Master of Science
Integrated Life Sciences

January, 21 2021

Module Handbook for the
Master of Science Integrated Life Sciences: Biology, Biomathematics, Biophysics

Department of Biology
Friedrich-Alexander-Universität Erlangen-Nürnberg

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Study plan for the Master's degree program Integrated Life Sciences

Code	Title	Course	SWS V	SWS Ü	SWS P	SWS S	Total ECTS	Workload averaged in ECTS 1. Sem.	2. Sem.	3. Sem.	4. Sem.	Specification exam/ ungraded tasked	Factor Grade
Mandatory module													
ILS-MA-M1	**Introduction to Statistics and Statistical Programming**	Introduction to Statistics	2				5		2			PL: written exam 90 min. + SL: exercise book appr. 50 pages	1
		Tutorial for Introduction to Statistics (Problem Session)		1					1.5				
		Lab class Statistical Programming		1					1.5				
		Total SWS and ECTS	**2**	**2**			**5**		**5**				
Mandatory Modules of Module group 1: Mathematical Modelling and Systems Biology													
ILS-MA-M2	**Biomathematics**	Biomathematics	4				10	7				PL: oral exam 30 min. or written exam 90 min. + SL: exercise book appr.50 pages	1
		Tutorial for Biomathematics		2				3					
ILS-MA-B1	**Systems Biology**	Systems Biology	2				5	3				PL: written exam 60 min.	1
		Laboratory course Systems Biology		1				2					
		Total SWS and ECTS of Module Group MG1 (mandatory)	**6**	**3**			**15**	**15**					
Elective Modules of Module Group 1: Mathematical Modelling and Systems Biology													
ILS-MA-I3	**Metabolic Networks II**	Metabolic Networks II	3				5			3		PL: oral exam 30 min.	1
		Laboratory course Metabolic Networks II		1						2			
ILS-MA-I4	**Spatial Modeling of Metabolic Processes**	Spatial Modelling of Metabolic Processes	4				10			6		PL: written exam 90 min. SL: exercise book appr.50 pages	1
		Tutorial for Spatial Modelling of Metabolic Processes		2						2			
		Laboratory course for Spatial Modelling of Metabolic Processes		2						2			
ILS-MA-M3	**Introduction to Mathematical Modeling**	Introduction to Mathematical Modeling	2				10	5				PL: oral exam 20 min. PL: oral presentation 20 min. PL: protocol 20 p.	1
		Tutorial/project for Introduction to Mathematical Modeling		2		2		5					
ILS-MA-M4	**Partial Differential Equations for Life Sciences**	Partial Differential Equations for Life Sciences	2				5		2.5			PL: written exam 60 min. SL: exercise book 50 pages	1
		Tutorial for Partial Differential Equations for Life Sciences		2					2.5				
ILS-MA-M6	**Mathematical Image Processing**	Mathematical Image Processing	2				5		3			PL: oral exam 20 min.	1
		Tutorial for Mathematical Image Processing		0.5					2				
ILS-MA-M8	**Stochastic Models in Life Sciences**	Stochastic Models in Life Sciences	2				5		3			PL: oral exam 30 min. SL: exercise book 50 pages	1
		Tutorial for Stochastic Models in Life Sciences		2					2				

ILS-MA-P1	**Complex Systems 1**	Complex Systems 1	2				5	2.5				PL: written exam 90 min.	1
		Tutorial for Complex Systems 1		2				2.5					
ILS-MA-P2	**Complex Systems 2**	Complex Systems 2	2				5		2.5			PL: written exam 90 min.	1
		Tutorial for Complex Systems 2		2					2.5				
ILS-MA-P3	**Complex Systems 3**	Complex Systems 3	2				5			2.5		PL: written exam 90 min.	1
		Tutorial for Complex Systems 3		2						2.5			
ILS-MA-P9	**Complex Systems 4**	Complex Systems 4	2				5				2.5	PL: written exam 90 min.	1
		Tutorial for Complex Systems 4		2							2.5		
ILS-MA-B5	**Developmental Biology 3: Visualization of Gene Regu-lation during Development**	Laboratory course and seminar Visualization of Gene Regulation during Development		7		1	7.5	7.5				PL: written exam 60 min. PL: written protocol 10-15 p. SL: presentation 30 min.	1
ILS-MA-B11	**Bioanalytics**	Laboratory course and seminar Bioanalytics		7		1	7.5		7.5			PL: oral exam 30 min. SL: written protocol 20 p. SL: presentation 30 min.	1
ILS-MA-B12	**Python Programming**	Practical: Introduction to Python Programming		2			5		5			SL: hands-on exercises PL: programming project	1
	Total SWS and ECTS of Module Group MG 1 (elective)		23	40.5	0	4	95	30	40	20	5		
Mandatory Modules of Module group 2: Bioimaging and Biophysics													
ILS-MA-I1A	**Bioimaging & Biophysics A**	Bioimaging & Biophysics I	2				7.5	2.5				PL: written exam 90 min. or oral exam 40 min. + SL: protocol 40 pages	1
		Laboratory course for Bioimaging & Biophysics I		4				5					
ILS-MA-I1B	**Bioimaging & Biophysics B**	Bioimaging & Biophysics II	2				7.5		2.5			PL: written exam 90 min. or oral exam 40 min.	1
		Laboratory course for Bioimaging & Biophysics II		4					5				
	Total SWS and ECTS of Module Group MG2 (mandatory)		4	4			15	7.5	7.5				
Elective Modules of Module Group 2: Bioimaging and Biophysics													
ILS-MA-M6	**Mathematical Image Processing**	Mathematical Image Processing	2				5		3			PL: oral exam 20 min.	1
		Tutorial for Mathematical Image Processing		0.5					2				
ILS-MA-P4	**Modern Optics: Advanced Optics**	Modern Optics: Advanced Optics	2				5	2.5				PL: oral exam 30 min.	1
		Tutorial for Modern Optics: Advanced Optics		2				2.5					
ILS-MA-P5	**Experimental Physics 3: Optics and Quantum Phenomena**	Experimental Physics 3: Optics and Quantum Phenomena	4				7.5	5				PL: oral exam 30 min.	1
		Tutorial for Experimental Physics 3: Optics and Quantum Phenomena		2				2.5					
ILS-MA-P10	**Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects**	Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects	2				5	2.5				PL: oral exam 30 min. PL: protocol (graded tasked)	1
		Laboratory course		2				2.5					

ILS-MA-B9	**Molecular Neurophysiology**	Laboratory course and seminar Molecular Neurophysiology		7		1	7.5		7.5			PL: oral exam 30 min. PL: written protocol 30 p. SL: presentation 30 min.	1
ILS-MA-B10	**Methods of Modern (Confocal-) Light Microscopy**	Laboratory course and seminar Methods of Modern (Confocal-) Light Microscopy		5		1	5		5			PL: oral exam 30 min. SL: oral presentation 30 min.	1
ILS-MA-B12	**Python Programming**	Practical: Introduction to Python Programming		2			5		5			SL: hands-on exercises PL: programming project	1
	Total SWS and ECTS of Module Group MG 2 (elective)		10	20.5	0	2	40	17.5	22.5	0	0		
Mandatory Modules of Module group 3: Biological Structures and Processes													
ILS-MA-I2A	**Interactions of Biological Macromolecules A**	Interactions of Biological Macromolecules A	2				5	3				PL: written exam 120 min. or oral exam 60 min. + SL: exercise book appr. 50 pages	1
		Seminar/Tutorial for Interactions of Biological Macromolecules A		1.5		0.5		2					
ILS-MA-I2B	**Interactions of Biological Macromolecules B**	Interactions of Biological Macromolecules B	2				5		3			PL: written exam 120 min. or oral exam 60 min.	1
		Seminar/Tutorial for Interactions of Biological Macromolecules B		1.5		0.5			2				
	Total SWS and ECTS of Module Group MG3 (mandatory)		**4**	**3**		**1**	**10**	**5**	**5**				
Elective Modules of Module Group 3: Biological Structures and Processes													
ILS-MA-P6	**Introduction to X-ray and Neutron Scattering I**	Elastic Scattering	2				5	2.5				PL: oral exam 30 min.	1
		Tutorial for Elastic Scattering		2				2.5					
ILS-MA-P7	**Introduction to X-ray and Neutron Scattering II**	Inelastic Scattering	2				5		2.5			PL: oral exam 30 min.	1
		Tutorial for Inelastic Scattering		2					2.5				
ILS-MA-B2	**Ion Transport and Signal Transduction**	Ion Transport and Signal Transduction				1	5		2			PL: oral exam 30 min. SL: oral presentation 30 min.	1
		Laboratory course Ion Transport and Signal Transduction		5					3				
ILS-MA-B7	**Structural Biology 1: Protein Design and Designer Proteins**	Laboratory Course and seminar Structural Biology 1: Protein Design and Designer Proteins		7		1	7.5	7.5				PL: written exam 60 min. PL: written protocol 15-20 p. PL: oral presentation 30 min.	1
ILS-MA-B8	**Structural Biology 2: Structure and Function Relationships in Biological Macromolecules**	Laboratory course and seminar Structural Biology2: Structure and function relationships in biological macromolecules		7		1	7.5		7.5			PL: written exam 60 min. PL: written protocol 15-20 p. PL: oral presentation 30 min.	1
ILS-MA-12	**Python Programming**	Practical: Introduction to Python Programming		2			5		5			SL: hands-on exercises PL: programming project	1
ILS-MAB13	**Developmental Biology 4: Genomic Engineering in Developmental Biology**	Laboratory course and seminar Developmental Biology 4: Genomic Engineering in Developmental Biology		7		1	7.5	7,5				PL: oral exam 30 min. PL: written protocol 10-15 p. SL: oral presentation 30 min	1
ILS-MA-B14	**Molecular dynamics simulation of biological membranes**	Lecture and computer course in Molecular dynamics simulation of biological membranes	2	4					7,5			PL: oral examination (30 min.) PL: project work & protocol (approx. 10 pages)	1
	Total SWS and ECTS of Module Group MG 3 (elective)		6	36	0	4	32.5	20	30	0	0		

Mandatory Modules of the Specialisation Part													
ILS-MA-VM	**Specialisation Module**	Lecture, seminar, practical training in chosen subject					20			20		PL: oral exam 30 min.	1
ILS-MA-TH	**Master’s thesis**	Master’s thesis					30				30	PL: Master's thesis appr. 20.000 words SL: Scientific report 30 min.	1
	Total ECTS of the Mandatory Modules (Specialisation pase)						**50**			**20**	**30**		
		Total ECTS (Individual Choise of Modules from MG1-MG3):					120	30	30	30	30		

Please note, that according to the “elektronischen Fernprüfungsordnung nach EFernPO i.V.m. BayFEV” chances of the examination regulations are allowed due to the restrictions of the coronavirus SARS-CoV- desease.

List of Contents

Supervision and support for the Master Life Sciences: Biology, Biomathematics, Biophysics at the Department of Biology of the Friedrich-Alexander-Universität Erlangen-Nürnberg

➔ **Studiendekan** (General enquiries concerning the studies)

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Mandatory Module

1	**Module name**	**ILS-MA-M1 Introduction to statistics and statistical programming** ILS-MA-M1 Einführung in die Statistik mit Rechnerübungen	**5 ECTS credits**
2	**Courses/lectures**	Lecture: **Introduction to Statistics**, 2 SWS Tutorial: **Introduction to Statistics**, 1 SWS Lab Class: **Statistical Programming**, 1 SWS	
3	**Lecturers**	Prof. C. Richard	

4	**Module co-ordinator**	Prof. Dr. C. Richard
5	**Contents**	• introduction to the statistical software R and elementary programming • descriptive statistics: visualisation und parameters of categorial and metric data, qq-plots, 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 targets 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	**Recommended prerequisites**	Mathematical and statistical background as taught in the BSc program Integrated Life Sciences is recommended.
8	**Integration in curriculum**	From semester two onwards (Mandatory module for module group 1, 2, and 3)
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: written examination 90 min. SL: exercise book (approx. 50 pages)
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	Teaching and examination language is English.
16	**Recommended reading**	lecture notes Rice, Mathematical Statistics and Data Analysis, Thomson 2007 www.cran.r-project.org

MG1 Mathematical Modeling and Systems Biology: Mandatory Modules

1	**Module name**	**ILS-MA-M2 Biomathematics** ILS-MA-M2 Biomathematik	**10 ECTS credits**
2	Courses/lectures	Lecture: **Biomathematics**, 4 SWS Tutorial: **Biomathematics**, 2 SWS	
3	Lecturers	Prof. Dr. V. Zaburdaev	

4	**Module co-ordinator**	Prof. Dr. 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 targets 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	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester one onwards (Mandatory module for module group 1)
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	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 examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	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**	**ILS-MA-B1- Systems Biology** ILS-MA-B1-Systembiologie	**5 ECTS credits**
2	Courses/lectures	Lecture: **Systems Biology**, 2 SWS Laboratory course: **Systems Biology**, 1 SWS compulsory attendance	
3	Lecturers	Profs. A. Burkovski, M. Klingler, U. Sonnewald Drs. S. Sonnewald, S. Uebe	

4	**Module co-ordinator**	Prof. Dr. U. Sonnewald
5	**Contents**	**Lecture:** The contents of the module deal with the following research topic in systems biology: • Genomics • Transcriptomics • Proteomics • Metabolomics • Network analysis • 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 targets 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	**Recommended prerequisites**	Not required
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: Written examination 60 min.
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 45 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Not required

MG1 Mathematical Modeling and Systems Biology: Mandatory Elective Modules

1	**Module name**	**ILS-MA-I3 Metabolic Networks II** ILS-MA-I3 Metabolische Netzwerke II	**5 ECTS credits**
2	Courses/lectures	Lecture: **Metabolic Networks II,** 3 SWS Laboratory course: **Metabolic Networks II,** 1 SWS	
3	Lecturers	Prof. Dr. A. Burkovski, Dr. A. Prechtel	

4	**Module co-ordinator**	Prof. Dr. A. 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 targets and skills**	Students learn to break down biological signal transduction processes into parts suitable for mathematic modelling, interprete, generate and optimize models and integrate own data.
7	**Recommended prerequisites**	Not required.
8	**Integration in curriculum**	From semester 3 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: oral examination 30 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Not required.

1	**Module name**	**ILS-MA-I4 Spatial Modeling of Metabolic Regulation** ILS-MA-I4 Räumliche Modelle der Stoffwechselregulation	**10 ECTS credits**
2	Courses/lectures	Lecture: **Spatial Modeling of Metabolic Regulation**, 4 SWS Tutorial: **Spatial Modeling of Metabolic Regulation**, 2 SWS Laboratory course: **Spatial Modeling of Metabolic Regulation**, 2 SWS	
3	Lecturers	Prof. Dr. U. Sonnewald, Dr. M. Neuss-Radu	

4	**Module co-ordinator**	Prof. Dr. U. Sonnewald, Dr. M. Neuss-Radu
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 targets 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 an 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	**Recommended prerequisites**	Suggested: Module Partial differential equations for life sciences
8	**Integration in curriculum**	From 3. Semester onwards
9	**Module compatibility**	MA Integrated Life Sciences

10	**Method of examination**	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 examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 120 h Independent study: 180 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	A course in Mathematical Biology, de Vries, Hillen, Lewis, Müller, Schönfisch, 2006

1	**Module name**	**ILS-MA-M3 Introduction to Mathematical Modeling** ILS-MA-M3 Einführung in Mathematische Modellierung	**10 ECTS credits**
2	Courses/lectures	Lecture: **Introduction to Mathematical Modeling**, 2 SWS Project: **Mathematical Modeling,** 2 SWS Tutorial: **Mathematical Modeling,** 2 SWS compulsory attendance (project)	
3	Lecturers	Prof. Dr. S. Kräutle, Drs. N. Ray, M. Neuss-Radu	

4	**Module co-ordinator**	Prof. Dr. S. 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 targets 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	**Recommended 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**	From semester 1 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	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**	Examination about theoretical part (oral examination): 50% Examination about practical part: 50%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 90 h Independent study: 210 h
14	**Module duration**	1 semester
15	**Teaching language**	German
16	**Recommended reading**	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**	**ILS-MA-M4 Partial Differential Equations for Life Sciences** ILS-MA-M4 Partielle Differentialgleichungen für Lebenswissenschaftler	**5 ECTS credits**
2	Courses/lectures	Lecture: **Partial Differential Equations for Life Sciences**, 2 SWS Tutorial: **Partial Differential Equations for Life Sciences**, 2 SWS	
3	Lecturers	N. N., Dr. M. Neuss-Radu	

4	**Module co-ordinator**	N.N.
5	**Contents**	● Introduction to and results for multiple integrals ● Linear partial differential equations, Maximum principle, Boundary conditions ● 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) ● Discretization in space and time for partial differential equations ● **Tutorials:** concrete examples are analysed and simulated by using standard software like Matlab or Klone.
6	**Learning targets 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 ● acquire elementary knowledge on numerical approaches for partial differential equations ● apply and evaluate software for simulation of partial differential equations ● acquire problem-oriented learning strategies and improve their skills in interdisciplinary approaches
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 2 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	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 examination 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	A course in Mathematical Biology, de Vries, Hillen, Lewis, Müller, Schönfisch, 2006

1	**Module name**	**ILS-MA-M6 Mathematical Image Processing** ILS-MA-M6 Mathematische Bildverarbeitung	**5 ECTS credits**
2	Courses/lectures	Lecture: **Mathematical Image Processing**, 2 SWS Tutorial: **Mathematical Image Processing**, 0.5 SWS	
3	Lecturers	Prof. Dr. E. Bänsch, Dr. M. Fried	

4	**Module co-ordinator**	Prof. Dr. E. Bänsch, Dr. M. Fried
5	**Contents**	● Basics for digital image processing ● deblurring using different partial differential equations: heat equation, Perona-Malik equation and Mean Curvature Flow ● example: image segmentation ● variational methods for image restauration and image segmentation ● finite element approach
6	**Learning targets and skills**	**students** ● develop a deeper understanding of mathematical and algorithmical methods for image processing ● develop finite element codes for deblurring ● analyse and evaluate algorithms for image processing ● further their self competence due to improved communication skills
7	**Recommended prerequisites**	
8	**Integration in curriculum**	From semester 2 onwards
9	**Module compatibility**	MA Integrated Life Sciences, MA. Mathematik, MA Computational and Applied Mathematics
10	**Method of examination**	PL: oral examination 20 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	Every second summer term
13	**Workload**	Contact hours: 30 h lecture, 7.5 h tutorial Independent study: 90 h (lecture), 22.5 h (tutorial/exercise)
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	

1	**Module name**	**ILS-MA-M8 Stochastic models in life sciences** ILS-MA-M8 Stochastische Modelle für Lebenswissenschaftler	**5 ECTS credits**
2	Courses/lectures	Lecture: **Stochastic models in life sciences**, 2 SWS Tutorial: **Stochastic models in life sciences**, 2 SWS compulsory attendance	
3	Lecturers	Prof. Dr. V. Zaburdaev	

4	**Module co-ordinator**	Prof. Dr. V. 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 targets and skills**	The students ● Have gained deepened knowledge concerning stochastic models in biology. ● are able to analyse and quantitatively model broad range of problems in biology. ● Have gained specialist competence concerning methods of stochastics. ● are able to analyse real biological experimental data and describe it by using stochastic concepts on the computer. ● have problem oriented analytic skills.
7	**Recommended prerequisites**	The course ILS-MA-M2 (Biomathematics) is recommended.
8	**Integration in curriculum**	from semester 2 onward
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	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 examination 100%
12	**Module frequency**	SS (summer semester)
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	One semester
15	**Teaching language**	English
16	**Recommended reading**	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

1	**Module name**	**ILS-MA-P1 Complex systems 1: critical phenomena, networks, evolutionary dynamics, reaction systems** ILS-MA-P1 Komplexe Systeme 1: Kritische Phänomene, Netzwerke, Evolutionäre Dynamik, Reaktionssysteme	**5 ECTS credits**
2	Courses/lectures	Lecture: **Complex systems 1**, 2 SWS Tutorial: **Complex systems 1**, 2 SWS	
3	Lecturers	Dr. C. Metzner	

4	**Module co-ordinator**	Dr. C. 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 targets and skills**	The students are able to: • understand intuitively multidisciplinary problems in the field of critical phenomena, networks, evolutionary dynamics, reaction systems; • understand the basic theoretical concepts, mathematical and computer simulation methods • understand and have gained the ability to use the methods and concepts in exercises • apply analytical, critical thinking and model building..
7	**Recommended prerequisites**	Recommended knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	From semester 1 onwards.
9	**Module compatibility**	MA. Integrated Life Sciences, BA / MA. in Physics, Mathematics, Material Physics, Computer Science.
10	**Method of examination**	PL: written examination 90 min.
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	Module is part of a 4 semester cycle. Modules 1-4 of the Complex Systems lecture series can be used independently.
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Not required

1	**Module name**	**ILS-MA-P2 Complex systems 2: Econo/Socio physics, continuum and discrete dynamical systems** ILS-MA-P2 Komplexe Systeme 2: Econo-/Socio-Physik, Kontinuierliche und diskrete dynamische Systeme	**5 ECTS credits**
2	Courses/lectures	Lecture: **Complex systems 2**, 2 SWS Tutorial: **Complex systems 2**, 2 SWS	
3	Lecturers	Dr. C. Metzner	

4	**Module co-ordinator**	Dr. C. Metzner
5	**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 targets 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	**Recommended prerequisites**	Required knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	From semester 1 onwards.
9	**Module compatibility**	MA Integrated Life Sciences, BA / MA in Physics, Mathematics, Material Physics, Computer Science.
10	**Method of examination**	PL: written examination 90 min.
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	Module is part of a 4 semester cycle. Modules 1-4 of the Complex Systems lecture series can be used independently.
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Not required

1	**Module name**	**ILS-MA-P3 Complex systems 3: Self-organization, game theory, discrete dynamical systems** ILS-MA-P3 Komplexe Systeme 3: Reaktionsnetzwerke, Evolutionsprozesse, Spieltheorie	**5 ECTS credits**
2	Courses/lectures	Lecture: **Complex systems 3**, 2 SWS Tutorial: **Complex systems 3**, 2 SWS	
3	Lecturers	Dr. C. Metzner	

4	**Module co-ordinator**	Dr. C. 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 targets 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	**Recommended prerequisites**	Required knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	From semester 1 onwards.
9	**Module compatibility**	MA Integrated Life Sciences, BA / MA in Physics, Mathematics, Material Physics, Computer Science.
10	**Method of examination**	PL: written examination 90 min.
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	Module is part of a 4 semester cycle. Modules 1-4 of the Complex Systems lecture series can be used independently.
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Not required

1	**Module name**	**ILS-MA-P9 Complex systems 4: Information, neurophysics, machine learning** ILS-MA-P3 Komplexe Systeme 4: Information, Neurophysik, Maschinenlernen	**5 ECTS credits**
2	Courses/lectures	Lecture: **Complex systems 4**, 2 SWS Tutorial: **Complex systems 4**, 2 SWS	
3	Lecturers	Dr. C. Metzner	

4	**Module co-ordinator**	Dr. C. 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 targets 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	**Recommended prerequisites**	Required knowledge: Basics of analysis, differential equations and statistics.
8	**Integration in curriculum**	From semester 1 onwards.
9	**Module compatibility**	MA Integrated Life Sciences, BA/ MA in Physics, Mathematics, Material Physics, Computer Science.
10	**Method of examination**	PL: written examination 90 min.
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	Module is part of a 4 semester cycle. Modules 1-4 of the Complex Systems lecture series can be used independently.
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Not required

1	**Module name**	**ILS-MA-B5 Developmental Biology 3: Visualization of Gene Regulation during Development** ILS-MA-B5 Entwicklungsbiologie 3: Visualisierung der Genregulation während der Entwicklung	**7.5 ECTS credits**
2	Courses/lectures	Laboratory course: **Developmental Biology 3**, 7 SWS Seminar: **Developmental Biology 3**, 1 SWS (for both, attendance is compulsory)	
3	Lecturers	Dr. E. El-Sherif	

4	**Module co-ordinator**	Dr. Ezzat El-Sherif
5	**Contents**	**Seminar** talks will cover basic principles of transcription in eukaryotes and different methods to investigate them, with more focus on imaging-based techniques. DNA/RNA labelling techniques and confocal and super-resolution microscopy will be discussed, emphasising on how they are applied to the study of gene regulation during development. Basics of computational methods to analyse microscopy data using Matlab and ImageJ will be covered. In the **laboratory course,** we start with applying single molecule FISH to label mRNA and enhancer RNA in fixed *Drosophila* embryos. Students will then use confocal and STED microscopy to visualize transcription products, then use Matlab and ImageJ to process the data they collected. The final phase is the data analysis, where students will investigate the correlation between enhancer, gene, and enhancer RNA activities and their co-localization in the nucleus, and how this sheds light on important events in the transcription cycle.
6	**Learning targets and skills**	Students will • have a basic understanding of principles of gene regulation in eukaryotes. • be familiar with experiments to investigate gene regulation, especially imaging-based techniques. • understand and apply RNA/DNA labeling techniques in fixed embryos (single-molecule FISH). • understand and apply confocal and super-resolution microscopy (STED and STORM). • understand and apply Image processing techniques for analyzing microscopy data (using Matlab and ImageJ).
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	MA. Integrated Life Sciences MA Zell- und Molekularbiologie
10	**Method of examination**	PL: written examination of 60 min. PL: protocol of 10-15 pages SL: seminar talk of ca. 30 min. (ungraded task)
11	**Grading procedure**	Written examination 50% Protocol 50%
12	**Module frequency**	once per year, WS
13	**Workload**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester (4 consecutive weeks)
15	**Teaching language**	English
16	**Recommended reading**	Not required

1	**Module name**	**ILS-MA-B11 BCMA IV-Bioanalytics** ILS-MA-B11 BCMA IV-Bioanalytik	**7.5 ECTS credits**
2	Courses/lectures	Lecture and Seminar: **Bioanalytics**, 1 SWS Laboratory course: **Bioanalytics**, 7 SWS compulsory attendance	
3	Lecturers	Prof. Dr. U. Sonnewald, Drs. S. Sonnewald, J. Hofmann, C.Lamm	

4	**Module co-ordinator**	Prof. Dr. U. Sonnewald
5	**Contents**	**Lecture and Seminar:** The contents of the module deal with the following research topic 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 targets 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	**Recommended prerequisites**	Not required
8	**Integration in curriculum**	1st and 2nd semester
9	**Module compatibility**	MA Cell and Molecular Biology; MA. Integrated Life Sciences
10	**Method of examination**	PL: oral examination 30 min. SL: protocol 20 pages SL: oral presentation20 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	Four-weeks
15	**Teaching language**	English
16	**Recommended reading**	Not required

1	**Module name**	**ILS-MA-B12 Introduction to Python Programming** ILS-MA-B12 Einführung in die Programmierung mit Python	**5 ECTS credits**
2	Courses/lectures	Practical: **Introduction to Python Programming (2 SWS)**	
3	Lecturers	Prof. Dr. R. Böckmann	

4	**Module co-ordinator**	Prof. Dr. R. Böckmann
5	**Contents**	The practical course will cover the basic principle of imperative and object oriented programming on the basis of the highly used programming language Python. Furthermore the extensive Standard Library as well as additional software packages like BioPython, Matplotlib and numpy will be part of the course. Python scripts will be used as interface to other programs like Pymol. In hands-on exercises during the course several problems from different fields of bioinformatics will be addressed. The homework programming projects should consolidate the learned concepts and impart some programming practice.
6	**Learning targets and skills**	The students • getting familiar with basic principles of programming • should be able to solve easy problems using Python • should be able to understand more complex programs written by others
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: programming project (approx. 10 pages)
11	**Grading procedure**	programming project 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	none

MG2 Bioimaging and Biophysics: Mandatory Modules

1	**Module name**	**ILS-MA-I1A Bioimaging & Biophysics A** ILS-MA-I1A Bioimaging & Biophysik A	**7.5 ECTS credits**
2	Courses/lectures	Lecture: **Bioimaging & Biophysics A**, 2 SWS Lab course: **Bioimaging & Biophysics A**, 4 SWS attendance compulsory	
3	Lecturers	Profs. P. Dietrich, A. Feigenspan, B. Kost, V. Sandoghdar, T. Winkler, Drs. N. Babai, R. Palmisano, R. Stadler, T. Reimann	

4	**Module co-ordinator**	Prof. Dr. B. 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 targets 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	**Recommended prerequisites**	none
8	**Integration in curriculum**	Semester 1
9	**Module compatibility**	MSc ILS
10	**Method of examination**	PL: oral examination 30 min. SL: protocol (ungraded task) approx. 40 pages
11	**Grading procedure**	Oral exam: 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 90 h Independent study:135 h
14	**Module duration**	One semester
15	**Teaching language**	English
16	**Recommended reading**	none

1	**Module name**	**ILS-MA-I1B Bioimaging & Biophysics B** ILS-MA-I1B Bioimaging & Biophysik B	**7.5 ECTS credits**
2	Courses/lectures	WS – Lecture: **Bioimaging & Biophysics B**, 2 SWS WS – Laboratory course: **Bioimaging & Biophysics B**, 4 SWS, attendance compulsory	
3	Lecturers	Profs. B. Fabry, T. Unruh, R. Hock	

4	**Module co-ordinator**	Prof. Dr. B. 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 targets 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 • are able to use the techniques and the equipment for the laboratory course in a proper way
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	Semester 2
9	**Module compatibility**	MSc ILS
10	**Method of examination**	PL: Written exam (90 minutes)
11	**Grading procedure**	Written examination: 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	One semester
15	**Teaching language**	English
16	**Recommended reading**	none

MG2 Bioimaging and Biophysics: Mandatory Elective Modules

1	**Module name**	**ILS-MA-M6 Mathematical Image Processing** ILS-MA-M6 Mathematische Bildverarbeitung	**5 ECTS credits**
2	Courses/lectures	Lecture: **Mathematical Image Processing**, 2 SWS Tutorial: **Mathematical Image Processing**, 0.5 SWS	
3	Lecturers	Prof. Dr. E. Bänsch, Dr. M. Fried	

4	**Module co-ordinator**	Prof. Dr. E. Bänsch, Dr. M. Fried
5	**Contents**	● Basics for digital image processing ● deblurring using different partial differential equations: heat equation, Perona-Malik equation and Mean Curvature Flow ● example: image segmentation ● variational methods for image restauration and image segmentation ● finite element approach
6	**Learning targets and skills**	**students** ● develop a deeper understanding of mathematical and algorithmical methods for image processing ● develop finite element codes for deblurring ● analyse and evaluate algorithms for image processing ● further their self competence due to improved communication skills
7	**Recommended prerequisites**	
8	**Integration in curriculum**	From semester 2 onwards
9	**Module compatibility**	MA Integrated Life Sciences, MA. Mathematik, MA Computational and Applied Mathematics
10	**Method of examination**	PL: oral examination 20 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	Every second summer term
13	**Workload**	Contact hours: 30h lecture, 7.5h tutorial Independent study: 90 h (lecture), 22.5 h (tutorial/exercise)
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	

1	Module name	**ILS-MA-P4 Modern Optics: Advanced Optics** ILS-MA-P4 Moderne Optik: Fortgeschrittene Optik	**5 ECTS credits**
2	Courses/lectures	Lecture: **Modern Optics I**: Advanced Optics, 2 SWS Tutorial: **Modern Optics I**: Advanced Optics, 2 SWS	
3	Lecturers	Prof. Dr. N. Joly	

4	**Module co-ordinator**	Prof. Dr. J. von Zanthier
5	**Contents**	Scalar wave optics: Maxwell equations, solutions to the wave equation; From Diffraction to Fourier optics: propagation in free space, through aperture and lenses, Image formation in microscopes using Fourier Optics; diffraction limit and super-resolution techniques for microscopy; Optics in waveguide: geometrical approach and Maxwell equation with boundary conditions, transverse modes, cutoff frequency; planar waveguide, optical fibers, tapers, couplers; linear properties (dispersion, modal content) of hollow-core and solid-core photonic crystal fibres; Bragg gratings.
6	**Learning targets and skills**	The students become familiar with the analytical tools and description methods of modern scalar as well as vectorial optics and acquire knowledge about state of the art applications in modern optics. In the tutorials the students get acquainted to solve problems of advanced optics.
7	**Recommended prerequisites**	Recommended lectures: EP-2, EP-3, TP-2
8	**Integration in curriculum**	From semester 4 onwards
9	**Module compatibility**	BA Physics, MA Physics, MAOT, ILS, BA Material Physics
10	**Method of examination**	PL: Oral examination 30 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	One semester
15	**Teaching language**	English
16	**Recommended reading**	Eugene Hecht: Optics (Addison-Wesley, New York, 1997); B. E. A. Saleh, M. E. Teich: Fundamentals of Photonics (John Wiley, New York, 2007); Born & Wolf: Principle of optics (Cambridge University Press, 1999); J. D. Jackson: Classical Electrodynamics (John Wiley & Sons, 1999).

1	**Module name**	**ILS-MA-P5 Experimental Physics 3: Optics and Quantum Phenomena** ILS-MA-P5 Experimentalphysik 3: Optik und Quantenphänomene	**7.5 ECTS credits**
2	Courses/lectures	Lecture: **Experimental Physics 3: Optics and Quantum Phenomena**, 4 SWS Tutorial: **Experimental Physics 3: Optics and Quantum Phenomena**, 2 SWS	
3	Lecturers	Prof. Dr. V. Sandoghdar	

4	**Module co-ordinator**	Prof. Dr. V. Sandoghdar
5	**Contents**	Light as a wave: Maxwell equations, wave equation in vacuum and solutions; Light and matter: dipole emission, scattering of light, propagation of light through a homogenous material, dielectric polarisation, wave equation with dielectric polarisation, reflection and refraction, Fresnel formulas, Brewster angle, (frustrated) total internal reflection, dispersion, susceptibility; Geometrical optics: ray optics, matrices for ray optics, aberrations, optical resonators; diffraction and interference: wave propagation including boundary conditions, Huygens–Fresnel principle, Fraunhofer diffraction, microscope, telescope, resolution limit, imaging techniques, the eye; Polarisation of waves: plane wave in a homogenous material, polarisation states, implications of polarisation for reflection and propagation, birefringence, polarizing elements; Fundamental experiments of quantum physics: particle character of light, photo-effect, black body radiation according tom Planck, Compton effect, wave character of massive particles (diffraction of electrons), consequences of the wave nature of the electron; Fundamental equations of quantum mechanics: Schrödinger equation, time independent Schrödinger equation, interpretation of the quantum mechanical wave function, particle in a box, quantum tunnelling
6	**Learning targets and skills**	The students become familiar with the standard analytical tools and description methods of geometrical and wave optics and acquire knowledge about the context of the most important experiments and optical applications. They also get acquainted with the fundamental principles of quantum mechanics. In the tutorials the students learn to solve problems of basis optics and quantum mechanics.
7	**Recommended prerequisites**	Recommended lectures: EP-1, EP-2
8	**Integration in curriculum**	From semester 3 onwards
9	**Module compatibility**	BA Physics, MA Physics, MAOT, ILS, BA Material Physics
10	**Method of examination**	PL: oral examination 30 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	One semester
15	**Teaching language**	German
16	**Recommended reading**	Eugene Hecht: Optics (Addison-Wesley, New York, 2015); Wolfgang Demtröder: Experimentalphysik 2, Elektrizität und Optik (Springer, Berlin, 2013); B. E. A. Saleh, M. E. Teich: Fundamentals of Photonics (John Wiley, New York, 2007); Dieter Meschede: Optik, Licht und Laser (Vieweg+Teubner, Stuttgart, 2008)

1	**Module name**	**ILS-MA-P10 Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects** **ILS-MA-P10 Zelladhäsion und Cytoskelett: Zellbiologische, biophysikalische und medizinische Aspekte**	**5 ECTS credits**
2	Courses/lectures	Lecture: Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects, 2 SWS Laboratory Course: Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects, 2 SWS	
3	Lecturers	Dr. I. Thievessen	

4	**Module co-ordinator**	Dr. I. 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 targets 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	**Recommended prerequisites**	Recommended knowledge: Basics of cell biology, material on specific topics is provided during the course.
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: oral examination 30 min. PL: protocol, graded tasked (10 pages)
11	**Grading procedure**	50% oral exam, 50% protocol
12	**Module frequency**	WS
13	**Workload**	Lecture: Contact 30 h; Independent study 45 h Practical course: Contact 30 h; Report preparation 45 h
14	**Module duration**	One semester
15	**Teaching language**	English
16	**Recommended reading**	

1	**Module name**	**ILS-MA-B9 Molecular Neurophysiology** ILS-MA-B9 Molekulare Neurophysiologie	**7.5 ECTS credits**
2	Courses/lectures	Lecture: **Molecular Neurophysiology**, 1 SWS Laboratory course: **Molecular Neurophysiology**, 7 SWS Compulsory attendance during practical course and seminar	
3	Lecturers	Prof. Dr. A. Feigenspan	

4	**Module co-ordinator**	Prof. Dr. A. 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 targets 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	**Recommended prerequisites**	None
8	**Integration in curriculum**	1. or 2. semester
9	**Module compatibility**	MA Cell and molecular biology MA Integrated Life Science
10	**Method of examination**	PL: oral examination 30 min. PL: written protocol approx. 30 pages PL: seminar talk 30 min.
11	**Grading procedure**	Arithmetic mean of oral exam and written protocol grades
12	**Module frequency**	SS
13	**Workload**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	4-week course during the summer term
15	**Teaching language**	English
16	**Recommended reading**	Mark F. Bear et al.: Neuroscience. Exploring the Brain. 4th ed. 2015, Wolters Kluwer Dale Purves et al.; Neuroscience. 5th ed. 2012, Sinauer

1	**Module name**	**ILS-MA-B10 (Confocal-) light microscopy methods in cell biology** ILS-MA-B10 (Konfokale-) Lichtmikroskopie in der Zellbiologie	**5 ECTS credits**
2	Courses/lectures	Seminar: **Light microscopy methods in cell biology,** 1 SWS Practical course: **Light microscopy methods in cell biology** 5 SWS, compulsory attendance	
3	Lecturers	Dr. R. Stadler, Dr. T. Reimann	

4	**Module co-ordinator**	Dr. T. Reimann
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 targets 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	**Recommended prerequisites**	none
8	**Integration in curriculum**	from semester 2 onwards
9	**Module compatibility**	MA Integrated Life Science
10	**Method of examination**	PL: oral examination: 30 min. SL: oral presentation of a publication: 30 min.
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 90h Independent study: 60h
14	**Module duration**	3 weeks block course (end of summer semester)
15	**Teaching language**	English
16	**Recommended reading**	

1	**Module name**	**ILS-MA-B12 Introduction to Python Programming** ILS-MA-B12 Einführung in die Programmierung mit Python	**5 ECTS credits**
2	Courses/lectures	Practical: **Introduction to Python Programming (2 SWS)**	
3	Lecturers	Prof. Dr. R. Böckmann	

4	**Module co-ordinator**	Prof. Dr. R. Böckmann
5	**Contents**	The practical course will cover the basic principle of imperative and object oriented programming on the basis of the highly used programming language Python. Furthermore the extensive Standard Library as well as additional software packages like BioPython, Matplotlib and numpy will be part of the course. Python scripts will be used as interface to other programs like Pymol. In hands-on exercises during the course several problems from different fields of bioinformatics will be addressed. The homework programming projects should consolidate the learned concepts and impart some programming practice.
6	**Learning targets and skills**	The students • getting familiar with basic principles of programming • should be able to solve easy problems using Python • should be able to understand more complex programs written by others
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: programming project (approx. 10 pages)
11	**Grading procedure**	programming project 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	none

MG3: Biological Structures and Processes: Mandatory Modules

1	**Module name**	**ILS-MA-I2A Interaction of Biological Macromolecules A**	**5 ECTS credits**
2	Courses/lectures	Lecture: **Interactions of Biological Macromolecules A** (2 SWS) Tutorial: **Interactions of Biological Macromolecules A** (2 SWS)	
3	Lecturers	Profs. Y. Muller, P. Dietrich, J. Eichler, H. Sticht, Dr. H. Lanig	

4	**Module co-ordinator**	Prof. Dr. Y. 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 bioinformatical prediction of contiguous and non-contiguous interaction segments in proteins, computational docking methods, 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 targets 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	**Recommended prerequisities**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences
10	**Method of examination**	PL: written examination 120 min. SL: exercise book (approx. 50 pages)
11	**Grading procedure**	Written examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	none

1	**Module name**	**ILS-MA-I2B Interactions of Biological Macromolecules B**	**5 ECTS credits**
2	Courses/lectures	Lecture: **Interactions of Biological Macromolecules, 2 SWS** Tutorial: **Interactions of Biological Macromolecules, 2 SWS**	
3	Lecturers	Profs. R. Böckmann, T. Unruh	

4	**Module co-ordinator**	Prof. Dr. R. 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 targets and skills**	The students will acquire the following 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	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences
10	**Method of examination**	PL: written examination 120 min
11	**Grading procedure**	Written exam100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	none

MG3: Biological Structures and Processes: Mandatory Elective Modules

1	**Module name**	**ILS-MA-P6 Introduction to X-ray and neutron scattering I**	**5 ECTS credits**
2	Courses/lectures	Lecture: **Elastic scattering**, 2 SWS Tutorial: **Elastic scattering**, 2 SWS	
3	Lecturers	Prof. Dr. T. Unruh	

4	**Module co-ordinator**	Prof. Dr. T. Unruh
5	**Contents**	• Introduction to the fundamentals of light, X-ray, and neutron scattering • Mode of operation of different neutron instruments for elastic scattering • realization of the components of instruments for elastic scattering(instrumentation) • kinematic theory for X-ray and neutron beam interferences • The lattice factor: • determination of particle size distributions • strain analysis with neutrons • The structure factor: • single crystal analysis • experimental determination of structure factors • the phase problem and its solution • examples of dynamical scattering theory • Small angle scattering • diffuse small angle scattering • complex interference effects at small scattering angles • contrast variation in neutron small angle scattering
6	**Learning targets and skills**	The students learn: • to apply the kinematic scattering theory in a wide range of scientific questions • to understand the operation mode of different types neutron instruments for elastic scattering • to estimate the suitability of different elastic scattering methods for the determination of atomic, molecular, and particulate structures in complex systems • to analyze X-ray and neutron diffraction patterns autonomously
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences
10	**Method of examination**	PL: oral examination 30 min.
11	**Grading procedure**	Oral examination 30 min. 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	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**	**ILS-MA-P7 Introduction to X-ray and neutron scattering II**	**5 ECTS credits**
2	Courses/lectures	Lecture: **Inelastic scattering**, 2 SWS Tutorial: **Inelastic scattering**, 2 SWS	
3	Lecturers	Prof. Dr. T. Unruh	

4	**Module co-ordinator**	Prof. Dr. T. 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) • Application examples: o dispersion relation of lattice vibrations o molecular motions in liquids and membranes o inter- and intra-molecular motions • Dynamic light scattering and inelastic X-ray scattering
6	**Learning targets 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	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 2 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences
10	**Method of examination**	PL: oral examination 30 min.
11	**Grading procedure**	Oral examination 30 min. 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 60 h Independent study: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	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**	**ILS-MA-B2 Ion Transport and Signaling** ILS-MA-B2 Ionentransport und Signaltransduktion	**5 ECTS credits**
2	Courses/lectures	Seminar: **Ion Transport and Signaling**, 1 SWS Laboratory Course: **Ion Transport and Signaling**, 5 SWS compulsory attendance	
3	Lecturers	Prof. Dr. P. Dietrich	

4	**Module co-ordinator**	Prof. Dr. P. 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 (Ca^{2+}-dependent) signal transduction networks, using theoretical approaches (literature, lecture, seminar) combined with experiments in the lab. The practical part focuses on the analysis of • Protein-protein interactions using different techniques • Use of genetically encoded calcium reporters for spatio-temporal analysis of Ca^{2+} oscillations and Ca^{2+} responses • Confocal microscopy • Molecular biology (cloning strategies and plasmid preparations) • Expression systems: yeast, Xenopus laevis oocytes, plant cells • Site-directed mutagenesis or analysis of function domains in ion channels Electrophysiological characterization of ion transport (optional for interested students only).
6	**Learning targets and skills**	Students will • learn experimental methods for studying membrane proteins • learn methods for studying calcium ‘signatures’ as information carriers • 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
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences
10	**Method of examination**	SL: oral presentation 30 min. (ungraded task) PL: oral examination 30 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 90 h Independent study: 60 h
14	**Module duration**	1 semester (3 consecutive weeks). 90h contact time during 3 weeks will allow attending lectures of other modules as well.
15	**Teaching language**	English
16	**Recommended reading**	

1	**Module name**	**ILS-MA-B7 Structural Biology I: Protein Design and Designer Proteins** ILS-MA-B7 Strukturbiologie I: Proteindesign und Designerproteine	**7.5 ECTS credits**
2	Courses/lectures	Seminar: **Structural Biology**, 1 SWS Laboratory Course: **Protein Design and Designer Proteins**, 7 SWS (attendance is compulsory for both)	
3	Lecturers	Profs. Y. Muller, R. Böckmann	

4	**Module co-ordinator**	Prof. Dr. Y. Muller
5	**Contents**	**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 targets and skills**	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	**Recommended prerequisites**	None
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences M.Sc. Zell- und Molekularbiologie
10	**Method of examination**	PL: written examination 90 min. PL: protocol of 15-20 pages PL: seminar talk 15 min.
11	**Grading procedure**	written examination 40% project protocol 40% seminar talk 20%
12	**Module frequency**	WS
13	**Workload**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	

1	**Module name**	**ILS-MA-B8 Structural Biology II: Structure and Function Relationships in Biological Macromolecules** ILS-MA-B8 Strukturbiologie II: Struktur-Funktionsbeziehungen in Biologischen Makromolekülen	**7,5 ECTS credits**
2	Courses/lectures	Seminar: Structural Biology, 1 SWS Laboratory Course: **Structure-Function Relationships in Biological Macromolecules**, 7 SWS (attendance is compulsory for both)	
3	Lecturers	Profs. Y. Muller, R. Böckmann, Dr. B. Schmid	

4	**Module co-ordinator**	Prof. Dr. Y. 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 targets 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	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences M.Sc. Zell- und Molekularbiologie
10	**Method of examination**	PL: written examination 90 min. PL: protocol of 15-20 pages PL: seminar talk 15 min.
11	**Grading procedure**	written examination 40% project protocol 40% seminar talk 20%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	

1	**Module name**	**ILS-MA-B12 Introduction to Python Programming** ILS-MA-B12 Einführung in die Programmierung mit Python	**5 ECTS credits**
2	Courses/lectures	Practical: **Introduction to Python Programming (2 SWS)**	
3	Lecturers	Prof. Dr. R. Böckmann	

4	**Module co-ordinator**	Prof. Dr. R. Böckmann
5	**Contents**	The practical course will cover the basic principle of imperative and object oriented programming on the basis of the highly used programming language Python. Furthermore the extensive Standard Library as well as additional software packages like BioPython, Matplotlib and numpy will be part of the course. Python scripts will be used as interface to other programs like Pymol. In hands-on exercises during the course several problems from different fields of bioinformatics will be addressed. The homework programming projects should consolidate the learned concepts and impart some programming practice.
6	**Learning targets and skills**	The students • getting familiar with basic principles of programming • should be able to solve easy problems using Python • should be able to understand more complex programs written by others
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: programming project (approx. 10 pages)
11	**Grading procedure**	programming project 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 30 h Independent study: 120 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	none

1	**Module name**	**ILS-MA-B13 Developmental Biology 4: Genetic Engineering in Developmental Biology** ILS-MA-B14 Entwicklungsbiologie 4: Genetic Engineering in der Entwicklungsbiologie	**7.5 ECTS credits**
2	Courses/lectures	Laboratory Course: **Developmental Biology 2**, 7 SWS Seminar: **Developmental Biology 2**, 1 SWS (for both, attendance is compulsory)	
3	Lecturers	Prof. Dr.M. Klingler, Dr. M. Schoppmeier	

4	**Module co-ordinator**	Prof. Dr. Klingler
5	**Contents**	**Seminar** talks cover topics concerning “Genome Editing” as well as gene regulation, development, pattern formation, evolution of developmental processes with an emphasis on the methods used. In the **laboratory course,** projects in small groups are pursued related to ongoing research in the participating labs, which address *Segmentation Clock*", limbs- or gonads development in the flour beetle *Tribolium*. Various genetic methods (Mutants, RNA-Interference, transgenic insects, CRISPR-editing), microscopy techniques (3D Fluorescene microscopy ApoTome, confocal Microscopy, Transmissionselectron-microscopy - TEM), microinjection, Immuno istology / in situ-colorings, as well as molecular and bioinformatic methods were used.
6	**Learning targets and skills**	Students will acquire the following skills: They will • be able to present and to critically discuss scientific data and results of research articles in the field of developmental biology • are able to present the data of a scientific paper in suitable manner • be able to present and to apply methods used for the analysis of developmental issues/questions • be able to independently develop working hypotheses, and to plan and conduct experiments to test these • learn to analyse and discuss their results and defend their conclusions in proper context
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Integrated Life Sciences M.Sc. Zell- und Molekularbiologie
10	**Method of examination**	PL: oral examination of 30 min. PL: protocol of 10-15 pages SL: seminar talk 20 min. (ungraded task)
11	**Grading procedure**	Oral examination 50% Written report 50%
12	**Module frequency**	once per year, SoSe
13	**Workload**	Contact hours: 120 h Independent study: 105 h
14	**Module duration**	1 semester (4 consecutive weeks)
15	**Teaching language**	English
16	**Recommended reading**	

1	**Module name**	**ILS-MA-B14: Molecular dynamics simulation of biological membranes** ILS-MA-B14: Molekulardynamische Simulationen biologischer Membranen	**7.5 ECTS-Punkte**
2	**Courses/lectures**	Lecture: 2 SWS Computer Lab: 4 SWS	
3	**Lecturers**	Prof. R. Böckmann	

4	**Module co-ordinator**	Prof. Dr. Rainer Böckmann
5	**Contents**	**Theory and Practice of Molecular Dynamics Simulations** **Membranes:** Composition of biological membranes, structure, dynamics, asymmetry, spontaneous association of lipids to membranes, role of cholesterol, domain formation in membranes ('lipid rafts'), protein-lipid interaction, receptor clustering **Theory:** physical interactions in MD simulations, Newton's equations of motion, integration of equations of motion, temperature control in simulations, boundary conditions, static and dynamic properties in biomolecular systems **Practice (Computer Lab):** Introduction to Python, implementation of MD simulation in Python, programming of simple analysis tools, introduction into simulation of membrane systems (Gromacs package)
6	**Learning targets and skills**	The students are able to • describe and explain standard methodologies in MD simulations • possess profound knowledge in theory of biomolecular interactions • learn the programming language Python • acquire problem-oriented programming strategies using Python • understand and explain molecular driving forces in domain formation of biomembranes
7	**Recommended prerequisites**	None
8	**Integration in curriculum**	From semester one onwards
9	**Module compatibility**	Master Zell- und Molekularbiologie Master Integrated Life Sciences
10	**Method of examination**	PL: oral examination (30 min.) PL: project work & protocol (approx. 10 pages)
11	**Grading procedure**	oral examination 50 %, written protocol 50 %
12	**Module frequency**	SoSe
13	**Workload**	Contact hours: 90 h Independent study: 135 h
14	**Module duration**	1 semester
15	**Teaching language**	Teaching and examination language is English
16	**Recommended reading**	• Lecture notes • Daan Frenkel, Berend Smit: „Understanding Molecular Simulation"

Advanced Module

1	**Module name**	**ILS-MA-VM Advanced Module**	**20 ECTS credits**
2	Courses/lectures	Lecture/Seminar/Practical: **Advanced Module**, 20 SWS	
3	Lecturers	Lecturer of the Departments Biology, Mathematics or Physics	

4	**Module co-ordinator**	Lecturer of the Departments Biology, Mathematics or Physics
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 targets 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	**Recommended prerequisites**	none
8	**Integration in curriculum**	3.semester
9	**Module compatibility**	M.Sc. Integrated Life Sciences
10	**Method of examination**	PL: oral examination 30 min.
11	**Grading procedure**	Oral examination 100%
12	**Module frequency**	WS or SS
13	**Workload**	600 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	none

1	Module name	**ILS-MA-TH Master Thesis**	30 ECTS credits
2	Courses/lectures	**Master Thesis**	
3	Lecturers	Lecturer of the Departments Biology, Mathematics or Physics	

4	**Module co-ordinator**	Lecturer of the Departments Biology, Mathematics or Physics
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 targets 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	**Recommended prerequisites**	60 ECTS in MA Integrated Life Sciences
8	**Integration in curriculum**	4th semester
9	**Module compatibility**	M.Sc. Integrated Life Sciences
10	**Method of examination**	PL: Master thesis approx. 20000 words SL: Scientific report 30 min.
11	**Grading procedure**	Master Thesis 100%
12	**Module frequency**	WS or SS
13	**Workload**	900 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	none