Friedrich-Alexander-Universität
Erlangen-Nürnberg

Module description

for the degree programme

Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics

(Version of examination regulation: 20192)

Table of contents

1	**Module name** 48081	**Advanced Module**	**20 ECTS**
2	Courses / lectures	No courses / lectures available for this module! The module has a workload of 600 hours, which are individually divided in contact hours and time for independent study (depending on the subject and research group.)	
3	Lecturers	No lecturers available since there are no courses / lectures for this module!	

4	**Module coordinator**	Prof. Dr. Rainer Böckmann
5	**Contents**	The advanced module can be chosen from courses and lectures of the Departments of Biology, Mathematics or Physics. It is designated to be a preparation for the Master thesis. Beside the work on a scientific project the module can include advanced lectures or special seminars of the respective Department which will be recommended by the advisor.
6	**Learning objectives and skills**	The students are • familiar with the actual topics of the respective research area • able to discuss the actual topics of the research area critically • able to understand the modern methods and their application in science • able to develop independently complex ideas and strategies • able to work and learn independently
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 3
9	**Module compatibility**	Pflichtmodul Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Oral (30 minutes)
11	**Grading procedure**	Oral (100%)
12	**Module frequency**	every semester
13	**Workload in clock hours**	Contact hours: - Independent study: -
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	none

1	**Module name** 48071	**Introduction to Statistics and Statistical Programming** Introduction to statistics and statistical programming	**5 ECTS**
2	Courses / lectures	Vorlesung: Introduction to Statistics and Statistical Programming (2 SWS) Übung: Computer lab classes "Introduction to Statistics and Statistical Programming" (1 SWS) Übung: Problem session "Introduction to Statistics and Statistical Programming" (1 SWS) Tutorium: Review session "Introduction to Statistics and Statistical Programming" (1 SWS) Review session: participation voluntary	- - - -
3	Lecturers	Prof. Dr. Christophorus Richard	

4	**Module coordinator**	Prof. Dr. Christophorus Richard
5	**Contents**	• Introduction to the statistical software R and elementary programming • Descriptive statistics: visualisation and parameters of categorial and metric data, qq-plot, curve fitting, log- and loglog-plots, robust techniques • Inferential statistics: methods for estimating and testing: parametric tests, selected non-parametric tests, exact and asymptotic confidence regions • Simulation: random numbers, Monte carlo
6	**Learning objectives and skills**	The students are able to • describe and explain standard techniques in descriptive and inferential statistics. • explain their solution of a non-trivial statistical problem to other people and to discuss alternative solutions within a group. • perform statistical standard analyses within a prescribed time limit on the computer, and to correctly interpret the computer output. • perform elementary statistical simulations. • formulate adequate questions concerning a given data set, suggest correct methods for analysis, and to implement these on the computer.
7	**Prerequisites**	Stochastische Modellbildung (strongly recommended)
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	MG1: Mathematical Modelling and Systems Biology Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20152 MG2: Bioimaging and Biophysics Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20152 MG3: Biological Structures and Processes Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20152

		Pflichtmodul Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Tutorial achievement Written examination (90 minutes)
11	**Grading procedure**	Tutorial achievement (0%) Written examination (100%)
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Lecture notes • Rice: Mathematical Statistics and Data Analysis; Thomson, 2007 • www.cran.r-project.org

1	**Module name** 1999	**Master thesis (M.Sc. Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192)** Master's thesis	**30 ECTS**
2	Courses / lectures	No courses / lectures available for this module! The Master Thesis has a workload of 900 hours, which are individually divided in contact hours and time for independent study (depending on the subject and research group.).	
3	Lecturers	No lecturers available since there are no courses / lectures for this module!	

4	**Module coordinator**	Prof. Dr. Rainer Böckmann
5	**Contents**	Independent work on an actual topic of the respective research area within a fixed period (6 months) • make up a scientific report • oral presentation and discussion of the results (30 min) within a seminar
6	**Learning objectives and skills**	The students are • able to work independently with scientific methods on a specific task • demonstrate their ability to apply experimental, theoretical, and/or computational approaches on adequately challenging biophysical or biomathematical research topics • are able to describe and discuss their results professionally in form of a scientific manuscript • able to present the results of the scientific project in a report • are able to apply the acquired skills in future.
7	**Prerequisites**	60 ECTS in MA Integrated Life Sciences
8	**Integration in curriculum**	semester: 4
9	**Module compatibility**	Pflichtmodul Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Course achievement Written (6 Monate) PL: Master thesis approx. 20000 words SL: Scientific report 30 min.
11	**Grading procedure**	Course achievement (0%) Written (100%) Master thesis 100%
12	**Module frequency**	every semester
13	**Resit examinations**	The exams of this moduls can only be resit once.
14	**Workload in clock hours**	Contact hours: - Independent study: -
15	**Module duration**	1 semester
16	**Teaching and examination language**	english

17	**Bibliography**	-

MG1: Mathematical Modelling and Systems Biology

1	**Module name** 48091	**Biomathematics**	**10 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Vasily Zaburdaev
5	**Contents**	• Systems of difference equations and of ordinary differential equations • Existence and uniqueness of solutions, steady-state solutions, linear stability analysis • Qualitative behavior and phase plane analysis • Discrete and continuous models for interacting populations (predator-pray models, competition models, mutualism and symbiosis) • Epidemic models and the dynamics of infectious diseases • Reaction kinetics (mass-action, enzyme kinetics) • Regulation mechanisms in biological systems • Excitable systems and dynamic behavior of neuronal membranes
6	**Learning objectives and skills**	Students are able to • analyse and simulate systems of ordinary differential equations • possess profound knowledge in the area of mathematical modelling of processes in biology • recognise the most important underlying mechanisms in biochemical and biophysical systems and give quantitative descriptions • acquire problem-oriented learning stategies and improve their skills in interdisciplinary approaches
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	MG1: Mathematical Modelling and Systems Biology Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: Oral examination 30 min. SL: Paper- and Computer exercises as a measure of performance level (exercise book; approx. 50 pages)
11	**Grading procedure**	Portfolio (100%) Oral examination 100%
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	• Systems Biology. A Textbook, Klipp, Liebermeister, Wierling, Kowald, Lehrach, Herwig,2010. • A course in Mathematical Biology, de Vries, Hillen, Lewis, Müller, Schönfisch, 2006

1	**Module name** 48101	**Systems Biology**	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Uwe Sonnewald
5	**Contents**	**Lecture:** The contents of the module deal with the following research topic in systems biology: • Genomics • Transcriptomics • Proteomics • Metabolomics • Network analayis • Computer models for biological pattern formation **Laboratory course:** Using experimental and computational approaches biological processes in cells, organs and organisms will be quantitatively analysed. Furthermore, next generation sequencing methods (NGS), and array-based transcriptome studies will be demonstrated.
6	**Learning objectives and skills**	Students are able to • explain the general principles of genomics, transcriptomics, proteomics and metabolomics. • describe basically the technological basis of omics technologies. • Understanding of bioinformatics in data mining and storage • analyse and to recognize patterns in complex protein, DNA or RNA data and to develop hypotheses on the basis of omics data • explain and distinguish biological processes at the systems level • independently solve biological questions with computational methods • apply conceptual application of quantitative models in biology • independently develop working hypotheses and to adapt existing models and programs to test these hypotheses • perform independent further training
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	MG1: Mathematical Modelling and Systems Biology Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written examination (60 minutes)
11	**Grading procedure**	Written examination (100%)
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 45 h

		Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

Mandatory Elective Modules Group 1

1	**Module name** 42291	**Bioanalytics**	**7,5 ECTS**
2	Courses / lectures	Seminar und Übung: Orientierungsmodul Biochemie IV: Bioanalytik (BCMA4) (8 SWS)	7,5 ECTS
3	Lecturers	Prof. Dr. Uwe Sonnewald Dr. Jörg Hofmann Dr. Christian Lamm	

4	**Module coordinator**	Prof. Dr. Uwe Sonnewald
5	**Contents**	**Lecture and Seminar:** The contents of the module deal with the following research topics in systems biology: • Plant transformation techniques • Agricultural Biotechnology • Metabolomics • Proteomics • Transcriptomics **Laboratory course:** The practical work will be a comparative analysis of different plant genotypes or of plants grown under different environmental conditions. Analysis will include metabolite extraction and analysis using HPLC-MS/MS as well as proteome analysis by mass spectrometry.
6	**Learning objectives and skills**	Students will acquire the following skills: • General understanding of proteomics and metabolomics. • The ability to design and conduct comparative metabolomics and proteomics experiments • The ability to recognize patterns in complex protein and metabolite data with the help of multivariate data analysis and to develop hypotheses on the basis of these data • A good understanding of biological processes at the systems level • The ability to independently solve biological questions using metabolomics and proteomics experiments • The ability of independently develop working hypotheses and to test these.
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: oral exam 30 min. SL: written protocol 20 p. SL: presentation 30 min.
11	**Grading procedure**	Portfolio (100%) oral exam 100%
12	**Module frequency**	only in summer semester

13	**Workload in clock hours**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	not required

1	**Module name** 48201	**Complex Systems I** Complex systems I	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lecturers	-	

4	**Module coordinator**	PD Dr. Claus Metzner
5	**Contents**	Power laws, phase transitions, Ising model, percolation, selforganized criticality, graphs, regular and random networks, real world networks, Barabasi-Albert model, Watts-Strogatz model, applied network theory, optimization, fitness landscapes, Monte-Carlo and simulated annealing, evolutionary optimization, evolution dynamics, genetic drift, discrete optimization, genetic programming, reaction processes, rate equations, Michaelis-Menton kinetics, covalent modification cycles, ultra-sensitivity, hysteresis, chemical oscillators, signal networks in cells, chemotaxis of E. Coli, cybernetics, control loops, entropy and information, reaction-diffusion systems, Turing mechanism, morphogenesis
6	**Learning objectives and skills**	• Intuitive understanding of multidisciplinary problems in the field of critical phenomena, networks, evolutionary dynamics, reaction systems; • Understanding of basic theoretical concepts, mathematical and computer simulation methods; • Ability to use the methods and concepts in exercises; • Training of analytical, critical thinking and model building.
7	**Prerequisites**	Required knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written examination (90 minutes)
11	**Grading procedure**	Written examination (100%)
12	**Module frequency**	Unregelmäßig
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Material on the various specific topics is provided during the course.

1	**Module name** 48211	**Complex Systems II** Complex systems II	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Complex Systems: Econo/Socio physics, continuum dynamical systems (4 SWS)	5 ECTS
3	Lecturers		

4	**Module coordinator**	PD Dr. Claus Metzner
5	**Contents**	**Contents** Dynamics of car traffic and passengers, epidemiology, SIR model, city growth, voting dynamics, egoism and cooperation, economy and physics, market equilibrium, El-Farol bar problem, minority games, evolution and innovation, lock-in, stock market fluctuations and modelling, portfolio optimization, phase space dynamics, attractors, time series, dynamical systems theory, chaos theory, quantum chaos.
6	**Learning objectives and skills**	The students are able to: • understand intuitively multidisciplinary problems in the field of Econo/Socio physics, continuum and discrete dynamical systems; • understand intuitively multidisciplinary problems; • understand the basic theoretical concepts, mathematical and computer simulation • methods; • use the methods and concepts in exercises; • apply analytical, critical thinking and model building.
7	**Prerequisites**	Required knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written examination (90 minutes)
11	**Grading procedure**	Written examination (100%)
12	**Module frequency**	Unregelmäßig
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

1	**Module name** 48216	**Complex Systems III** Complex systems III	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lecturers	-	

4	**Module coordinator**	PD Dr. Claus Metzner
5	**Contents**	Synchronization, Kuramoto theory, self-organization, swarm dynamics, stigmergy, synergetics, Bayesian learning, game theory, Nash equilibrium, minimax solution, mixed strategies, imperfect information, evolutionary game theory, prisoner's dilemma, strategies with memory, self-organizing cooperation, cellular automata, coupled map lattices, boolean networks, Kauffman N-K networks.
6	**Learning objectives and skills**	The students are able to: • understand intuitively multidisciplinary problems in the field of Self-organization, game theory, discrete dynamical systems; • understand intuitively multidisciplinary problems in the field of Understanding of basic theoretical concepts, mathematical and computer simulation methods; • use the methods and concepts in exercises apply analytical, critical thinking and model building.
7	**Prerequisites**	Required knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written examination (90 minutes)
11	**Grading procedure**	Written examination (100%)
12	**Module frequency**	Unregelmäßig
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

1	**Module name** 48217	**Complex Systems IV** Complex systems IV	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Complex Systems 2: Econo/ Socio physics, continuum dynamical systems (4 SWS)	5 ECTS
3	Lecturers	PD Dr. Claus Metzner	

4	**Module coordinator**	PD Dr. Claus Metzner
5	**Contents**	Shannon information theory, information processing, central nervous system, human brain, biological neurons, neuron models, perceptrons, pattern recognition, classification, network training, associative memory, Hopfield networks, selforganizing maps, biological neural networks, machine learning approaches, Boltzmann machines, generative stochastic models, contrastive divergence learning, auto-encoders, self-organized feature detectors, deep belief networks, deep learning and physics,convolutional networks, image recognition, computer generated art.
6	**Learning objectives and skills**	The students are able to: • understand intuitively multidisciplinary problems in the field of Information, neurophysics, machine learning; • understand intuitively multidisciplinary problems in the field of Understanding of basic theoretical concepts, mathematical and computer simulation methods; • use the methods and concepts in exercisesapply analytical, critical thinking and model building • apply analytical, critical thinking and model building.
7	**Prerequisites**	Required knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written examination (90 minutes)
11	**Grading procedure**	Written examination (100%)
12	**Module frequency**	Unregelmäßig
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

1	**Module name** 48161	**Introduction to Mathematical Modeling**	**10 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester. compulsory attendance (project)	
3	Lecturers	-	

4	**Module coordinator**	PD Dr. Serge Kräutle
5	**Contents**	The module combines theory and practice, it links and extends the contents of various introductory math courses. **Theory: (lecture and tutorial)** ● Methods (basic tools) of mathematical modeling, such as dimensional analysis, asymptotic expansions, stability, sensitivity, existence and positivity of solutions ● Models given by linear systems (electric circuits, girder bridge, relation to minimization problems), by non-linear systems of equations (chemical reactions), and by initial value problems of differential equations (predator-prey models, biological models) **Practice: (project work in team):** Modeling, analytical investigation and solving of problems coming from engineering and natural sciences (e.g. mechanics or life science)
6	**Learning objectives and skills**	The students ● get to know the basic methods of mathematical modelling and apply the approaches to real-life problems ● develop, analyse and evaluate mathematical models given by systems of algebraic or differential equations ● solve real-life problems in a team by using analytical and numerical methods ● develop the competence to solve general problems ● develop management skills (team work, time and project management), are empowered by reporting in the projects to lecture presentation and scientific writing (The attendance of the project is compulsory due to the teamwork.)
7	**Prerequisites**	Modules of analysis and linear algebra or introductory math courses of two semesters are strongly recommended. Basic Knowledge in numerical mathematics (use of MATLAB) and knowledge in ordinary differential equations is recommended.
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: Oral examination 20 min. PL: seminar talk about status-quo and progress of the project work (20 min.) and a written assignment about the final results in the project (20 pages)
11	**Grading procedure**	Portfolio (100%)

		Examination about theoretical part (oral examination): 50% Examination about practical part: 50%
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	Ch. Eck, H. Garcke, P. Knabner. "Mathematische Modellierung". Springer-Verlag, 2. Auflage, Berlin 2011 F. Hauser, Y. Luchko. "Mathematische Modellierung mit MATLAB“. Spektrum Akademischer Verlag 2011 G. Strang. "Introduction to Applied Mathematics". Wellesley-Cambridge Press, Wellesley 1986

1	**Module name** 48241	**Mathematical Image Processing**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Mathematical Image Processing (2 SWS) Tutorium: Tutorial for Mathematical Image Processing (1 SWS) This module is offered in every second summer term. The next course will be held in the summer semester 2024.	5 ECTS -
3	Lecturers	Dr. Daniel Tenbrinck	

4	**Module coordinator**	Dr. Daniel Tenbrinck
5	**Contents**	This module covers mathematical image processing techniques based on Fourier domain filters, variational methods, and partial differential equations. In particular, the following content will be introduced to the students: • contrast enhancement • filtering in Fourier and image domain • Bayesian image denoising • image deblurring / deconvolution • pixel-based clustering • region-based segmentation • image inpainting • nonlocal image processing using graphs
6	**Learning objectives and skills**	Students following this course will • learn how image data can be modeled and analyzed mathematically • develop a deeper understanding of mathematical basics and methods for image processing • implement own algorithms for mathematical image processing • discover connections to related mathematical fields, e.g., inverse problems and convex analysis
7	**Prerequisites**	Knowledge in calculus and linear algebra is **recommended** to understand the mathematical foundations of image processing. Knowledge in functional analysis, numerical mathematics, or inverse problems is **helpful** to understand advanced concepts in mathematical image processing.
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192 Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written or oral Oral examination (20 min.) or written examination (60 min.) depending on size of course.
11	**Grading procedure**	Written or oral (100%) Oral exam (100%) or written exam (100%) depending on size of course.

12	**Module frequency**	Unregelmäßig
13	**Workload in clock hours**	Contact hours: 37,5 Independent study: 112,5
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• G. Aubert & P. Kornprobst: Mathematical problems in Image Processing, Springer • K. Bredies & D. Lorenz, Mathematical Image Processing, Springer • S. Osher & R. Fedkiw, Level Set Methods and Dynamic Implicit Surfaces, Springer • A. Elmoataz , O.Lezoray, S. Bougleux: Nonlocal Discrete Regularization on Weighted Graphs: a framework for Image and Manifold Processing, IEEE Transactions On Image Processing, 17 (7), pp: 1047-1060, 2008

1	**Module name** 48131	**Metabolic Networks II**	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Andreas Burkovski
5	**Contents**	**Lecture:** concepts of signal transduction, global regulatory networks in bacteria, protein-protein-interactions in nitrogen control, development of a mathematical metabolic network model, integration of own experimental data. **Practical part:** Generation and interpretation of experimental data as basis for modelling
6	**Learning objectives and skills**	Students learn to break down biological signal transduction processes into parts suitable for mathematic modelling, interpret, generate and optimize models and integrate own data.
7	**Prerequisites**	Not required.
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Oral Oral exam 30 min.
11	**Grading procedure**	Oral (100%)
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Not required.

1	**Module name** 48181	**Partial Differential Equations for Life Sciences**	**5 ECTS**
2	Courses / lectures	Vorlesung: Partial Differential Equations for Life Sciences (2 SWS) Übung: Tutorial to Partial Differential Equations for Life Sciences (2 SWS)	- -
3	Lecturers	Prof. Dr. Maria Neuß	

4	**Module coordinator**	Prof. Dr. Maria Neuß
5	**Contents**	• Derivation of partial differential equations for processes in life sciences and corresponding initial- and boundary-value problems • Analysis of linear partial differential equations, Maximum principle • Nonlinear elliptic and parabolic equations and systems • Applications to processes in life sciences: reaction, diffusion, convection, transport in chemical or electrical gradients (like in Chemotaxis or Nernst-Planck) • Tutorials: Various methods for solving PDEs are introduced and trained: Method of characteristics, Separation of variables, Travelling wave solutions etc.
6	**Learning objectives and skills**	Students ● possess elementary knowledge in the area of mathematical modelling with partial differential equations ● are able to analyse well posedness for elementary partial differential equations ● apply methods for solving elementary partial differential equations ● acquire problem-oriented learning strategies and improve their skills in interdisciplinary approaches
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written or oral PL: Written examination 60 min. SL: Paper- and Computer exercises as a measure of performance level (exercise book; approx. 50 pages)
11	**Grading procedure**	Written or oral (100%) written exam 100%
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	A course in Mathematical Biology, de Vries, Hillen, Lewis, Müller, Schönfisch, 2006

1	**Module name** 48142	**Spatial Modeling of Metabolic Processes**	**10 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Maria Neuß Prof. Dr. Uwe Sonnewald
5	**Contents**	**Lecture** a) The biological part deals with the following topics: • Metabolic Networks • Allosteric Regulation of Metabolism The dual role of metabolites as signalling molecules and intermediates • Metabolite Channeling • Reversible Formation of Protein Complexes • Concepts of Synthetic Biology • Membrane Transport and Membrane Association of Proteins b) Within the mathematical part, the mathematical modeling of the processes studied in the biological part is performed and the models are simulated by using standard simulation software like e.g. Matlab. The mathematical and simulation approaches include: • modelling approaches accounting for the spatial structure of cells: compartments, organelles, membrane systems and the spatial distribution of enzymes and metabolites • a hierarchy of mathematical models are considered, including compartment models (systems of coupled ordinary differential equations) and continuous models in space and time (systems of partial differential equations) like reaction -diffusion-transport systems subjected to appropriate boundary and transmission conditions • implementation of temporal and spatial discretizations for transmission problems in Matlab or other simulation software. **Laboratory course** Metabolite quantitation by HPLC-tandem mass spectrometry. Protein biochemistry to assess the architecture of protein complexes: differential centrifugation, SDS-PAGE, western blot, etc. **Tutorial** Within the tutorial, the mathematical notions are discussed and deepened by means of blackboard and computer homework
6	**Learning objectives and skills**	Students • gain insight into feedback regulation of plant metabolism by metabolic intermediates • learn to conduct advanced analytical methods • are in touch with state-of-the art research topics • will be trained to apply the acquired knowledge on the analysis of protein complexes • acquire a in-depth knowledge and understanding in the area of mathematical modelling of intracellular processes

		• compare different modelling and simulation approaches and interpret the results in the framework of the biological application • investigate working methods from different disciplines (biology and mathematics) and develop new interdisciplinary approaches.
7	**Prerequisites**	Suggested: Module Partial differential equations for life sciences
8	**Integration in curriculum**	semester: 3;2
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written or oral (60 minutes) PL: Written examination 90 min. SL: Paper- and Computer exercises as a measure of performance level (exercise book; approx. 50 pages)
11	**Grading procedure**	Written or oral (100%) Written exam 100%
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 180 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	A course in Mathematical Biology,de Vries, Hillen, Lewis, Müller, Schönfisch, 2006

1	**Module name** 48151	**Stochastic Models for Life Sciences**	**5 ECTS**
2	Courses / lectures	Vorlesung: ILS-MA-M8: Stochastic Models for Life Sciences (Lecture) (2 SWS) Übung: ILS-MA-M8: Stochastic Models for Life Sciences (Tutorial) (2 SWS)	5 ECTS 5 ECTS
3	Lecturers	Prof. Vasily Zaburdaev	

4	**Module coordinator**	Prof. Vasily Zaburdaev
5	**Contents**	**Lecture:** A theory (random walks, stochastic transport, normal and anomalous diffusion) B in biology (active transport, search, motility as random walk, chemotaxis) C in practice (analysis of trajectories, interpretation of FCS and FRAP imaging data) **Tutorial:** theoretical and computer exercises relating to the contents of the lectures
6	**Learning objectives and skills**	The students • Have gained deepened knowledge concerning modelling in molecular biology. • are able to analyse and quantitatively model problems in molecular biology. • Have gained specialist competence concerning methods of stochastics. • are able to analyse and model stochastic concepts and biological examples within a predescribed time limit on the computer. • have problem oriented analytic skills.
7	**Prerequisites**	The course ILS-MA-M2 (Biomathematics) is recommended.
8	**Integration in curriculum**	semester: 2;3
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Oral (30 minutes) PL: oral examination 30 min. SL: Paper- and Computer exercises as a measure of performance level (exercise book; approx. 50 pages)
11	**Grading procedure**	Oral (100%) oral examination 100%
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	First steps in Random Walks, Sokolov and Klafter, 2011 Stochastic Foundations in Movement Ecology, Méndez, Campos, and Bartumeus, 2014 Random walks in Biology, Berg, 1993 Fokker-Planck Equation, Risken, 1996

MG2: Bioimaging and Biophysics

1	**Module name** 48111	**Bioimaging and Biophysics A**	**7,5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester. attendance compulsory	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Benedikt Kost
5	**Contents**	**LECTURE:** • Cell biology: cytoskeleton, membrane transport, cell division • Basic optical physics • Optical analytics: optics, detectors, FRET • Microscopic techniques: transmitted light, epi-fluorescence (deconvolution, structured illumination), TIRF, confocal (CLSM, spinning disk), multi-photon, STED • Manipulation of microscopic samples: lasers (FRAP, photoconversion/-activation, uncaging), optical tweezers, electrophysiology, microinjection (-> mouse transformation) **LABORATORY COURSE:** Experiments, projects and demonstrations illustrating and expanding topics covered in the lecture
6	**Learning objectives and skills**	Students: • know essential cellular structures and processes • understand the theoretical principles underlying light microscopy and digital image acquisition • obtain an overview of available light microscopic techniques and their applications • are familiar with available techniques to manipulate microscopic samples and with applications of these techniques • are capable of identifying appropriate bioimaging and biophysical techniques to address specific scientific questions
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	MG2: Bioimaging and Biophysics Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: oral examination 30 min. SL: protocol (ungraded task) approx. 40 pages
11	**Grading procedure**	Portfolio (100%) Oral exam: 100%
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester

15	**Teaching and examination language**	english
16	**Bibliography**	none

1	**Module name** 48112	**Bioimaging and Biophysics B**	**7,5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: MG 2 BioImaging & Biophysics (6 SWS) attendance compulsory	7,5 ECTS
3	Lecturers	Prof. Dr. Tobias Unruh Prof. Dr. Ben Fabry	

4	**Module coordinator**	Prof. Dr. Ben Fabry
5	**Contents**	**LECTURE:** • CCD sensors and cameras, principles and technical aspects • noise sources and noise behaviour in digital images • feature tracking and sub-pixel arithmetic • introduction to stereology • Molecular mobility, Brownian motion and diffusion • Anomalous diffusion and diffusion in crowded media • Measurement of molecular motions by light scattering and neutron spectroscopy • structure analysis of DNA **LABORATORY COURSE:** • Introduction to image analysis with Python • image correction, segmentation, noise analysis, super-resolution, photo-bleaching • optical transformation for illustration of DNA structure analysis
6	**Learning objectives and skills**	Students: • Can build high-end microscopes for dedicated purposes • Can write computer programs for image data acquisition and analysis • have a deep understanding of the nature of molecular motions in liquids and membranes • can solve common differential equations related to diffusion • can write simple computer programs for simulating molecular diffusion • have a deep understanding of the structure determination of complex molecular structures by scattering of X-rays
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	MG2: Bioimaging and Biophysics Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: written examination
11	**Grading procedure**	Portfolio (100%) written examination 100%
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	none

Mandatory Elective Modules Group 2

1	**Module name** 48500	**Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects**	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Dr. Ingo Thievessen
5	**Contents**	**Lecture:** Cell-ECM and cell-cell adhesion; Cytoskeleton components; Mechanically loaded and non-loaded cell adhesions; Building principles and components of cytoskeleton-adhesion linkages; Cellular force generation; Activation of integrins and cadherins; Adhesion and cytoskeleton morphodynamics; Cytoskeletal pre-stress and cell morphodynamics; Cell migration cycle; Rho-GTPases; Adhesion signaling and control of cell proliferation/apoptosis, polarity, differentiation; Durotaxis, Haptotaxis, Chemotaxis; 2D and 3D cell migration; Cell migration modes; Cell adhesion and migration in embryonic development, tissue morphogenesis, tissue homeostasis and diseases; Fibrosis, myopathies, cancer, autoimmunity; Cell adhesion in tissue engineering; Fluorescent proteins and modern microscopy techniques in cell adhesion/cytoskeleton research. **Laboratory course:** siRNA-mediated gene knockdown; High resolution short-term and low resolution long term live cell microscopy; Immunofluorescence staining; Western blot; Image analysis and data evaluation.
6	**Learning objectives and skills**	Lecture The students are able to: • understand the basic concepts in cell and tissue mechanics and the concept of “molecular medicine”; • able to discern cellular, physical, and molecular aspects in biomedical contexts; • apply analytical and critical thinking and model building. Laboratory course: The students are able to: • postulate and experimentally test a hypothesis; • practice and learn how to apply standard cell biological, biophysical, biochemical, and • microscopical techniques.
7	**Prerequisites**	Recommended knowledge: Basics of cell biology, material on specific topics is provided during the course.
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written Oral (30 minutes) PL: oral examination 30 min. PL: protocol, graded tasked (10 pages)
11	**Grading procedure**	Written (50%)

		Oral (50%) 50% oral exam, 50% protocol
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

1	**Module name** 66122	**Experimental Physics 3: Optics and Quantum Phenomena**	**7,5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Christoph Marquardt
5	**Contents**	**Optik und Quantenphänomen** **Licht als Welle** Belege für die Wellennatur des Lichts, Herleitung der Wellengleichung aus den Maxwell-Gleichungen, Lösungen in Form von ebenen Wellen, Kugelwellen, monochromatische Felder. **Licht und Materie** Einzelstreuer (getriebener Dipol, Lichtstreuung), Feldausbreitung im homogenen Material, Polarisation und Stromdichte, modifizierte Maxwell-Gleichungen, modifizierte Wellengleichung, Stetigkeitsbedingungen an Grenzflächen, Brechungsgesetz, Fresnelformeln, Brewsterwinkel, Totalreflexion, frustrierte Totalreflexion und Tunneleffekt bei Licht, Polarisation des Materials (Suszeptibilität, Dispersion). **Geometrische Optik** Strahlenoptik, Matrizenoptik (Prinzip, Anwendung auf Linsen, Abbildungen), Hauptebenen, Abbildungsfehler (chromatische Aberrationen, Fehler für monochromatische Wellen), optische Resonatoren. **Beugung und Interferenz** Ausbreitungsgleichung unter Randbedingungen, Huygenssches Prinzip, Fraunhoferbeugung (Entstehung des Beugungsbildes, Beugungsbilder, Grenzen), Mikroskope, Teleskope, Auflösungsgrenzen, Abbildungstechniken, das Auge. Polarisation elektromagnetischer Felder Ebene Wellen im homogenen Material, Polarisationsformen von Licht, Polarisationsphänomene im durchstrahlten Material, Doppelbrechung, polarisierende Elemente. **Grundlegende Experimente zu Quantenphänomenen** Teilchencharakter des Lichts, äußerer lichtelektrischer Effekt (Photoeffekt), Hohlraumstrahlung nach Planck, Compton-Effekt, Wellencharakter von Teilchen (Elektronenbeugung, Streuung im Kristall), Konsequenzen der Wellennatur des Elektrons. **Grundgleichungen der Quantenmechanik**

		Schrödinger-Gleichung, zeitunabhängige Schrödinger-Gleichung, Interpretation der quantenmechanischen Wellenfunktion, Kastenpotenzial, Tunneleffekt mit Materiewellen.
6	**Learning objectives and skills**	Die Studierenden • erläutern und erklären die experimentellen Grundlagen und die quantitativ-mathematische Beschreibung der Optik und von Quantenphänomenen gemäß den detaillierten Themen im Inhaltsverzeichnis • wenden die physikalischen Gesetze und jeweiligen mathematischen Methoden auf konkrete Problemstellungen an
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Oral (30 minutes)
11	**Grading procedure**	Oral (100%)
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german
16	**Bibliography**	-

1	**Module name** 48241	**Mathematical Image Processing**	**5 ECTS**
2	Courses / lectures	Vorlesung mit Übung: Mathematical Image Processing (2 SWS) Tutorium: Tutorial for Mathematical Image Processing (1 SWS) This module is offered in every second summer term. The next course will be held in the summer semester 2024.	5 ECTS -
3	Lecturers	Dr. Daniel Tenbrinck	

4	**Module coordinator**	Dr. Daniel Tenbrinck
5	**Contents**	This module covers mathematical image processing techniques based on Fourier domain filters, variational methods, and partial differential equations. In particular, the following content will be introduced to the students: • contrast enhancement • filtering in Fourier and image domain • Bayesian image denoising • image deblurring / deconvolution • pixel-based clustering • region-based segmentation • image inpainting • nonlocal image processing using graphs
6	**Learning objectives and skills**	Students following this course will • learn how image data can be modeled and analyzed mathematically • develop a deeper understanding of mathematical basics and methods for image processing • implement own algorithms for mathematical image processing • discover connections to related mathematical fields, e.g., inverse problems and convex analysis
7	**Prerequisites**	Knowledge in calculus and linear algebra is **recommended** to understand the mathematical foundations of image processing. Knowledge in functional analysis, numerical mathematics, or inverse problems is **helpful** to understand advanced concepts in mathematical image processing.
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 1 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192 Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written or oral Oral examination (20 min.) or written examination (60 min.) depending on size of course.
11	**Grading procedure**	Written or oral (100%) Oral exam (100%) or written exam (100%) depending on size of course.

12	**Module frequency**	Unregelmäßig
13	**Workload in clock hours**	Contact hours: 37,5 Independent study: 112,5
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• G. Aubert & P. Kornprobst: Mathematical problems in Image Processing, Springer • K. Bredies & D. Lorenz, Mathematical Image Processing, Springer • S. Osher & R. Fedkiw, Level Set Methods and Dynamic Implicit Surfaces, Springer • A. Elmoataz , O.Lezoray, S. Bougleux: Nonlocal Discrete Regularization on Weighted Graphs: a framework for Image and Manifold Processing, IEEE Transactions On Image Processing, 17 (7), pp: 1047-1060, 2008

1	**Module name** 48331	**Methods of Modern (Confocal-) Light Microscopy** Methods of Modern (Confokal-) Light Microscopy	**5 ECTS**
2	Courses / lectures	Übung: ILS-MA-B10: Methods of modern (confocal) light microscopy (6 SWS)	5 ECTS
3	Lecturers	PD Dr. Ruth Stadler	

4	**Module coordinator**	Dr. Christina Müdsam
5	**Contents**	Theoretical and practical introduction to following topics: • Cloning of XFP-fusion constructs • Transformation of model plants and cell systems • Expression and localization experiments using different fluorescent proteins and dyes • Protein interaction and dynamics (photoactivation; photoconversion, FRAP, BiFC) • Genetic and pharmacological inhibition of cell biological processes • Immunofluorescence
6	**Learning objectives and skills**	The students will: • get an overview of (confocal) microscopy techniques and the application of different fluorescent proteins as well as dyes in modern cell and molecular biology. • critically discuss and evaluate publications addressing cell biological and plant physiological questions by employing microscopy techniques • get a hands on training in molecular biological techniques and confocal laser microscopy using various imaging methods.
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Masterprüfung Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20152 Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: oral examination: 30 min. SL: oral presentation of a publication: 30 min.
11	**Grading procedure**	Portfolio (100%) Oral examination 100%
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 60 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Will be provided 2-3 weeks prior to the seminar

1	**Module name** 48311	**Modern Optics 1: Advanced Optics** Modern optics 1: Advanced optics	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Stephan Götzinger
5	**Contents**	Scalar wave optics: Maxwell equations, solutions to the wave equation, interference effects; Fourier optics: propagation in free space, through aperture and lenses, Fourier transformation in the far field; Vectorial wave optics: Maxwell equation and solution of the vectorial fields: Gaussian laser beam (fundamental and higher order modes), focusing of vector fields in free space, vector fields with optical angular momentum; Optics in waveguides: geometrical approach and Maxwell equation with boundary conditions, transverse modes, cutoff for planar waveguide, optical fibers, tapers, couplers; Whispering gallery mode resonators: modal description, applications.
6	**Learning objectives and skills**	Students • explain the relevant topics of the lecture • apply the methods to specific examples
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Oral (30 minutes) PL: Oral examination 30 min.
11	**Grading procedure**	Oral (100%)
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

1	**Module name** 48313	**Modern Optics 3: Quantum Optics** Modern optics 3: Quantum optics	**5 ECTS**
2	Courses / lectures	Vorlesung: Modern Optics 3: Quantum Optics (2 SWS)	5 ECTS
3	Lecturers	Prof. Dr. Maria Chekhova	

4	**Module coordinator**	Prof. Dr. Maria Chekhova
5	**Contents**	**Contents:** 1. Basic concepts of statistical optics 2. Spatial and temporal coherence. Coherent modes, photon number per mode 3. Intensity fluctuations and Hanbury Brown and Twiss experiment 4. Interaction between atom and light (semiclassical description) 5. Quantization of the electromagnetic field 6. Quantum operators and quantum states 7. Heisenberg and Schrödinger pictures 8. Polarization in quantum optics 9. Nonlinear optical effects for producing nonclassical light 10. Parametric down-conversion and four-wave mixing, biphotons, squeezed light 11. Single-photon states and single-photon emitters 12. Entanglement and Bells inequality violation
6	**Learning objectives and skills**	**Learning goals and competences:** Students • explain the relevant topics of the lecture • apply the methods to specific examples
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written examination PL: oral examination 30 Min.
11	**Grading procedure**	Written examination (100%)
12	**Module frequency**	every semester
13	**Workload in clock hours**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

1	**Module name** 63301	**Molecular Neurophysiology**	**7,5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester. Attendence is compulsory.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Andreas Feigenspan
5	**Contents**	**Lecture/Seminar** Theoretical and practical approaches including cell culture, transfection of cells and the investigation of ion channel function in heterologous expression systems using electrophysiological and imaging techniques will be taught. Students will present seminar talks based on current original research papers. **Laboratory course** The expression of an ion channel protein will be investigated from cloning of vectors and transfection of cells to functional studies using cell and molecular biology techniques, epifluorescence microscopy and patch-clamp recordings.
6	**Learning objectives and skills**	Students • know latest developments, concepts and experimental approaches in molecular neuroscience; • are capable to present scientific research papers in a coherent and critical way; • know important methods in cell and molecular biology as well as modern electrophysiological and imaging techniques; • are capable of presenting and discussing data from experiments carried out independently are able to discuss and reflect the topics of the seminar.
7	**Prerequisites**	-
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 2 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: oral examination 30 min. PL: written protocol approx. 30 pages PL: seminar talk 30 min.
11	**Grading procedure**	Portfolio (100%) Arithmetic mean of oral exam, seminar talk and written protocol grades
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	Mark F. Bear et al.: Neuroscience. Exploring the Brain. 4th ed. 2015, Wolters Kluwer Dale Purves et al.; Neuroscience. 5th ed. 2012, Sinauer

MG3: Biological Structures and Processes

1	**Module name** 48121	**Interactions of Biological Macromolecules A**	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Yves Muller
5	**Contents**	**Lectures** and **Tutorials** cover topics of interactions between biological macromolecules extending from protein-protein to protein-DNA and protein-ligand interactions. The following topics will be discussed: Energetic and thermodynamic contributions, the description of structural determinants, the use of homology modelling, the prediction of contiguous and non-contiguous interaction sites in proteins, experimental methods for studying interactions, the analysis of interaction surfaces via peptide mapping as well as selected examples of protein interactions involved in plant signalling networks.
6	**Learning objectives and skills**	The students will • acquire an in-depth knowledge of structure-function relationships in interacting macromolecules • be able to assess the suitability of current experimental methods such as X-ray crystallography, NMR, peptide mapping, ITC and SPR for studying protein-protein and protein-ligand interactions. • become familiar with bioinformatics methods to predict and analyse interactions between biological macromolecules. • gain fundamental knowledge in plant signalling networks • be able to present and critically discuss current research articles • be able to discuss their results and defend their conclusions in proper context • extended their capacity for teamwork and their communication as well as social competence
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	MG3: Biological Structures and Processes Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: written examination 120 min. SL: exercise book (approx. 50 pages)
11	**Grading procedure**	Portfolio (100%) written examination 100 %
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h

14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	none

1	**Module name** 48122	**Interactions of Biological Macromolecules B**	**5 ECTS**
2	Courses / lectures	Übung: ILS-MA-I2B: Interactions at Biological Macromolecules (Tutorial) (2 SWS) Vorlesung: ILS-MA-I2B: Interactions at Biological Macromolecules (Lecture) (2 SWS)	2 ECTS 3 ECTS
3	Lecturers	Prof. Dr. Rainer Böckmann Prof. Dr. Tobias Unruh	

4	**Module coordinator**	Prof. Dr. Rainer Böckmann
5	**Contents**	**Lectures** and **Tutorial** cover topics of interactions at biological membranes and physical mechanisms, including basic membrane electrostatics, Nernst-Planck Equation, membrane currents, thermodynamics of membranes, membrane elasticity, Helfrich theory.
6	**Learning objectives and skills**	The students will acquire the folowing skills. They • obtained an understanding of composition, structure, dynamics, and function of biological membranes • are acquainted with theoretical and experimental methods in the investigation of biomembranes • are able to present and critically discuss membrane models in current research articles • can discuss their results and defend their conclusions in proper context • extended their capacity for teamwork and their communication as well as social competence.
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	MG3: Biological Structures and Processes Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written or oral written examination 120 min.
11	**Grading procedure**	Written or oral (100%) written examination 100%
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	-

Mandatory Elective Modules Group 3

1	**Module name** 42241	**Developmental Biology 2: Tissue Differentiation and Organogenesis** Developmental Biology 2: Molecular Control of Stem Cell and Organ Differentiation	**7,5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Wiebke Herzog
5	**Contents**	**Seminar** talks cover topics concerning the molecular mechanisms controlling developmental processes with an emphasis on tissue and organ development involving progenitor and stem cells in vertebrate and invertebrate model organisms. In the **laboratory course**, projects in small groups are pursued related to ongoing research in the participating labs, which address gene functions, transcriptional, and signalling processes during embryonic development and organogenesis (gonad, early embryo, muscle, and heart development). Among the techniques applied are molecular methods (PCR, gene cloning, sequencing), genetic methods (mutants, transgenic insects, RNAi, morpholino antisense nucleotides, gene over-expression), detection methods (in situ hybridization, histochemistry, transgenic markers), and microscopy (fluorescence microscopy, structured illumination, confocal microscopy) as well as other molecular and bioinformatic methods.
6	**Learning objectives and skills**	Students will acquire the following skills: They will • be able to present and critically discuss results of current developmental research articles • become familiar with current concepts of developmental biology, including the molecular basis of developmental regulation • obtain an understanding of genetic techniques and methods used for analysis of developmental problems • be able to independently develop working hypotheses, and to plan and conduct experiments to test these • learn to discuss their results and defend their conclusions in proper context
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 3 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: oral presentation (15 min.) PL: poster presentation (10 min.)
11	**Grading procedure**	Portfolio (100%) Oral presentation 50% Poster pesentation 50%

12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	Review articles will be provided electronically

1	**Module name** 48251	**Introduction to X-ray and Neutron Scattering I** Introduction to X-ray and neutron scattering 1	**5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Tobias Unruh
5	**Contents**	• Introduction to the basics of X-ray, light, and neutron scattering • mode of operation of different neutron instruments for elastic scattering • realization of components of neutron scattering instruments • kinematic theory of X-ray and neutron beam interferences • the lattice factor: particle size determination, strain analysis by neutron diffraction • the structure factor: single crystal structure analysis, experimental determination of the structure factor, the phase problem and its solution • implications for dynamic scattering theory • small angle scattering: diffuse small angle scattering, complex interferences in the small angle regime, contrast variation • introduction to the theory of inelastic scattering • mode of operation of neutron spectrometers • applications: phonons, molecular diffusion, intra-molecular motions
6	**Learning objectives and skills**	Students • explain the relevant topics of the lecture • apply the methods to specific examples
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 3 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Written or oral PL: oral examination 30 min.
11	**Grading procedure**	Written or oral (100%) Oral examination 100%
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• G. L. Squires, Introduction to the Theory of Thermal Neutron Scattering, Cambridge University Press / Dover Publications, 1978 / 1996. ISBN 0-486-69447-X

		• Max von Laue, Röntgenstrahlinterferenzen, Akademische Verlagsgesellschaft, Frankfurt am Main, 3rd edition, 1960 • P. Luger, Modern X-Ray Analysis on Single Crystals, de Gruyter 1980, ISBN 3-110-068303-7 • O. Kratky, O. Glatter, Small Angle X-Ray Scattering, Academic Press, London, 1982, ISBN 0-12-286280-5 • A. Messiah, Quantenmechanik, volume 1, Walter de Gruyter, Berlin, 1st edition, 1976, ISBN 3-11-003686-X • F. Hippert, E. Geissler, J.L. Hodeau, E. Lelievre-Berna, J.-R. Regnard (Eds.), Neutron and X-ray Spectroscopy, Springer 2006, ISBN-10 1-4020-3336-2

1	**Module name** 48261	**Introduction to X-ray and Neutron Scattering II** Introduction to X-ray and neutron scattering II	**5 ECTS**
2	Courses / lectures	No teaching units are offered for the module in the current semester. For further information on teaching units please contact the module managers.	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Tobias Unruh

5	**Contents**	• Introduction to the theory of nuclear inelastic neutron scattering
		• Mode of operation of most relevant types of neutron spectrometers
		• Realization of compounds of neutron spectrometers (instrumentation)
		•
		  ◦ dispersion relation of lattice vibrations
		  ◦ molecular motions in liquids and membranes
		  ◦ inter- and intra-molecular motions
		• Dynamic light scattering and inelastic X-ray scattering

6	**Learning objectives and skills**	The students learn • to apply the theory of inelastic neutron scattering to systems of simple and moderate complexity • to understand the operation mode of different types of neutron spectrometers • to estimate the suitability of different inelastic scattering methods for the determination of specific dynamic processes in simple and complex systems • to analyze neutron spectra autonomously
7	**Prerequisites**	-
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 3 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Oral PL: oral examination 30 min.
11	**Grading procedure**	Oral (100%)
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	G. L. Squires, Introduction to the Theory of Thermal Neutron Scattering, Cambridge University Press / Dover Publications, 1978 / 1996. ISBN 0-486-69447-X;

		Max von Laue, Röntgenstrahlinterferenzen, Akademische Verlagsgesellschaft, Frankfurt am Main, 3rd edition, 1960 P. Luger, Modern X-Ray Analysis on Single Crystals, de Gruyter 1980, ISBN 3-110-068303-7 O. Kratky, O. Glatter, Small Angle X-Ray Scattering, Academic Press, London, 1982, ISBN 0-12-286280-5 A. Messiah, Quantenmechanik, volume 1, Walter de Gruyter, Berlin, 1st edition, 1976, ISBN 3-11-003686-X F. Hippert, E. Geissler, J.L. Hodeau, E. Lelievre-Berna, J.-R. Regnard (Eds.), Neutron and X-ray Spectroscopy, Springer 2006, ISBN-10 1-4020-3336-2

1	**Module name** 48301	**Ion Transport And Signal Transduction**	**5 ECTS**
2	Courses / lectures	Seminar und Übung: ILS-MA-B2: Ion transport and signal transduction (6 SWS)	5 ECTS
3	Lecturers	Prof. Dr. Petra Dietrich	

4	**Module coordinator**	Prof. Dr. Petra Dietrich
5	**Contents**	Ion channels in the membrane are often involved in responses to external stimuli, representing early components of signal transduction pathways. During the module, the students will extensively study the role of ion channels for transport processes and signal transduction networks, using theoretical approaches (literature, lectures, seminars) combined with experiments in the lab. The practical part focuses on the analysis of • structure-function relations in ion channels • protein-protein interactions using different techniques • Ca2+-responses as early signaling elements using calcium reporters, and introduces different cloning strategies for plasmid preparation as well as different expression systems, such as *E. coli*, yeast cells, *Xenopus* oocytes, and plant cells. Electrophysiological characterization of ion transport (optional for interested students only).
6	**Learning objectives and skills**	Compulsatory attendance, in order to • learn experimental methods for studying membrane proteins • design and conduct scientific experiments in life sciences • optimize time schedules for practical experiments • analyze and interpret experimental data • present and discuss own experimental data • present and critically discuss data published in original research articles
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 3 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: oral examination 30 min. SL: oral presentation 30 min.
11	**Grading procedure**	Portfolio (100%) Oral examination 100%
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 60 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english

16	**Bibliography**	Material for Recommended reading will be provided on the StudOn-platform.

1	**Module name** 42062	**Python for bioinformatics and data analysis**	**7,5 ECTS**
2	Courses / lectures	Seminar und Übung: Python for Bioinformatics and Data Analysis (8 SWS) The attendance in the computer lab is compulsory.	7,5 ECTS
3	Lecturers	Marius Trollmann Prof. Dr. Rainer Böckmann	

4	**Module coordinator**	Prof. Dr. Rainer Böckmann
5	**Contents**	**Python Basics:** Introduction to modern scripting language Python and Jupyter Notebooks for creating code and visualizations; Data structures, conditions, branching, loops, functions, numpy, scipy, matplotlib libraries **Applications in Data Analysis:** handling of data and image files, visualization of data for publication, regression & correlation analysis, hypothesis testing, image analysis **Applications in Bioinformatics:** sequence alignments, RNA-Seq/Gene expression data analysis, NGS data, use of Protein Data Bank, processing of super-resolution image data
6	**Learning objectives and skills**	The students • understand basic concepts of Python programming and Linux shell • acquire problem-oriented programming skills using Python • apply basic Python libraries in data analysis and bioinformatics • solve and implement simple application problems
7	**Prerequisites**	None
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 3 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Portfolio PL: written examination (120 min). SL: voluntary homework (bonus to improve the grade of the written examination)
11	**Grading procedure**	Portfolio (100%)
12	**Module frequency**	only in summer semester
13	**Workload in clock hours**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	• Lecture notes • Jupyter Notebooks

1	**Module name** 42201	**Structural Biology I: Protein Design and Designer Proteins** Structural biology I: Protein design and designer proteins	**7,5 ECTS**
2	Courses / lectures	The teaching units in the module are only offered in the winter semester. Die Übungen sind anwesenheitspflichtig. The attendance is compulsary. Unterrichtssprache Zell- und Molelkularbiologie: Deutsch Teaching language Integrated Life Sciences: english	
3	Lecturers	-	

4	**Module coordinator**	Prof. Dr. Yves Muller
5	**Contents**	**SEM:** Lehre von methodischen und theoretischen Ansätzen zum Designen von Proteinen mit veränderten Eigenschaften wie z.B. phage und yeast display, directed evolution und computational protein design. Besprechung herausragender Proteindesignstudien unter aktiver Beteiligung der Studierenden. **UE**: Die Übungen konzentrieren sich auf die Gebiete computational biology (Schwerpunkt Proteinseitenkettenpackungsalgorithmen oder molecular dynamics Simulationen). Zusätzlich werden Methoden zur experimentellen Verifizierung von Computermodellen wie z.B. Isotherme Titrationskalorimetrie (ITC) und CD-Spektroskopie in hands-on Versuchen vermittelt. Die Übungen erfolgen zu 50 % als individuelle Mitarbeit an aktuellen Projekten der beteiligten Arbeitskreise. **Seminar talks** cover theoretical and methodological approaches for the design of proteins with modified characteristics including phage and yeast display, directed evolution and computational protein design. A selection of seminal protein design studies will be discussed. **Laboratory course** focuses on computational protein design (using protein side-chain packing algorithms, or molecular dynamics simulations). Additionally, students are introduced to experimemtal validation techniques such as isothermal titration calorimetry (ITC) and CD spectroscopy in hands-on lab-training units. The main focus of the practical course will be the active participation in ongoing research projects in the participating labs.
6	**Learning objectives and skills**	Die Studierenden • können die neuesten Erkenntnisse, Konzepte und methodischen Ansätze beim Design von Proteinen mit neuen Eigenschaften erklären und diskutieren; • sind in der Lage, neueste Forschungsergebnisse in diesem Fachgebiet kritisch zu besprechen und zu hinterfragen; • verstehen die aktuellsten Arbeitsmethoden und deren Anwendungen beim Designen von Proteinen; • können den Inhalt eines wissenschaftlichen Primärartikels erarbeiten, die verwendeten Methoden/Ergebnisse

		erklären und kritisch bewerten und in einem Referat fachgruppengerecht präsentieren und diskutieren; • sind aufgrund der regelmäßigen aktiven Teilnahme fähig, spezifische strukturbiologische Experimente zu planen und durchzuführen; • können mit anwendungsspezifischen wissenschaftlichen Messgeräten sowie mit Programmen zur Struktursimulation umgehen; • können strukturbiologische Versuche auswerten und die Ergebnisse in einem Protokoll darstellen sowie kritisch diskutieren. The students are • acquainted with novel insights, concepts, and methods for the design of proteins with novel properties • understand state-of-the-art methods in protein design and their limitations • are able to independently develop working hypotheses, to independently design and conduct experiments • able to present and critically discuss current research articles / their results and defend their conclusions in a proper context
7	**Prerequisites**	keine/none
8	**Integration in curriculum**	semester: 1;2
9	**Module compatibility**	Mandatory Elective Modules Group 3 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Variable PL: schriftliche Prüfung/written examination (45 Min.) PL: mündlicher Seminarvortrag /oral presentaion (20 Min.) PL: schriftliches Protokoll /written protokoll (ca. 15-20 Seiten)
11	**Grading procedure**	Variable (100%) - Schriftliche Prüfung/written examination: 40% - mündlicher Seminarvortrag/oral presentaion : 20%, - schriftliche Protokollheft/written protokoll: 40%
12	**Module frequency**	only in winter semester
13	**Workload in clock hours**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	german or english
16	**Bibliography**	-

1	**Module name** 42211	**Structural Biology II: Structure and Function Relationships in Biotechnologically Relevant Macromolecules** Structural biology II: Structure and function relationships in biotechnologically relevant macromolecules	**7,5 ECTS**
2	Courses / lectures	Seminar und Übung: Structural Biology II: Structure and Function Relationships in Biotechnologically Relevant Macromolecules (8 SWS) The attendance is compulsory.	7,5 ECTS
3	Lecturers	Prof. Dr. Yves Muller Prof. Dr. Rainer Böckmann	

4	**Module coordinator**	Prof. Dr. Yves Muller
5	**Contents**	**Seminar** talks cover theoretical and methodological approaches for the study of structure-function relationships in proteins with a focus on the structural determinants that are responsible for the regulation of protein function. **Laboratory course** focuses on advanced methods to study structure-dynamics-function relationships in proteins. Both experimental (heterologous protein production in eukaryotic cells, X-ray analysis, mutation studies) as well as theoretical methods (atomistic and coarse-grained molecular dynamics simulations) will be addressed. Additionally, students are introduced to X-ray crystallography and investigating protein stability via CD spectroscopy in hands-on lab-training units. The focus of the practical course will be the active participation in ongoing research projects in the participating labs.
6	**Learning objectives and skills**	The students are • acquainted with novel insights, concepts, and methods in the study of protein-dynamics-function relationships • understand state-of-the-art methods in the analysis of protein structure, dynamics, function and their limitations • are able to independently develop working hypotheses, to independently design and conduct experiments • able to present and critically discuss current research articles / their results and defend their conclusions in proper context
7	**Prerequisites**	none
8	**Integration in curriculum**	semester: 2;1
9	**Module compatibility**	Mandatory Elective Modules Group 3 Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics 20192
10	**Method of examination**	Variable PL: written examination (45 min.) PL: seminar talk (20 min.) PL: written protocol (approx. 15-20 pages)
11	**Grading procedure**	Variable (100%) written examination 40 %, seminar talk 20 %, written protocol 40 %
12	**Module frequency**	only in summer semester

13	**Workload in clock hours**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching and examination language**	english
16	**Bibliography**	introductory articles will be provided electronically