressing the microbial retinal protein

Teaching methods

- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
M. Lübben

Further information
Review and specific research literature will be handed out in time

Expression, Purification and FTIR spectroscopic investigation of GTPases					
Module 3.31	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–3 students

Prerequisites
none

Learning outcomes
Students will acquire an overview on advanced applications to adress issues in an ongoing research project. They will be introduced to independent laboratory work and gain insights to recent research topics in biochemical and biophysical analysis of the function of a selected microbial retinal protein. Expression host of proteins will be either the eubacterium *Escherichia coli* or the eukaryote *Pichia pastoris*. Depending on the expression system, the students will learn the molecular biological handling of the respective organism, and the isolation and biophysical characterization of membrane proteins which are applied in optogenetics.

Content
Safety instructions
Practical course
- Heterologous expression of a GTPase
- Purification of the protein by ion exchange, gel filtration and/or affinity chromatography
- Nucleotide exchange from GDP to caged-GTP, control of the exchange by HPLC
- Start of the reaction by a XeCl excimer laser flash and time resolved FTIR of the purified protein
- Discussion of the obtained infrared spectra and kinetics

Seminar
- Protein expression and isolation
- FTIR difference spectroscopy of proteins
- Discussion of the results (Note that this outline is an example, the actual content can vary)

Teaching methods
- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
C. Kötting

Further information
Review and specific research literature will be handed out in time

Proteins: Structure and Biological Function – Protein crystallography					
Module 3.32	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–3 students

Prerequisites
none

Learning outcomes
After completion of the course students will have acquired basic practical skills in the expression and purification of soluble proteins for structural biology. They will also have had first practical experience with protein crystallization and single crystal X-ray diffraction.

Content
Safety instructions
Practical course

- Starting from an expression plasmid, students will introduce them into a suitable E. coli expression strain, grow large cell cultures for protein preparation. Standard purification techniques like centrifugation and fast protein liquid chromatography with Aekta-Systems will be used to obtain pure protein for structural studies. Progress of purification will be followed by SDS-page analysis.
- The purified protein will be used to set up crystallization screens in order to obtain 3D-crystals suitable for X-ray analysis.
- Crystals will be analyzed with the inhouse diffractometer.

Teaching methods

- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Eeighted by CP

Module coordinator and lecturer(s)
E. Hofmann

Further information
Review and specific research literature will be handed out in time

MD simulations on selected transmembrane proteins – microbial rhodopsins

Module 3.33	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–5 students

Prerequisites
none

Learning outcomes
Students will acquire an overview on advanced applications to adress issues in an ongoing research project. They will be introduced to independent computational research and gain insights to recent research topics in theoretical simulations of selected transmembrane proteins. The respective content of the project depends on and is taken from the current research at the Department of Biophysics

Content

- Basics of Molecular Dynamics simulations: Molecular Mechanics, force field concept
- Usage of MD, visualization, and modeling programs
- Combining, comparing, and assessing computational and experimental results
- Theoretical quantum chemistry to calculate Infrared (IR) or UV/VIS spectra
- Application of MD simulations on virtually constructed site-specific mutations in retinal proteins
- Calculation, visualization, and analysis of structural dynamics of biomedical relevant proteins e. g. for optogenetic applications by identification of light induced formation of channels in transmembrane proteins, such as channelrhodopsin

Teaching methods

- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
T. Rudack

Further information
Review and specific research literature will be handed out in time

NMR spectroscopy of proteins – practice and data evaluation

Module 3.34	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–3 students

Prerequisites
none

Learning outcomes
The students should become acquainted with the fundamentals of preparing and purifying isotopically enriched (^{15}N, ^{13}C) protein samples. Furthermore, the theoretical and technical basics of multidimensional heteronuclear biomolecular nuclear magnetic resonance (NMR) spectroscopy will be discussed. This will put the students into the position to record and analyse multidimensional NMR spectra and to ultimately determine the structure of biomolecules at atomic resolution.

Content
Safety instructions
Practical course

- Biochemistry of Proteins
- Cloning and purification of isotopically enriched (^{15}N, ^{13}C) protein samples
- Introduction to theoretical fundamentals of multidimensional NMR spectroscopy
- Introduction to recording and analysing multidimensional NMR spectra
- Use of NMR data bases
- Structure determination based on NMR data
- Validation of calculated molecular structures

Teaching methods

- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
R. Stoll

Further information
Review and specific research literature will be handed out in time
www.rub.de/bionmr

Practical Bioinformatics of Proteomics

Module 3.35	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–3 students

Prerequisites
none

Learning outcomes
The students will be made familiar with a typical identification / quantification workflow in mass spectrometry based Proteomics. Furthermore, they will gain insight into programming / utilization of workflow tools (e.g. knime)

Content
Safety instructions
Practical course

- Setup of programming/workflow environment
- Inspection of existing analysis packages and modules and programming/workflow mechanisms
- Implementation of identification/quantification workflow on a benchmark data set with existing quantification values:
  - data handling (e.g. conversion of spectra files)
  - spectrum identification (with one or more search engines)
  - false-discovery-rate estimation with decoy approach
  - protein inference (assembling peptides to proteins)
  - label-free quantification (e.g. spectral counting or LC-MS map-based)
- Calculation of fold change and p-value (statistical significance)
- Conversion of results into standard formats
  - Annotation of result list with existing knowledge (enrichment analysis or pathway analysis)

Teaching methods

- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
M. Eisenacher

Further information
Review and specific research literature will be handed out in time

Proteomics methods in clinical research

Module 3.36	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–4 students

Prerequisites
none

Learning outcomes
Students will gain insight into modern proteomics methods and their application in clinical research. They are introduced to independent laboratory work and receive accompanying seminars on topics related to the methods used, such as sample preparation for mass spectrometric analysis, mass spectrometry and interpretation of mass spectrometric proteomic data, as well as insights into current research topics in clinical proteomics.

Content
Safety instructions
Practical course

- Sample preparation, in particular preparation of total protein lysates
- 1D/2D gel electrophoresis
- Western blot
- Sample preparation for mass spectrometry-based analysis using different approaches (e.g. proteolytic digestion, peptide fractionation, peptide purification)
- Mass spectrometry-based analyses (LC-ESI-MS and MALDI-MS)
- Data analysis and interpretation

Teaching methods

- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results and/or current publications in the research field of clinical proteomics.

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
K. Barkovits-Boeddinghaus (For the research departments of K. Marcus and B. Sitek)

Further information
Review and specific research literature will be handed out in time.

Label-free infrared imaging of human tissues for cancer diagnostics

Module 3.37	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Proteins in Biomedicine)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–3 students

Prerequisites
none

Learning outcomes
The students will be made familiar with state-of-the-art infrared microscopes and data analysis used in biomarker research for the early detection of diseases such as cancer. Therefore, human tissue thin sections will be measured with spatial and spectral resolution. The data will then be analysed with bioinformatics methods so the students will also acquire basic skills in bioinformatics (e.g. machine learning).

Content
Safety instructions
Practical course
- measurement of tissues (colon, lung or bladder) by infrared microscopy
- evaluation of the results by bioinformatics
  - Basics in Python
  - cluster analysis
  - classical machine learning (Random Forest)
  - deep learning (convolutional neural networks)
- Discussion of the obtained images and spectra
- Origin of the tissues
- Instrumental setups

Teaching methods
- A two-week all-day practical lab course in a research group
- A compulsory seminar presentation of the obtained results

Mode of assessment
Assessment of active and successful participation in the practical (50%), a written project report (25%), and the oral presentation of the experimental results (25%)

Requirement for the award of credit points
Achievement of at least the mark “sufficient” regarding the above modes of examination

Module applicability
M. Sc. Biochemistry

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
F. Großerüschkamp

Further information
Review and specific research literature will be handed out in time.
www.prodi.rub.de

Bacterial natural products					
Module 3.38	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Molecular Biology and Biotechnology of Plants and Microorganisms)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 1–3 students

Prerequisites
none

Learning outcomes
After completion of the course students will have learnt to cultivate bacteria, to isolate natural products from bacterial cultures and to characterize natural products using chromatographic and spectroscopic methods.

Content
- Preparation of complex and chemically defined media.
- Handling of vegetative bacteria and spores. Harvesting cells and culture supernatants.
- Liquid/liquid extraction.
- Chromatographic separation of natural products.
- Mass spectrometry-based analysis.
- Students participate in an active research project for two weeks.

Teaching methods
Practical

Mode of assessment
Assessment of active and successful participation in the practical (50%) and a written project report (50%)

Requirement for the award of credit points
Active and successful participation in the practical and a written project report.

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
J. Bandow and teaching assistants

Further information

Antibiotic Mechanisms					
Module 3.39	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Focal Point Molecular Biology and Biotechnology of Plants and Microorganisms)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 1–3 students
Prerequisites none					
Learning outcomes After completion of the course students will have learnt to cultivate bacteria, to isolate protein from bacterial cultures and to analyze bacterial proteins and proteomes.					
Content • Preparation of chemically defined media. • Handling of vegetative bacteria. Harvesting and disrupting bacterial cells. • Protein separation by isoelectric focusing, SDS-PAGE, analysis of 2D gels. • Or: protein digest and LC-MS/MS-based proteome/protein analysis. • Students participate in an active research project for two weeks.					
Teaching methods Practical					
Mode of assessment Assessment of active and successful participation in the practical (50%) and a written project report (50%)					
Requirement for the award of credit points Active and successful participation in the practical and a written project report.					
Module applicability (in other studies courses)					
Weight of the mark for the final score Weighted by CP					
Module coordinator and lecturer(s) J. Bandow and teaching assistants					
Further information					

Rational design of a 4-phenol oxidase

Module 3.40	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 2 weeks
Courses (Molecular Biology and Biotechnology of Plants and Microorganisms)			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 2–4 students

Prerequisites
Knowledge of basic laboratory techniques in molecular biology and chemical synthesis

Learning outcomes
White biotechnology is an emerging field in chemical industry offering green alternatives and additions to the repertoire of classical chemical methods. A key point for this development is the targeted improvement of nature's catalysts – enzymes – beyond their natural scope using either rational design or directed evolution.
An important step in multi cascade reactions is the activation of sole carbon moieties. Bacterial 4-phenol oxidases fulfill this task site- and stereo-selectively while requiring only molecular oxygen as co-substrate. These enzymes perform the oxidation of C–C, C–O and C–N bonds as well as hydroxylation reactions. This high promiscuity will be used to tailor an improved catalyst using the methods mentioned above.

Content
This practical course is dedicated to gain and apply knowledge for practical enzyme design and the effective use of biocatalysts. For this, a mutant library of a 4-phenol oxidase will be produced by rational design and transformed in an *E. coli* host for overproduction in a 96-well format. Screening will be performed in a cell-free crude extract for altered substrate scope and improved variants will be selected for sequencing. Mutations will be further analyzed by bioinformatic methods before positive hits will be applied in whole cell biocatalysis. Product formation will be tracked by GC-MS measurements. The following methods will be applied:

- Mutagenesis:
  - PCR
  - Transformation in *E. coli*
  - Photometric 96-well plate screening
- Biocatalysis:
  - Overproduction of enzymes in *E. coli*
  - GC-MS analytics
- Bioinformatics:
  - Structure analysis using PyMol and Yasar

Teaching methods
Practical, a two-week all-day practical lab course

Mode of assessment
Assessment of active and successful participation in the practical (60%), a written project report in form of a scientific short communication (40%)

Requirement for the award of credit points
Achievement of at least the mark "sufficient" regarding the above modes of examination.

Module applicability (in other studies courses)

Weight of the mark for the final score
Weighted by CP

Module coordinator and lecturer(s)
D. Tischler, N. Weindorf

Further information

Twelve courses offered in the Focal Point Molecular Medicine					
Module 3.41	Credits 4 CP	Workload 120 h	**Term** 1st semester	**Frequency** only winter term	Duration 1 semester
Courses Twelve courses offered in the Focal Point Molecular Medicine (see below).			**Contact hours** 64 h	**Self-Study** 56 h	**Group size** 1–4 students

Prerequisites
none

Learning outcomes
Students learn advanced techniques applied in research labs of the focal point Molecular Medicine as well as theoretical aspects of the topics investigated in these labs.
Details on the learning outcomes of the individual courses can be found on the following pages.

i. After completion of the course, students will have acquired the basic practical skills in the generation of dendritic cells in vitro; Purification of T-helper cells from whole spleen cells by magnetic sorting; Flow cytometry; Cell culture; ELISA
ii. After completion of the course, students will have acquired the basic practical skills in PCR technology, Primer design for PCR, Vector cloning, Plasmid preparation, DNA sequencing
iii. After completion of the course, students will have acquired basic practical skills in genomic DNA isolation of own buccal swabs; Genomic DNA isolation of own white blood cells ; Agarose gel electrophoresis; HLA-D typing for *DRB1* and *DQB*1 genes by PCR with sequence-specific primers (SSP-PCR) and other methods (i.e. non-radioactive sequencing); SNP analyses of certain genes like *GSTM1*, *GSTT1* and *GSTP1* using two different techniques (PCR-RFLP and Real-time PCR) and two different DNA sources (buccal swabs and EDTA blood); Deduction of the acetylation status by analysis of seven SNPs in the *NAT2* gene by a combination of sequencing and LightCycler analyses.
iv. After completion of the course, students will have acquired the basic practical skills in DNA extraction; Mutation analysis: HRM analysis, Sanger sequencing, Pyrosequencing; Promotor methylation analysis: Pyrosequencing, MSP analysis
v. After completion of the course, students will have acquired the basic practical skills Gene transfer into mammalian cells; Protein-protein interactions; Mechanism of ubiquitination: E1, E2, and E3 enzymes; Different modes of ubiquitination; Functional consequences of ubiquitination
vi. After completion of the course, students will have acquired the basic practical skills in cell culture and isolation of CD34+ cells from whole blood and leukemia cell lines, Phenotypic characterization of cancer stem cells by FACS analysis, Characterization of cancer stem cells by immunocytochemical methods (ICC)
vii. After completion of the course, students will have acquired the basic practical skills in gene transfer into mammalian cells; Protein-protein interactions; Mechanism of cell death; Intracellular trafficking of protein; Import into the endoplasmic reticulum
viii. After completion of the course, students will have acquired the basic practical skills in the preparation of protein extract by using different protein extraction procedures, protein determination by different methods, SDS-PAGE, electrophoresis, silver-staining, IgE immunoblotting (allergogram with sera from sensitized patients), IgG immunoblotting with sera from immunized rabbits, inhibition immunoblot, performance of ELISA measurements, characterization of cross-reactivity, allergen quantification in of allergens in processed extracts.
ix. After completion of the course, students will have acquired basic practical practical skills to study the interaction of dendritic cells with T-lymphocytes, generation of dendritic cells in

vitro; purification of T-helper cells from whole spleen cells by magnetic sorting; Flow cytometry; Cell culture; ELISA

x. After completion of the course, students will have acquired the basic practical skills in standard experimental designs, good laboratory practice, insights into protein redox biology, introduction to a variety of redox biology methods. Physiological stress experiments with E. coli; Cell culture of immune cell lines; Co-cultivation of immune cells and bacteria; Characterization of redox-active proteins with UV-VIS, CD, mass spectrometry, SDS PAGE, Western blot, HPLC; Molecular biology, rational mutagenesis of proteins; Protein purification.
xi. After completion of the course, students will have acquired basic practical skills in biochemical, microbiological and molecular biological methods. The students will learn how to isolate protein complexes by affinity chromatography and how to characterize these complexes according to their size (size-exclusion chromatography) and constituents (SDS-PAGE, immunoblotting).
xii. After completion of the course, students will have acquired basic practical skills in testing biomaterial according to DIN EN ISO 109903 and beyond. This includes qualitative and quantitative analyses of cell viability, toxicity, and apoptosis of cells on electro-spun, surface-functionalized biomaterials; 3D bioprinting of cells mixed in tissue-specific bioink, subsequent culture, biochemical and mechanical analyses of biomaterial.

Content

i. Schmitz, Peters: Interaction of dendritic cells with T-lymphocytes.
ii. Hahn: PCR and vector cloning
iii. Brüning, Rihs: HLA-D typing and LightCycler applications
iv. Tannapfel: Molecular pathology
v. Winkelhofer: Analysis of protein ubiquitination
vi. Strumberg: Cancer stem cells and molecular oncology
vii. Tatzelt: Protein misfolding and neurodegeneration
viii. Raulf: Allergy research – from the production of allergen extract to allergen characterization
ix. Leichert: Redox Biology
x. Erdmann: Characterization of proteins isolated from peroxisomes and
xi. peroxisomal membranes of the yeast Saccharomyces cerevisiae.
xii. Salber: Biocompatibility assessment and biomanufacturing of 3D tissue constructs

Teaching methods

Practical

Mode of assessment

Successful participation in the practical and written project report.

Requirement for the award of credit points

Successful participation in the practical

Module applicability (in other studies courses)

Weight of the mark for the final score

Weighted by CP

Module coordinator and lecturer(s)

See content.

Further information