Master of Science

Integrated Life Sciences

April, 11 2018

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

Department of Biology
Friedrich-Alexander-Universität Erlangen-Nürnberg

Latest version: 11.04.2018
With reference to:

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

	Code	Title	Course	spezification exam /ungraded task	Semester
Module group 1: Mathematical Modeling and Systems Biology					
mandatory modules	ILS-MA-M1	**Introduction to Statistics and Statistical Programming**	Introduction to Statistics Tutorial for Introduction to Statistics (Problem Session) Lab class Statistical Programming	PL: written exam 90 min. SL: weekly exercises	2
mandatory modules	ILS-MA-M2	**Biomathematics**	Biomathematics Tutorial for Biomathematics	PL: oral exam 30 min SL: paper- and computer exercises	1
mandatory modules	ILS-MA-B1	**Systems Biology**	Systems Biology Laboratory course Systems Biology	PL: written exam 60 min.	1
mandatory elective modules	ILS-MA-I3	**Metabolic Networks II**	Metabolic Networks II Laboratory course Metabolic Networks II	PL: oral exam 30 min.	3
mandatory elective modules	ILS-MA-I4	**Spatial Modeling of Metabolic Processes**	Spatial Modelling of Metabolic Processes Tutorial for Spatial Modelling of Metabolic Processes Laboratory course for Spatial Modelling of Metabolic Processes	PL: written exam 90 min. SL: exercise sheets	3
mandatory elective modules	ILS-MA-M3	**Introduction to Mathematical Modeling**	Introduction to Mathematical Modeling Tutorial/project for Introduction to Mathematical Modeling	PL: oral exam 20 min. PL: oral presentation 20 min. PL: protocol 20 p.	1
mandatory elective modules	ILS-MA-M4	**Partial Differential Equations for Life Sciences**	Partial Differential Equations for Life Sciences Tutorial for Partial Differential Equations for Life Sciences	PL: written exam 60 min. SL: exercise sheets	2
mandatory elective modules	ILS-MA-M6	**Mathematical Image Processing**	Mathematical Image Processing Tutorial for Mathematical Image Processing	PL: oral exam 20 min.	2
mandatory elective modules	ILS-MA-M8	**Stochastic Models in Life Sciences**	Stochastic Models in Life Sciences Tutorial for Stochastic Models in Life Sciences	PL: oral exam 30 min. SL: weekly exercises	2
mandatory elective modules	ILS-MA-P1	**Complex Systems 1**	Complex Systems 1 Tutorial for Complex Systems 1	PL: written exam 90 min.	1/3
mandatory elective modules	ILS-MA-P2	**Complex Systems 2**	Complex Systems 2 Tutorial for Complex Systems 2	PL: written exam 90 min.	2/4
mandatory elective modules	ILS-MA-P3	**Complex Systems 3**	Complex Systems 3 Tutorial for Complex Systems 3	PL: written exam 90 min.	1/3
mandatory elective modules	ILS-MA-P9	**Complex Systems 4**	Complex Systems 4 Tutorial for Complex Systems 4	PL: written exam 90 min.	2/4

	ILS-MA-B5	**Developmental Biology 3: Computer simulations of embryonal pattern formation**	Laboratory course and seminar Computer simulations of embryonal pattern formation	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	PL: oral exam 30 min. SL: written protocol 20 p. SL: presentation 30 min.	2
	ILS-MA-B12	**Python Programming**	Practical: Introduction to Python Programming	SL:- hands-on exercises PL: programming project	2
	ILS-MA-B13	**Bio-Perl: Perl-Programming for Biology**	Lecture: Perl Programming for Biology Computer lab: Perl Programming for Biology	PL: graded homework assignments	1/2
	ILS-MA-B14	**Sequence Analysis and Statistical Genomics**	Lecture: Sequence Analysis and Statistical genomics Computer lab: Sequence Analysis and Statistical genomics	PL: graded homework assignments	2
Module group 2: Bioimaging and Biophysics					
mandatory modules	ILS-MA-M1	**Introduction to Statistics and Statistical Programming**	Introduction to Statistics Tutorial for Introduction to Statistics (Problem Session) Lab class Statistical Programming	PL: written exam 90 min. SL: weekly exercises	2
mandatory modules	ILS-MA-I1A	**Bioimaging & Biophysics A**	Bioimaging & Biophysics A Laboratory course Bioimaging & Biophysics A	PL: oral exam 30 min. SL: protocol 40 p.	1
mandatory modules	ILS-MA-I1B	**Bioimaging & Biophysics B**	Bioimaging & Biophysics B Laboratory course Bioimaging & Biophysics B	PL: written exam 90 min.	2
mandatory elective modules	ILS-MA-M6	**Mathematical Image Processing**	Mathematical Image Processing Tutorial for Mathematical Image Processing	PL: oral exam 20 min.	2
mandatory elective modules	ILS-MA-P4	**Modern Optics: Advanced Optics**	Modern Optics: Advanced Optics Tutorial for Modern Optics: Advanced Optics	PL: written exam 120 min.	1/3
mandatory elective modules	ILS-MA-P5	**Experimental Physics 3: Optics and Quantum Phenomena**	Experimental Physics 3: Optics and Quantum Phenomena Tutorial for Experimental Physics 3: Optics and Quantum Phenomena	PL: oral exam 30 min.	3
mandatory elective modules	ILS-MA-P10	**Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects**	Lecture: Cell Adhesion and Cytoskeleton: Cell Biological, Biophysical, and Medical Aspects Laboratory course	PL: oral exam 30 min. PL: protocol (graded tasked)	1
mandatory elective modules	ILS-MA-B9	**Molecular Neurophysiology**	Laboratory course and seminar Molecular Neurophysiology	PL: oral exam 30 min. PL: written protocol 30 p. SL: presentation 30 min.	2
mandatory elective modules	ILS-MA-B10	**Methods of Modern (Confocal-) Light Microscopy**	Laboratory course and seminar Methods of Modern (Confocal-) Light Microscopy	PL: written exam 60 min. SL: oral presentation 30 min.	2
mandatory elective modules	ILS-MA-12	**Python Programming**	Practical: Introduction to Python Programming	SL:- hands-on exercises PL: programming project	2

Module group 3: Biological Structures and Processes

mandatory modules	ILS-MA-M1	**Introduction to Statistics and Statistical Programming**	Introduction to Statistics Tutorial for Introduction to Statistics (Problem Session) Lab class Statistical Programming	PL: written exam 90 min. SL: weekly exercises	2
	ILS-MA-I2A	**Interaction of Biological Macromolecules A**	Interactions of Biological Macromolecules A Seminar/Tutorial for Interactions of Biological Macromolecules A	PL: written exam 120 min. SL: exercise sheets	1
	ILS-MA-I2B	**Interaction of Biological Macromolecules B**	Interactions of Biological Macromolecules B Seminar/Tutorial for Interactions of Biological Macromolecules B	PL: written exam 120 min.	2
mandatory elective modules	ILS-MA-P6	**Introduction to X-ray and Neutron Scattering I**	Elastic Scattering Tutorial for Elastic Scattering	PL: oral exam 30 min.	1/3
	ILS-MA-P7	**Introduction to X-ray and Neutron Scattering II**	Inelastic Scattering Tutorial for Inelastic Scattering	PL: oral exam 30 min.	2
	ILS-MA-B2	**Ion Transport and Signal Transduction**	Ion Transport and Signal Transduction Laboratory courser Ion Transport and Signal Transduction	PL: oral exam 30 min. SL: oral presentation 30 min.	1
	ILS-MA-B3	**Developmental Biology 1: Pattern Formation, Growth, and Evolution**	Laboratory course and seminar Developmental Biology 1: Pattern Formation, Growth, and Evolution	PL: oral exam 30 min. PL: written protocol 10-15 p. SL: oral presentation 30 min.	2
	ILS-MA-B4	**Developmental Biology 2: Molecular Control of Stem Cell and Organ Differentiation**	Laboratory course and seminar Developmental Biology 2: Molecular Control of Stem Cell and Organ Differentiation	PL: oral exam 30 min. PL: written protocol 10-15 p. SL: oral presentation 30 min.	2
	ILS-MA-B6	**Developmental Biology 4: Cell Migration and Morphogenesis**	Laboratory course and seminar Developmental Biology 4: Cell Migration and Morphogenesis	PL: oral exam 30 min. PL: written protocol 10-15 p. SL: oral presentation 30 min.	1
	ILS-MA-B7	**Structural Biology 1: Protein Design and Designer Proteins**	Laboratory Course and seminar Structural Biology 1: Protein Design and Designer Proteins	PL: written exam 60 min. PL: written protocol 15-20 p. PL: oral presentation 30 min.	1/3
	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	PL: written exam 60 min. PL: written protocol 15-20 p. PL: oral presentation 30 min.	2
	ILS-MA-12	**Python Programming**	Practical Introduction to Python Programming	SL:- hands-on exercises PL: programming project	2
	ILS-MA-VM	**Advanced Module**	Lecture, seminar, practical training in chosen subject	PL: oral exam 30 min.	3
	ILS-MA-TH	**Master thesis**	Master thesis	PL: Master thesis, SL: scientific report, (presentation of results 30 min.)	4

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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Presentation of the Master Life Sciences: Biology, Biomathematics, Biophysics

MG1 Mathematical Modeling and Systems Biology: Mandatory Modules

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. Dr. C. Richard, Prof. Dr. G. Keller	

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: weekly exercises
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

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	Dr. L. Schewe	

4	**Module co-ordinator**	Dr. L. Schewe
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
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	Prof. Dr. A. Burkovski, Prof. Dr. M. Klingler, Dr. S. Sonnewald, Prof. Dr. U. Sonnewald, Prof. Dr. L. Taher, Dr. 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, interpret, 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
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	Dr. M. Neuss-Radu, Prof. Dr. S. Kräutle	

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**	
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-M3 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	Prof. Dr. P. Knabner, Dr. M. Neuss-Radu	

4	**Module co-ordinator**	Prof. Dr. P. Knabner
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
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 Stoachastic models in life sciences** ILS-MA-M8 Stochastische Modelle für Lebenswissenschaftler	**5 ECTS credits**
2	Courses/lectures	Lecture: **Stoachastic models in life sciences**, 2 SWS Tutorial: **Stoachastic models in life sciences**, 2 SWS compulsory attendance	
3	Lecturers	Prof. Dr. A. Greven, Prof. Dr. C. Richard	

4	**Module co-ordinator**	Prof. Dr. A. Greven
5	**Contents**	Lecture: A stochastic analysis of chemical reaction networks (Gillespie algorithm, gene expression) B interaction networks (protein-protein interactions, evolution of networks) C population genetics (Wright-Fisher model, coalescent, recombination) Tutorial: theoretical and computer exercises relating to the contents of the lectures
6	**Learning targets 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	**Recommended prerequisites**	The course ILS-MA-M2 (Biomathematics) is recommended.
8	**Integration in curriculum**	from semester 2 onward (next opportunity SoSe 2019)
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: oral examination 30 min. SL: weekly one exercise sheet
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**	Stochastic Modelling for Systems Biology, Wilkinson, 2006 Population Genetics: A concise guide, Gillespie, 2004

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	PD Dr. C. Metzner	

4	**Module co-ordinator**	PD 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**	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	**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**	Material on the various specific topics is provided during the course.

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	PD Dr. C. Metzner	

4	**Module co-ordinator**	PD 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**	Intuitive understanding of multidisciplinary problems in the field of Econo/Socio physics, continuum and discrete dynamical 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	**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**	Material on the various specific topics is provided during the course.

	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**
	Courses/lectures	Lecture: **Complex systems 3**, 2 SWS Tutorial: **Complex systems 3**, 2 SWS	
	Lecturers	PD Dr. C. Metzner	

4	**Module co-ordinator**	PD 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**	Intuitive understanding of multidisciplinary problems in the field of Self-organization, game theory, discrete dynamical 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	**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**	Material on the various specific topics is provided during the course.

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

4	**Module co-ordinator**	PD 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**	Intuitive understanding of multidisciplinary problems in the field of Information, neurophysics, machine learning; 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	**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**	Material on the various specific topics is provided during the course.

1	**Module name**	**ILS-MA-B5 Developmental Biology 3: Computer simulations of embryonic patterning processes** ILS-MA-B5 Entwicklungsbiologie 3: Computer-simulationen embryonaler Musterbildungsprozesse	**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	Prof. Dr. M. Klingler	

4	**Module co-ordinator**	Prof. Dr. M. Klingler
5	**Contents**	**Seminar** talks cover topics concerning the mechanisms of pattern formation in the development of animals and plants, with emphasis on reaction diffusion systems. In the **laboratory course,** we start with simple systems (radioactive decay, diffusion laws, biochemical oscillations, predator-prey models, travelling chemical waves, lateral inhibition systems) and then move to more complex models, such as formation of stripes in 2D, Drosophila segmentation, vertebrate somitogenesis, growth of veins, positioning of leaf primordia (phyllotaxis). On this basis then models from the current literature are brought into our software environment and we explore the properties and experimental implications of these models in the computer.
6	**Learning targets and skills**	Students will acquire the following skills: they • are familiar with current concepts concerning the biochemical basis of pattern formation in developmental biological processes • have obtained an understanding of the practical use of differential equations and reaction diffusion models • are able to present and critically discuss mathematical models in current developmental research articles • are able to independently develop working hypotheses, and to plan, program and analyse reaction diffusion models to test these hypotheses • can discuss their results and defend their conclusions in proper context • are able to use the techniques and the equipment for the laboratory course in a proper way • are able to discuss and reflect the topics of the seminar
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 examinationof 60 min. PL: protocol of 10-15 pages SL: seminar talk of ca. 30 min. (ungraded task)
11	**Grading procedure**	Oral examination50% 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**	Introductory review articles will be provided electronically

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, Dr. S. Sonnewald, Dr. J. Hofmann, Dr. M. Kraner	

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**	SL: hands-on exercises during the course PL: programming project
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 BioPerl: Perl Programming for Biology** ILS-MA-B13 BioPerl: Perl Programmierung für Biologie	**5 ECTS credits**
2	Courses/lectures	Lecture: **Perl Programming for Biology**, 2 SWS Computer Lab: **Perl Programming for Biology**, 3 SWS	
3	Lecturers	Prof. Dr. L. Taher	

4	**Module co-ordinator**	Prof. Dr. L. Taher
5	**Contents**	Lecture: The lectures will cover basic data structures, reading and writing files, program control, and regular expressions. The Perl programming language will be used to introduce skills and concepts to process and interpret biological data. The extensive BioPerl modules will be part of the course. Computer Lab: Students will work through examples focused on typical problems in bioinformatics research, in particular, in the field of sequence analysis. Homework programming projects should consolidate the learned concepts and impart some programming practice.
6	**Learning targets and skills**	The students • acquire basic abilities to design algorithms to solve specific problems • become familiar with basic principles of programming • are able to perform basic software development task and phrase research questions using Perl • are 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: (graded) homework assignment approx. 10 pages
11	**Grading procedure**	Homework 100%
12	**Module frequency**	each semester
13	**Workload**	Contact hours: 75 h Independent study and homework:75 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Learning Perl (O'Reilly) Introduction to Algorithms (The MIT Press) Algorithms on Strings, Trees and Sequences (Cambridge University Press)

1	**Module name**	**ILS-MA-B14 Sequence Analysis and Statistical Genomics** ILS-MA-B14 Sequenzanalyse und statistische Genomik	**5 ECTS credits**
2	Courses/lectures	Lecture: **Sequence analysis and statistical genomics**, 2 SWS Computer Lab: **Sequence analysis and statistical genomics**, 2 SWS	
3	Lecturers	Prof. Dr. L. Taher	

4	**Module co-ordinator**	Prof. Dr. L. Taher
5	**Contents**	The course aims to present some of the most basic algorithms and statistical models for DNA sequence analysis. It focuses on teaching students how to formulate a problem as a mathematical and computational problem, and then solve it using efficient algorithms and appropriate statistical methods. Lecture: The lectures will cover basic data visualization and summarization, statistical methods, parameter estimation, hypothesis testing, sequence alignment and genome assembly algorithms, population variation, and genome association studies. Computer Lab: Students will work on problems and through statistical analyses using the freely available software R.
6	**Learning targets and skills**	The students • appreciate the stochastic nature of biological phenomena • summarize and visualize data • understand some commonly used algorithms in genomics • understand the mathematical models behind population association studies • choose appropriate statistical methods to assess statistical significance • critically evaluate and interpret statistical methods used in primary research articles • implement a variety of analytical tasks on real datasets
7	**Recommended prerequisites**	None
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	MA Integrated Life Sciences
10	**Method of examination**	PL: 2 (graded) homework assignments approx. 10 pages
11	**Grading procedure**	Homework 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 60 h Independent study and homework: 90 h
14	**Module duration**	1 semester
15	**Teaching language**	English
16	**Recommended reading**	Bioinformatics for Biologists (Cambridge University Press) Biological Sequence Analysis (Cambridge University Press) Algorithms on Strings, Trees, and Sequences (Cambridge University Press)

MG2 Bioimaging and Biophysics: Mandatory Modules

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. Dr. C. Richard, Prof. Dr. G. Keller	

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: weekly exercises
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

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. Drs. P. Dietrich, A. Feigenspan, B. Kost, V. Sandoghdar, T. Winkler PD Dr. R. Stadler	

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. Drs. 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, 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 waveguide: 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 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: Written examination 120 min.
11	**Grading procedure**	Written 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); Lukas Novotny, Bert Hecht: Nano-Optics (Cambridge University Press, Cambridge, 2012).

1	**Module name**	**ILS-MA-P3 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. G. Leuchs	

4	**Module co-ordinator**	Prof. Dr. G. Leuchs
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: Understanding of basic concepts in cell and tissue mechanics and the concept of “molecular medicine”; Learn to discern cellular, physical, and molecular aspects in biomedical contexts; Training of analytical and critical thinking. Laboratory course: Ability to postulate and experimentally test a hypothesis; Practice and learn how to apply standard cell biological, biophysical, biochemical, and microscopical techniques.
7	**Recommended prerequisites**	
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**	Recommended knowledge: Basics of cell biology, material on specific topics is provided during the course.

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	PD. Dr. R. Stadler, Dr. A.. Montes	

4	**Module co-ordinator**	Dr. A. Montes
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: written examination: 60 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**	Will be provided 2-3 weeks prior to the seminar via StudOn

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**	M.Sc. Integrated Life Sciences
10	**Method of examination**	SL: hands-on exercises during the course PL: programming project
11	**Grading procedure**	programming project 100%
12	**Module frequency**	SS
13	**Workload**	Contact hours: 30 h Independent study: 120h
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-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. Dr. C. Richard, Prof. Dr. G. Keller	

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: weekly exercises
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

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	Prof. Dr. Y. Muller, Prof. Dr. P. Dietrich, Prof. Dr. J. Eichler, Prof. Dr. H. Sticht, PD Dr. H. Lang	

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 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 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 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. SL: six one page exercise sheets (ungraded task)
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 Membranes**, 2 SWS Tutorial: **Interactions of Biological Membranes**, 2 SWS	
3	Lecturers	Prof. Dr. R. Böckmann, Prof. Dr. 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: o determination of particle size distributions o strain analysis with neutrons • The structure factor: o single crystal analysis o experimental determination of structure factors o the phase problem and its solution o examples of dynamical scattering theory • Small angle scattering o diffuse small angle scattering o complex interference effects at small scattering angles o 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 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 • Ca^{2+}-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 targets and skills**	Students will • 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	**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**	3 weeks (block)
15	**Teaching language**	English
16	**Recommended reading**	Material for Recommended reading will be provided on the StudOn-platform.

1	**Module name**	**ILS-MA-B3 Developmental Biology 1: Pattern Formation, Growth and Evolution** ILS-MA-B3 Entwicklungsbiologie 1: Musterbildung, Wachstum und Evolution	**7.5 ECTS credits**
2	Courses/lectures	Laboratory Course: **Developmental Biology 1**, 7 SWS Seminar: **Developmental Biology 1**, 1 SWS (for both, attendance is compulsory)	
3	Lecturers	Prof. Dr. M. Klingler, Dr. R. Rübsam, Dr. I. Reim	

4	**Module co-ordinator**	Prof. Dr. Martin Klingler
5	**Contents**	**Seminar** talks cover topics concerning the evolution of developmental processes (evo-devo) and interpret investigations in non-model systems in the light of well-understood mechanisms in *Drosophila,* mouse, zebra fish and other well-understood systems. In the **laboratory course,** in small groups projects are pursued related to on-going research in our labs, i.e. embryonic development and organogenesis (limb, gonad and muscle development). Among the techniques applied are genetic methods (CRISPR mediated genome editing, homologous recombination, systemic RNAi, gene over-expression), detection methods (in situ hybridization, histochemistry, transgenic markers), and microscopy (3D fluorescence microscopy, structured illumination, confocal microscopy, electron microscopy) as well as other molecular and bioinformatics methods
6	**Learning targets and skills**	Students will acquire the following skills: they • are able to present and critically discuss results of current developmental research articles • are familiar with current concepts of developmental biology, including its evolutionary aspects • have obtained an understanding of genetic techniques and methods used for analysis of developmental problems • are able to independently develop working hypotheses, and to plan and conduct experiments to test these • can 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**	MA. Integrated Life Sciences MA Zell- und Molekularbiologie
10	**Method of examination**	PL: oral examination of 30 min. PL: protocol of 10-15 pages SL: seminar talk 30 min. (ungraded task)
11	**Grading procedure**	Oral 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**	Review articles will be provided electronically

1	**Module name**	**ILS-MA-B4 Developmental Biology 2: Molecular Control of Stem Cell and Organ Differentiation** ILS-MA-B4 Entwicklungsbiologie 2: Molekulare Kontrolle der Stammzell- und Organdifferenzierung	**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. Frasch, PD Dr. I. Reim, PD Dr. A. Schambony, PD Dr. M. Schoppmeier	

4	**Module co-ordinator**	Prof. Dr. Manfred Frasch
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 l**aboratory 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 targets 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	**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 30 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**	Review articles will be provided electronically

1	**Module name**	**ILS-MA-B6 Developmental Biology 4: Cell Migration and Morphogenesis** ILS-MA-B6 Entwicklungsbiologie 4: Zellmigration und Morphogenese	**7.5 ECTS credits**
2	Courses/lectures	Seminar: **Developmental Biology 4:** Cell migration and morphogenesis, 1 SWS Laboratory Course: **Developmental Biology 4:** Cell migration and morphogenesis, 7 SWS compulsory attendance	
3	Lecturers	PD Dr. A. Schambony	

4	**Module co-ordinator**	PD Dr. A. Schambony
5	**Contents**	**Seminar:** The students prepare and present talks covering state-of-the art topics of molecular mechanisms in cell migration and morphogenetic movements in embryonic development. The students discuss the presented topics. (Language: English). **Laboratory courses:** The students work in small teams on mini-projects addressing the molecular control of cell migration and morphogenetic movements. In these projects the students will learn and use methods in cell biology, biochemistry, molecular biology, modern imaging techniques, embryology depending on the specific projects. Model systems include mammalian and amphibian cell culture and *Xenopus laevis* embryos.
6	**Learning targets and skills**	**Seminar:** The students present and discuss research publications on the module topic including background and methodology. **Laboratory course:** The students should • know and employ concepts and methods in cell biology and embryology to address a specific research problem. • Develop hypotheses, plan and carry out experiments based on their hypothesis • Document, present and critically discuss their results
7	**Recommended prerequisites**	none
8	**Integration in curriculum**	From semester 1 onwards
9	**Module compatibility**	M.Sc. Cell and Molecular Biology M.Sc. Integrated Life Sciences
10	**Method of examination**	PL: oral examination of 30 min. PL: protocol of 10-15 pages SL: seminar talk 30 min. (ungraded task)
11	**Grading procedure**	Oral examination 50% Written report 50%
12	**Module frequency**	Once per year, WS
13	**Workload**	Contact hours: 120h Independent study: 105 h
14	**Module duration**	1 semester, 4 consecutive weeks full-time
15	**Teaching language**	English
16	**Recommended reading**	The corresponding chapters on cell migration / morphogenesis in the following text books: Alberts, Bruce: Molecular Biology of the Cell, latest edition Gilbert, Scott F.: Developmental Biology, latest edition Review articles and Seminar topics will be provided electronically.

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	Prof. Dr. Y. Muller, Prof. Dr. 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 ribosome display, directed evolution and computational protein design; Discussion of seminal protein design studies. **Laboratory course** are focused on computational protein design (usingwe protein side-chain packing algorithms, or molecular dynamics simulation). Additionally, students are introduced into experimemtal validation techniques such as e.g. protein crystallography or CD spectroscopy in hands-on lab trainings. The main part of the practical course is devoted to active cooperation in ongoing research projects of the participating labs.
6	**Learning targets and skills**	The students are • acquainted with novel insights, concepts, and methods for the design of proteins with new, different characteristics • 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 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 60 min. PL: protocol of 15-20 pages PL: seminar talk 15 min.
11	**Grading procedure**	written examination 40% project protocol 20% seminar talk 40%
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**	introductory articles will be provided electronically

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	Prof. Dr. Y. Muller, Prof. Dr. 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 structural determinants in regulation of protein function. **Laboratory course** are focused on advanced methods in the study of structure-dynamics-function relationships of proteins. Both experimental (heterologous protein production in eucaryotic cells, X-ray analysis, mutation studies) as well as theoretical methods (atomistic and coarse-grained molecular dynamics simulations) will be addressed. The main part of the practical course is devoted to active cooperation in ongoing research projects of 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 60 min. PL: protocol of 15-20 pages PL: seminar talk 15 min.
11	**Grading procedure**	written examination 40% project protocol 20% seminar talk 40%
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**	introductory articles will be provided electronically

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**	M.Sc. Integrated Life Sciences
10	**Method of examination**	SL: hands-on exercises during the course PL: programming project
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

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

Master thesis

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. 50 pages 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