Fakultät für Biologie

Module description

Master of Science in the subject Neuroscience
(Examination regulations version 2021)

Second Semester:

Module 3: Advanced Topics in Neuroscience
Module 4: Elective Subjects

Module 3: Advanced Topics in Neuroscience

Name of module	Number of module
Advanced Topics in Neuroscience	09LE03MO-NA-2021
course	
Advanced Topics in Neuroscience	
Event type	Number
seminar	09LE03S-NA-T1
Faculty	
Fakultät für Biologie	

ECTS-Points	3.0
Hours of week	3.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Workload	90 h

Content
Recent research findings in neuroscience including current neuroscience research taking place at the University of Freiburg. The module takes places twice per week. On one appointment, students present recent research findings from the neuroscientific literature while on the other appointment neuroscientists from Freiburg present their own research.
Qualification
The student ■ can summarize several recent research findings in neuroscience including current neuroscientific research taking place at the University of Freiburg. ■ has the competence to extract the important findings from a research publication and present them in a meaningful and well-structured scientific presentation in English
Examination achievement
none
Course achievement
■ Regular participation ■ Presentation of a neuroscience research topic (30 min plus discussion)
Compulsory requirement

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Module 4: Elective Subjects

Name of module	Number of module
Elective Subjects (Focus Area 1: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
Elective Subjects (Focus Area 2: Computational Neuroscience)	09LE03MO-NE-2-2021
Elective Subjects (Focus Area 3: Neurotechnology)	09LE03MO-NE-3-2021
Responsible	
Neural Circuits and Behavior: Prof. Ilka Diester, Prof. Andrew Straw (Faculty of Biology)	
Computational Neuroscience: Prof. Stefan Rotter (Faculty of Biology)	
Neurotechnology: Prof. Thomas Stieglitz (Faculty of Engineering)	

ECTS-Points	27
Recommended semester	2
Pflicht/Wahlpflicht (P/WP)	Core elective
Workload	750 h
Frequency	Only in the summer term

Compulsory requirement
None
Content
For the "Elective Subjects" the student chooses one focus area from the following list: ▪ Neural Circuits and Behavior (coordinators: Prof. Diester, Prof. Straw) ▪ Computational Neuroscience (coordinator: Prof. Rotter) ▪ Neurotechnology (coordinator: Prof. Stieglitz) Each focus area consists of mandatory and elective (i.e. optional) modules. The student must choose a sufficient number of elective modules such that mandatory and elective modules together are worth at least 27 ECTS. For further questions regarding the focus areas, please contact the coordinator of the focus area, the program coordinator Dr. Ahrens or Prof. Mehring.
Qualification
▪ The students have acquired in-depth knowledge in a research area of the neurosciences which each student chooses individually from the following available areas: (1) Neural Circuits and Behavior (2) Computational Neuroscience (3) Neurotechnology. ▪ The students are able to critically evaluate and discuss important findings and scientific publications from the chosen area ▪ The students can apply area specific experimental and/or theoretical research methods
Examination achievement (Prüfungsleistung, PL)
Each focus area has two graded assessments ("Prüfungsleistung", PL). The type and scope of the assessments are defined in the module descriptions and are announced to the students at the beginning of each course. To do a PL, it may be required to successfully complete coursework in advance, e.g. you may need to successfully complete some exercises during the course before you can do an exam.
Course achievement (Studienleistung, SL)
Specific criteria that need to be met to pass a "Studienleistung" are explained in the module description and announced by the lecturer at the beginning of the term. Examples of such

"Studienleistung" are a report, a presentation or a written/oral exam, all of which are not graded, i.e. they can only be "passed" or "failed". Sometimes you will receive a grade for a "Studienleistung" but this grade is only for your information to give you further feedback on your performance.
Examination weight
Each focus area has two graded assessments ("Prüfungsleistungen", PL). All other courses will not be graded but may contain ungraded assessments ("Studienleistungen", SLs). The overall grade of the module "Elective Subjects" will be calculated as the weighted sum of both PLs as follows: Module grade = w1*grade PL1 + w2*grade PL2 w1 = ECTS PL1/(ECTS PL1 + ECTS PL2) w2 = ECTS PL2/(ECTS PL1 + ECTS PL2)
Recommendation
Please note: Several modules are taught not only to MSc Neuroscience students but at the same time to students from other degree programs (e.g. M.Sc. Biology, M.Sc. Computer Science, M.Sc. Applied Physics etc.). The same module may have different assessments depending on the degree program of the student. For example, while a report may be an SL for M.Sc. Neuroscience students (and therefore can only be "passed" or "failed)" it may be a PL (and therefore be graded) for a student from the M.Sc. Computer Science. A few of the elective modules take place during winter term (as indicated by 'WS' behind the module name). In this case the participation takes places during the 3rd semester while students carry out their research project. It is usually not a problem do take part in a teaching module in parallel to a research project, however, this should be agreed by the supervisor of the research project. Please also note that research projects can already be started before the 3rd semester, e.g. in summer. Some focus areas and modules have limitations with regard to the number of participants. In the case of too many applicants for a focus area or a module, students will be selected according to a procedure outlined in the M.Sc. Neuroscience examination regulations. Students which unfortunately cannot be registered for their first choice will be given the opportunity to choose other elective modules with sufficient number of places.

Focus Area 1:

Neural Circuits and Behavior

All students in this Focus Area attend the exercise “Methods in Neurobiology” as their first graded assessment (PL 1) and choose another course as their second graded assessment (PL 2; either “Cognitive Neuroscience”, “Developmental Neuroscience”, “Neurobiology in Genetic Model Organisms” or “Neuroscience – Optophysiology”).

Additionally, you can either choose one more of these 9 ECTS courses as an ungraded assessment (SL). In this case, you need to make sure to choose courses that don’t overlap in time.

If you decide to take only one of these 9 ECTS courses, you need to take all three additional courses.

All students in this focus area attend:	**ECTS**	**mandatory/ elective**	**SL/PL**
Methods in Neurobiology	9	m	PL
Students choose from these additional courses:			
A. Developmental Neuroscience	9	e	PL/SL
A. Neurobiology in Genetic Model Organisms	9	e	PL/SL
A. Neuroscience – Optophysiology	9	e	PL/SL
B. Cognitive Neuroscience	9	e	PL/SL
B. Neurophysiology in vitro	9	e	PL/SL

Example:

All students in this focus area attend:	**ECTS**	**mandatory/ elective**	**SL/PL**
Methods in Neurobiology	9	m	PL 1
Students choose from these additional courses:			
A. Developmental Neuroscience	9	e	PL 2
A. Neurobiology in Genetic Model Organisms	9	e	PL/SL
A. Neuroscience – Optophysiology	9	e	PL/SL
B. Cognitive Neuroscience	9	e	PL/SL
B. Neurophysiology in vitro	9	e	SL
Total ECTS	**27**		

The table below contains more detailed information about the specific parts of the courses (some contain e.g. a lecture and an exercise or seminar) and the Professors in charge.

Detailed information on the content of each course can be found in the module descriptions below

Methods in Neurobiology Prof. Dierk Reiff Faculty of Biology	Exercise	09LE03Ü-SP1-05_0002
Developmental Neuroscience Prof. Wolfgang Driever Faculty of Biology		
Development of the Nervous System	Lecture	09LE03V-WM-07_0001
Methods in Developmental Neurobiology	Exercise	09LE03Ü-WM-07_0002
Establishing the Nervous System	Seminar	09LE03S-WM-07_0003
Neurobiology in Genetic Model Organisms Prof. Dierk Reiff Faculty of Biology		
Neural Circuits guiding behavior in Drosophila	Lecture	09LE03V-WM-13_0001
Quantitative behavior and functional dissection of neural circuitries in Drosophila	Exercise	09LE03Ü-WM-13_0002
Neural Circuits and Behavior	Seminar	09LE03S-WM-13_0003
Neuroscience – Optophysiology Prof. Ilka Diester Faculty of Biology		
Optogenetics for Neuroscience	Lecture	09LE03V-WM-31_0001
Optophysiology	Exercise	09LE03Ü-WM-31_0002
Cognitive Neuroscience Dr. Sven Heinrich, Dr. Nicole Roßkothen-Kuhl Faculty of Biology		
Major Concepts in Cognitive Neurosciences	Lecture	09LE03V-WM-05_0001
Methods in Cognitive Neurosciences	Exercise	09LE03Ü-WM-05_0002
Selected Topics in Neurosciences	Seminar	09LE03S-WM-05_0003
Neurophysiology in Vitro Prof. Uli Egert Faculty of Engineering	Exercise	09LE03Ü-WM-30_0002

Focus Area 2:

Computational Neuroscience

In the Focus Area "Computational Neuroscience", you choose two PL out of the three mandatory courses ("Models of Neurons and Networks", "Biological Learning, Control and Decision Making" and "The Neural Code: Quantitative Analysis of Neural Activity") and take the third one as SL. More SL are chosen from the list of additional courses.

All students in this focus area attend:	ECTS	mandatory/ elective	SL/PL
Models of Neurons and Networks	9	m	PL/SL
Biological Learning, Control and Decision Making	9	m	PL/SL
Quantitative Methods 2	9	m	PL/SL
Current Topics in Computational Neuroscience	3	e	SL
Machine Learning (WS)	6	e	SL
Neuroprosthetics	3	e	SL
Numerical Optimal Control in Science and Engineering	6	e	SL
Signal Processing and Analysis in Brain Signals	3	e	SL
Simulation of Biological Neuronal Networks	3	e	SL

Example:

All students in this focus area attend:	ECTS	mandatory/ elective	SL/PL
Models of Neurons and Networks	9	m	PL 1
Biological Learning, Control and Decision Making	9	m	PL 2
Quantitative Methods 2	9	m	SL
Current Topics in Computational Neuroscience	3	e	SL
Machine Learning (WS)	6	e	SL
Neuroprosthetics	3	e	SL
Numerical Optimal Control in Science and Engineering	6	e	SL
Signal Processing and Analysis in Brain Signals	3	e	SL
Simulation of Biological Neuronal Networks	3	e	SL
Total ECTS	**27**		

The table below contains more detailed information about the specific parts of the courses (some contain e.g. a lecture and an exercise or seminar) and the Professors in charge. Detailed information on the content of each course can be found in the module descriptions below.

Course	Event type	Number
Models of Neurons and Networks Prof. Stefan Rotter Faculty of Biology	Lecture + Exercise	09LE03V-NE-2-T1.1 09LE03Ü-NE-2-T1.1
Biological Learning, Control and Decision Making Prof. Carsten Mehring Faculty of Biology	Lecture + Exercise	09LE03V-NE-2-T1.2 09LE03Ü-NE-2-T1.2
Quantitative Methods 2 Prof. Christian Leibold Faculty of Biology	Lecture + Exercise	09LE03V-NE-2-T1.3 09LE03Ü-NE-2-T1.3
Current Topics in Computational Neuroscience Prof. Stefan Rotter, Prof. Carsten Mehring, Prof. Christian Leibold Faculty of Biology	Seminar	09LE03S-NE-2-T11
Machine Learning (WS) Prof. Josif Grabocka Faculty of Engineering	Lecture + Exercise	11LE13V-1153 11LE13Ü-1153
Neuroprosthetics Prof. Ulrich Hofmann Faculty of Engineering	Seminar	04LE50V-5318
Numerical Optimal Control in Science and Engineering Prof. Moritz Diehl Faculty of Engineering	Lecture + Exercise	11LE50V-5249 11LE50Ü-5249
Signal Processing and Analysis in Brain Signals Prof. Thomas Stieglitz Faculty of Engineering	Lecture	11LE50V-5312
Simulation of Biological Neuronal Networks Prof. Stefan Rotter Faculty of Biology	Exercise	09LE03Ü-NE-2-T2

Focus Area 3:

Neurotechnology

In the Focus Area “Neurotechnology”, all students take “Biomedical Microsystems” as their first and “Neuroprosthetics” as their second PL. Additional SL can be chosen from the list below. Please note that some courses are taking place in winter term.

All students in this focus area attend:	ECTS	mandatory/ elective	SL/PL
Biomedical Microsystems	5	m	PL
Neuroprosthetics	3	m	PL
Biomedical Instrumentation I	3	m	SL
Students choose from these additional courses:			
Cognitive Neuroscience	9	e	SL
Machine Learning (WS)	6	e	SL
Numerical Optimal Control in Science and Engineering	6	e	SL
Fundamentals of electrical stimulation (WS)	3	e	SL
Implant manufacturing technologies (WS)	3	e	SL
Signal Processing and Analysis in Brain Signals	3	e	SL

Example:

All students in this focus area attend:	ECTS	mandatory/ elective	SL/PL
Biomedical Microsystems	5	m	PL 1
Neuroprosthetics	3	m	PL 2
Biomedical Instrumentation I	3	m	SL
Students choose from these additional courses:			
Cognitive Neuroscience	9	e	SL
Machine Learning (WS)	6	e	SL
Numerical Optimal Control in Science and Engineering	6	e	SL
Fundamentals of electrical stimulation (WS)	3	e	SL
Implant manufacturing technologies (WS)	3	e	SL
Signal Processing and Analysis in Brain Signals	3	e	SL
Total ECTS	**29**		

The table below contains more detailed information about the specific parts of the courses (some contain e.g. a lecture and an exercise or seminar) and the Professors in charge. Detailed information on the content of each course can be found in the module descriptions below.

Course	Event type	Number
Biomedical Microsystems Prof. Thomas Stieglitz Faculty of Engineering	Lecture + Exercise	11LE50V-7900 11LE50Ü-7900
Neuroprosthetics Prof. Ulrich Hofmann Faculty of Engineering	Seminar	04LE50V-5318
Biomedical Instrumentation I Prof. Thomas Stieglitz Faculty of Engineering	Lecture + Exercise	11LE50V-5301 11LE50Ü-5301
Cognitive Neuroscience Dr. Sven Heinrich, Dr. Nicole Roßkothen-Kuhl Faculty of Biology		
Major Concepts in Cognitive Neurosciences	Lecture	09LE03V-WM-05_0001
Methods in Cognitive Neurosciences	Exercise	09LE03Ü-WM-05_0002
Selected Topics in Neurosciences	Seminar	09LE03S-WM-05_0003
Machine Learning (WS) Prof. Josif Grabocka Faculty of Engineering	Lecture + Exercise	11LE13V-1153 11LE13Ü-1153
Numerical Optimal Control in Science and Engineering Prof. Moritz Diehl Faculty of Engineering	Lecture + Exercise	11LE50V-5249 11LE50Ü-5249
Fundamentals of electrical stimulation (WS) Prof. Thomas Stieglitz Faculty of Engineering	Lecture	11LE50V-5306
Implant manufacturing technologies (WS) Prof. Thomas Stieglitz Faculty of Engineering	Lecture + Exercise	11LE50V-5313 11LE50Ü-5313
Signal Processing and Analysis in Brain Signals Prof. Thomas Stieglitz Faculty of Engineering	Lecture	11LE50V-5312

Detailed Module Descriptions

Focus Area 1: Neural Circuits and Behavior

Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Methods in Neurobiology	
Event type	Number
excercise course	09LE03Ü-SP1-05_0002
Faculty	
Fakultät für Biologie	

ECTS-Points	9.0
Hours of week	7.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	110 Stunden
Independent study	160 Stunden
Workload	270 Stunden

Content

Three different ‘hands on’ courses are offered that provide students with the opportunity to perform small neuroscience research projects. An additional course covers the simulation of biophysically inspired neuron models. Each course will be accompanied by group discussions and interactive presentations of theoretical and practical aspects. Students write a lab report on performed research.

Qualification

Students
- can design, perform and document experiments in different fields of neuroscience research, from early visual processing (ERG) to navigation behaviour in different insect species, from EEG & EMG recordings in humans to the control of muscles, movement and basic neuroprosthetic devices.
- are able to perform computer-controlled physiological recording experiments, quantitative measurements of movement and behaviour.
- are able to analyse and interpret recorded data.
- can relate their experiments to important theoretical concepts.
- can present, evaluate and discuss the results from own experiments and integrate them into the state of art in the research field.
- can explain both the usefulness and limitations of research on model organisms and humans.

Examination achievement

- Evaluation of lab report

Course achievement

- Active participation in all courses
- Written lab report

Literature
Course scripts for experimental work, preparatory literature like original articles and reviews will be provided during the course.
Compulsory requirement
s. Modulebene
Teaching method
Experimental work by the students performed in small groups using electrophysiological, behavioral and computational techniques, supported by tutors. Practical demonstration of key techniques. Use of computer and Python software. Interactive presentations using blackboard and powerpoint / PDF, discussion as a group.
Target group
■ M.Sc. Biology ■ M.Sc. Neuroscience ■ M.Sc. Bioinformatics & Systems Biology ■ Diplom Biology ■ Joint Master in Neuroscience

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Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Development of the Nervous System	
Event type	Number
lecture course	09LE03V-WM-07_0001
Faculty	
Fakultät für Biologie	

ECTS-Points	1.5
Hours of week	1.5
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	
Language	english
Attendance	18 Stunden
Independent study	27 Stunden
Workload	45 Stunden

Content

The lecture series presents the distinct phases of nervous system development starting from neural induction during gastrulation until formation of functional axonal connections and synapses between neurons. Examples for molecular mechanisms (transcriptional regulation, signaling pathways) that contribute to these developmental processes will be presented in order to enable a mechanistic understanding of developmental control. In addition, important techniques and methods for analysis of nervous system development will be presented.

Topics of the lectures:

- Neuron and Glia
- Neural Crest Introduction into neural development
- Neural Induction
- Neurulation
- Anterioposterior Patterning in the Neural Plate; Regional Organizing Centers
- Hindbrain Segmentation
- Dorsoventral Patterning in the Nervous System
- Axon Guidance systems molecular mechanisms
- Axon Guidance spatial mechanisms and topographic representations
- Neurotrophic Factors and Neuronal Cell Death
- Synaptogenesis and Remodeling
- and Peripheral Nervous System
- Neurogenesis
- Neuronal Differentiation
- Sensory Organ Development
- Neural Stem Cells
- From Development to Behaviour: Ontogeny of visually mediated eye movements
- Optogenetic techniques to study circuit development and function
- 2-photon microscopy and optical techniques

Qualification
The students are able to: ■ structure the fundamental phases of development of the nervous system from neural induction to formation of functional neuronal connections ■ explain molecular mechanisms of neural development (transcriptional control, signaling mechanisms) using examples ■ present how neural cells are induced from pluripotent early embryonic cells by the signaling systems active in gastrulation ■ derive the fundamental morphogenetic processes during neurulation based on the participating signaling centers and the specific cell behavior ■ explain the organisation of the vertebrate brain and spinal cord based on the anterioposterior and dorsoventral patterning mechanisms that establish this organisation ■ explain the causal role that transcription factors and signals actin in pattern formation have during region specific neuronal differentiation ■ argue how Delta-Notch signaling control neurogenesis ■ explain the roles of neural stem cells and their stem cell niches in neural development and regeneration ■ develop how distinct molecular mechanisms contribute to formation of functional connections in axonogenesis and synaptogenesis ■ explain the formation of functional neuronal circuits in the embryo for simple behavioral paradigms (optomotor response, swim behavior of fishes) ■ explain important classical and modern techniques for the experimental analysis of the distinct phases of neural development
Examination achievement
none
Course achievement
none
Literature
The following literature is recommended for independent preparation and follow-up of the course contents: ■ Sanes et al., Development of the Nervous System (2012, 3rd. Ed. chapt. 1-7) ■ Price et. al. Building Brains (2011, chapt.1-12) ■ Kandel et al. Principles of Neural Sciences (2012, 5th Ed. Part VIII)
Compulsory requirement
s. Modulebene
Teaching method
Lectures using PowerPoint or Keynote presentations Handouts of lecture slides as b&w prints and als color PDFs on Illias server. Up-to-date scientific reviews for each topic provided on Illias server Development of schemes using chalk / board Discussion of concepts and open questions
Recommendation
lecture materials will be made available on Illias

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Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Methods in Developmental Neurobiology	
Event type	Number
excercise course	09LE03Ü-WM-07_0002
Faculty	
Fakultät für Biologie	

ECTS-Points	6.0
Hours of week	6.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	90 Stunden
Independent study	90 Stunden
Workload	180 Stunden

Content

The practical classes present classical experimental embryology techniques as well as modern molecular genetics, signaling research, and microcopy techniques applied to the development of the nervous system using vertebrate model organisms.
The trained techniques include:

- life imaging using transmitted light, epifluorescence and confocal microscopy
- analysis of genetic mutants
- transgenic animal model systems
- embryo culture
- gene expression analysis and immunohistology
- overexpression of genes using mRNA microinjection or conditional gene expression systems
- pharmacological manipulation of signaling pathways
- analysis of motor behavior development
- analysis of sense organ development
- analysis of axonogenesis

Qualification

The students are able to:

- operate transmitted light, epifluorescence and confocal microscopes and generate scientifically meaningful digital image data
- apply specific experimental or genetic methods for in vivo fluorescent labelling of defined neuronal populations.
- use time lapse analysis to investigate mechanisms and temporal progress of specific processes in neural development
- identify essential anatomical structures in the nervous system of the vertebrate embryo
- accomplish microinjections at the one-cell stage of embryos
- apply gene expression analysis and immunohistology to study development of the nervous system.
- evaluate different genetic techniques for the manipulation of signaling pathways and transcriptional control and apply appropriate techniques in experiments

- evaluate and apply pharmacological techniques for signaling pathway manipulation
- utilize open source software to analyze digital immunofluorescence image data
- statistically evaluate data for significance.
- plan and conduct experiments in teams, respect competencies of others and contribute their own skills constructively.

Examination achievement

none

Course achievement

- at least 80% active participation practical classes.
- preparation of scientific standard lab reports of laboratory projects

Literature

The following literature is recommended for independent preparation and follow-up of the course contents:

- Sanes et al., Development of the Nervous System (2012, 3rd. Ed. chapt. 1-7)
- Price et. al. Building Brains (2011, chapt. 1-12)
- Kandel et al. Principles of Neural Sciences (2012, 5th Ed. Part VIII)

Compulsory requirement

s. Modulebene

Teaching method

Instructions for practical work by faculty. Students perform experiments independently in teams of two or small groups with support by teaching staff.

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Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Establishing the Nervous System	
Event type	Number
seminar	09LE03S-WM-07_0003
Faculty	
Fakultät für Biologie	

ECTS-Points	1.5
Hours of week	1.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	12 Stunden
Independent study	33 Stunden
Workload	45 Stunden

Content
Each student presents a primary research scientific publication from the field of developmental neurosciences. The research ppaer will be discussed in the plenum by all participants of the seminar.
Qualification
The students are able to: ■ recognize the important findings in a research publication and present them in a meaningful way using PowerPoint slides ■ critically evaluate the techniques, analysis methods and conclusions of a research publication ■ relate the findings of a primary research publication to the scientific context in this closer field of research ■ prepare and present a well structured scientific presentation.
Examination achievement
none
Course achievement
■ at least 80% active participation in seminar classes. ■ preparation and presentation of a scientific seminar reporting a primary research publication from the field of developmental neurosciences.
Literature
The following literature is recommended for independent preparation and follow-up of the course contents: - Sanes et al., Development of the Nervous System (2012, 3rd. Ed. chapt.1-7)   - Price et. al. Building Brains (2011, chapt.1-12)   - Kandel et al. Principles of Neural Sciences (2012, 5th Ed. Part VIII)
Compulsory requirement
s. Modulebene

Teaching method
Discussion of the independently prepared seminar presentation before and after the seminar with the supervising faculty member Students will be guided to contribute actively to the critical discussion of the publication in the plenum.

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Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Neural circuits guiding behavior in Drosophila	
Event type	Number
lecture course	09LE03V-WM-13_0001
Faculty	
Fakultät für Biologie	

ECTS-Points	2.0
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	
Language	english
Attendance	30 Stunden
Independent study	30 Stunden
Workload	60 Stunden

Content

The lecture covers the basic neuronal mechanisms underlying vision, visually guided behavior , and variable hot topics in current fly-research. There is a focus on the question how flies use sensory information to guide their behavior. State-of-the-art genetic methods for functional neuroanatomy and neuro-/optogenetics for the functional dissection of the nervous system are presented.

- Vision in *Drosophila* (including a comparison with vertebrate vision)
- Neuroanatomy of the sensory systems
- Neural mechanisms underlying visually guided and other responses in flies
- Tools for the genetic interference with neuronal function: Optogenetics, thermogenetics and other important neurogenetic approaches.
- Genetic tools for functional neuroanatomy
- Design of experiments for the establishment of a causal relationship between identified neurons, neuronal processing and behavior
- Quantitative analysis of behavior in wild type and mutant animals
- Statistics and data analysis

All sections will be presented and discussed at a ‚medium-to-advanced level'.

Qualification

The students can

- describe the basic concepts of how sensory information is transduced and integrated in a neuronal network
- explain the basic neuronal mechanisms underlying olfaction and vision in vertebrates, flies and worms.
- explain the basic encoding of visual and other sensory information by the nervous system and know how this information is used to guide behavior in flies.
- use genetic techniques for the identification of the function of genes and proteins in neurons.
- design neurogenetic experiments in the introduced systems to disclose basic rules of information processing in neural networks.
- design complex behavioral experiments and use appropriate equipment and technology.

- make use of the great potential of recentopto- and neurogenetic tools for the functional dissection of the brain.
- explain the basic functional properties and working principle of the most prominent neuro- and optogenetic actuators of neural activity.

Examination achievement
none
Course achievement
none
Literature
The following literature is recommended for independent preparation and follow-up of the course contents: ■ Principles of Neural Science (4th ed. Kandel, Schwartz, Jessel), Chapter 1-3 (Brain, Nerve Cells, Genes & Behavior), Chapter 26-29 (Vision), Chapter 32 (Smell & Taste) and other chapters. ■ Further Literature will be provided during the course.
Compulsory requirement
s. Modulebene
Teaching method
■ Power-Point presentations ■ Comprehensive video material ■ Interactive Black Board ■ Hand-Outs ■ Open discussion rounds ■ 'Flipped classroom'

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Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Quantitative behavior and functional dissection of neural circuitries in Drosophila	
Event type	Number
excercise course	09LE03Ü-WM-13_0002
Faculty	
Fakultät für Biologie	

ECTS-Points	6.0
Hours of week	5.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	75 Stunden
Independent study	105 Stunden
Workload	180 Stunden

Content

Based on the facts and theory covered by the lecture this course provides students with the opportunity to perform hands-on behavioral experiments guided by expert-instructors. Flies are used as genetically amenable model organisms to establish causal relationships between identified neurons and behavior as described above.

- Optogenetic actuators like Channelrhodopsin are used to dissect sensory information processing, motor control and behavior in flies. State-of-the-art experimental techniques and equipment are used to control the activity of genetically targeted neurons by light in behaving animlas.
- Combined genetic and functional anatomical studies are performed to disclose underlying neurons and circuitries. Mutant animals may be analyzed to demonstrate that certain genes and proteins are required for animal behavior. The students will learn to use information on functional neuronal anatomy to design their experimetns .
- Drosophila and a selection of neuro-/optogenetic tools are used to investigate information processing and the neuronal control of behavior. Populations of genetically identified neurons are activated / inactivated by heat, light, or using other techniques. In parallel movement of the fly is monitored and on-line technology is used to analyze the recoded data.
- Discussion of theory and experiment.
- Theory meets practical use of neuro-/optogenetic tools in behaving animals.
- Hands-on experience and insights into the daily life in the lab (experimental neurobiology & behavior).

Qualification

The students

- can explain the basic concepts of how the nervous system controls behavior
- can use or develop neurogenetic strategies for experimental investigation.
- are able to design and perform combined neuro- /optogenetic and behavioral experiments in flies.
- are able to quantify and statistically analyze experimental data and to design appropriate control experiments.
- are capable of discussing complex problems, of developing goal-oriented strategies and of solving problems in teams.

■ can plan and conduct experiments in teams, respect competencies of others and contribute their own skills constructively.
Examination achievement
none
Course achievement
■ Active participation on all days. ■ Students are obligated to present (ppt) their experiments and results. ■ Diligent record keeping (lab-book). ■ Writing of a report), assessed by course instructor.
Literature
Literature will be provided about two weeks prior the official beginning of the module.
Compulsory requirement
s. Modulebene
Teaching method
■ Hands on, this is a practical course! ■ Small teams of 2-3 students will be assisted by expert course instructors . Close interactions between students, teams, and instructors characterize this course. ■ Black board and round-table discussions are used to debate questions, ideas, problems and results. ■ Power-Point presentations will be used if inevitable.

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Neural circuits and behavior	
Event type	Number
seminar	09LE03S-WM-13_0003
Faculty	
Fakultät für Biologie	

ECTS-Points	1.0
Hours of week	0.5
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	7,5 Stunden
Independent study	22,5 Stunden
Workload	30 Stunden

Content
Each student will prepare and present a research article on behavioral neuroscience to the members of the course and instructors (in English, using Power-Point or comparable). Science and style of presentation will be discussed be the whole team.
Qualification
The students can: ■ analyze a research article written in English. ■ compile its content and present it in English to a small audience using PowerPoint. ■ perform a critical evaluation of published work and demonstrate that published articles and information are not sacrosanct. ■ discuss a scientific article and answer questions in front of an audience.
Examination achievement
none
Course achievement
■ Each student will present (ppt) a recent research article in English. ■ Active participation in all seminar sessions
Literature
Students can chose articles or articles will be provided.
Compulsory requirement
s. Modulebene

Teaching method
■ PowerPoint presentations including videos ■ Handouts and original research publications ■ Discussion of data and style of presentation

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Optogenetics for Neuroscience	
Event type	Number
lecture course	09LE03V-WM-31_0001
Faculty	
Fakultät für Biologie	

ECTS-Points	1.0
Hours of week	1.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	
Language	english
Attendance	15 Stunden
Independent study	15 Stunden

Content

The lecture covers optogenetic aspects of neuroscience.
Specifically, the following topics are addressed

- translation, transcription, genetic constructs
- Cloning strategies
- Delivery of opsins
- Cell type specificity and circuit targeting
- Combined optogenetic stimulation, neural recordings and behavior
- Putative clinical applications
- Calcium imaging via Two-Photon microscopy
- Opsin variants and Opsin development
- Non-opsin tools
- Two photon imaging combined with optogenetic stimulation
- optogenetic applications

Qualification

The students

- can understand and summarize the contents of the lectures and answer detailed questions regarding these
- can use this acquired knowledge and insights to read, understand and critically discuss scientific publications in the neurosciences

Examination achievement

none

Course achievement

none

Literature

The following literature is recommended for independent preparation and follow-up of the course contents:

- Optogenetics: A Roadmap. Springer Protocols, Springer. Volume 133, ISBN 978-1-4939-7415-3
- Course script, primary literature and academic reviews as provided at the beginning of the course

Compulsory requirement
s. Modulebene
Teaching method
The course will be taught in the form of ■ Interactive presentations The following media will be used: ■ PowerPoint presentations

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Optophysiology	
Event type	Number
excercise course	09LE03Ü-WM-31_0002
Faculty	
Fakultät für Biologie	

ECTS-Points	8.0
Hours of week	8.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	120 Stunden
Independent study	120 Stunden

Content

The course covers cloning and histological aspects as well as electrophysiological and optogenetic aspects of neuroscience. Neuronal activity is assed in cell cultures of cortical neurons to teach 2-Photon Calcium imaging and analyzing the activity and properties of individual neurons and networks. Extracellular recordings with optogenetic stimulations are provided from adult rats, which will be analyzed. Histology is performed on brain slices from adult rats. The course is an intense exercise using advanced techniques of neurophysiological and optogenetic research, emphasizing independent use of high-tech equipment and critical analysis and interpretation of own research data.
Specifically, participants will perform

- Molecular cloning (restriction enzyme cloning and Gibson assembly)
- Transient transfection of mammalian cells in culture
- Histology
- Calcium imaging via Two-Photon microscopy
- Measure fundamental properties of neurons and networks,
- Conduct antibody staining and fluorescence microscopy to assess opsin expression,
- Visualize activity dynamics in neuronal cultures,
- Analyses of the recorded neural data.

The results obtained will be presented in the style of a conference workshop among the participants

Qualification

The students

- understand the basics behind molecular cloning, are aware of the various cloning techniques available to them and are able to perform restriction based cloning and Gibson assembly
- are able to prepare and document immunocytochemical stains of brain slices
- can name neuronal subtypes in the cortex, cortical layers, fiber tracts and their connectivity and explain their functions, respectively
- can record and analyze electrical activity in individual neurons and networks with tools used in current research

- are able to assess the electrophysiological properties of individual neurons, synaptic properties and network dynamics with the corresponding experimental paradigms and techniques
- can stimulate neurons and neural tissue for different paradigms
- are able to present in speech and writing the concepts, implementations and interpretation of electrophysiological experiments in scientific style using own data
- are able to critically assess electrophysiological experiments
- are able to connect neurobiological concepts and signal with methods for their quantitative analysis.
- can modify algorithms in a standard scripting language to analyze neural data

can use this acquired knowledge, insights and skills to read, understand and critically discuss scientific publications in the experimental neurosciences

Examination achievement

none

Course achievement

- Preparation for the practical parts using the course script
- Active participation in the practical parts incl. written lab reports
- Active participation in the interactive colloquia and seminar presentations
- Active participation in all course days (100%)

Literature

The following literature is recommended for independent preparation and follow-up of the course contents:
- Optogenetics: A Roadmap. Springer Protocols, Springer. Volume 133, ISBN 978-1-4939-7415-3
- Course script, primary literature and academic reviews as provided at the beginning of the course

Compulsory requirement

s. Modulebene

Teaching method

The course will be taught in the form of
- Interactive presentations
- Individual work on imaging and histological setups
- individual work on molecular cloning and transient transfection
- group work
- lab visits to research laboratories
- tutoring during practical sessions and data analysis
- seminar presentations
- colloquia

The following media will be used:
- scripts for practical sessions
- electrophysiological research equipment
- lab equipment for histology
- PowerPoint presentations
- several software toolboxes for data analysis and visualization
- data from neurophysiological recordings

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Major Concepts in Cognitive Neurosciences	
Event type	Number
lecture course	09LE03V-WM-05_0001
Faculty	
Fakultät für Biologie	

ECTS-Points	3.0
Hours of week	4.3
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	
Language	english
Attendance	60 Stunden
Independent study	30 Stunden
Workload	90 Stunden

Content

Topics of the lectures given by various teachers are intentions, methods, and results of diverse fields of research that together contribute to our understanding of the relationship between cognition and the structure and physiology of brains.
Topics contain:

- Brain evolution
- Cognitive Psychology
- Neuroplasticity
- Perception
- Brain-machine interfaces
- Imaging methods
- Animal cognition
- Clinical neuroscience
- Neurophilosophy

Qualification

- Students can name major stages of human brain evolution.
- They can explain and differentiate several levels of neuroplasticity.
- They can name major benefits and limits of computational concepts for understanding cognitive functions.
- They identify similarities and differences between human and animal cognition.
- They can give examples of logical complications faced by the cognitive neurosciences.

Examination achievement

none

Course achievement

none

Literature
The following literature is recommended for independent preparation and follow-up of the course contents: ■ Tim Shallice, Richard P. Cooper: The organization of mind. Oxford Univ. Press 2011 ■ Kenneth M. Heilman, Edward Valenstein (Eds.): Clinical neuropsychology. 4th ed., Oxford Univ. Press 2003.
Compulsory requirement
s. Modulebene
Teaching method
Lectures will be given as Power-Point presentation, including multimedia elements, backed by slide handouts. Intermitting discussions will be encouraged and coached.
Target group
■ M.Sc. Biology ■ M.Sc. Bioinformatics & Systems Biology ■ M.Sc. Neuroscience ■ Diploma Biology

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Methods in Cognitive Neurosciences	
Event type	Number
excercise course	09LE03Ü-WM-05_0002
Faculty	
Fakultät für Biologie	

ECTS-Points	2.0
Hours of week	0.5
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	6 Stunden
Independent study	54 Stunden
Workload	60 Stunden

Content
■ demonstration of key methods in the cognitive neurosciences ■ participation in experiments as subjects.
Qualification
The students can: ■ identify major components and regions of human brain anatomy. ■ explain EEG recordings, name the necessary equipment for it, and assess its fields of application. ■ explain the principles of an MRI measurement and identify reasonable fields of application. ■ plan and conduct experiments in teams, respect competencies of others and contribute their own skills constructively.
Examination achievement
keine
Course achievement
■ 100% active participation in 2 of 3 practical courses ■ writing a lab report each about the experimental procedures done or seen.
Literature
The following literature is recommended for independent preparation and follow-up of the course contents: ■ Lennart Heimer: The human brain and spinal cord. 2nd ed., Springer Verlag, New York 1994.
Compulsory requirement
s. Modulebene

Teaching method
Students will be given hands-on experience of key-methods used in the cognitive neurosciences.
Target group
■ M.Sc. Biology ■ M.Sc. Bioinformatics & Systems Biology ■ Diploma Biology

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neural Circuits and Behavior)	09LE03MO-NE-1-2021
course	
Selected Topics in Cognitive Neurosciences	
Event type	Number
seminar	09LE03S-WM-05_0003
Faculty	
Fakultät für Biologie	

ECTS-Points	4.0
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	30 Stunden
Independent study	90 Stunden
Workload	120 Stunden

Content
■ Two seminar blocks will be held for students to learn and discuss original papers about the cognitive neurosciences in general and about brain and language specifically. ■ The students will learn how to read and evaluate original research reports. ■ They will understand how to structure and present complex issues of current research. ■ They will participate in scientific discussions and learn how to deal with controversies
Qualification
Students present and discuss specific scientific terms and concepts, observing the fundamental distinction between data and their interpretation.
Examination achievement
keine
Course achievement
■ 100% active participation in two seminar blocks ■ Two seminar presentations of data and concepts contained in original literature
Literature
To be distribute during the preparatory session.
Compulsory requirement
s. Modulebene
Teaching method
Seminars will be given by each student as media-supported Power-Point presentations.

Target group
■ M.Sc. Biology ■ M.Sc. Bioinformatics & Systems Biology ■ Diploma Biology

↑

Name des Moduls	Nummer des Moduls
WM-30 Neurophysiology: Measuring Neuronal Activity Dynamics and Plasticity in vitro	09LE03M-WM-30
Verantwortliche/r	
Prof. Dr. Ulrich Egert	
Fachbereich / Fakultät	
Fakultät für Biologie	

ECTS-Punkte	9,0
Arbeitsaufwand	270 Stunden
Präsenzstudium	135 Stunden
Selbststudium	135 Stunden
Semesterwochenstunden (SWS)	9,0
Mögliche Fachsemester	2
Moduldauer	1
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Angebotsfrequenz	nur im Sommersemester

Teilnahmevoraussetzung laut Prüfungsordnung
OM-05 and SP1-05

Zugehörige Veranstaltungen					
Name	Art	P/WP	ECTS	SWS	Arbeitsaufwand
Neurophysiology in vitro	Übung	Pflicht	9,0	9,0	270 Stunden

Lern- und Qualifikationsziele der Lehrveranstaltung

The students
- are able to prepare and document immunocytochemical stains of brain slices
- can name neuronal subtypes in the hippocampus, fiber tracts and their connectivity and explain their functions, respectively
- can record and analyze electrical activity in individual neurons and networks with tools used in current research.
- are able to assess the electrophysiological properties of individual neurons, synaptic properties and network dynamics with the corresponding experimental paradigms and techniques.
- can stimulate neurons and neural tissue for different paradigms
- are able to present in speech and writing the concepts, implementations and interpretation of electrophysiological experiments in scientific style using own data.
- are able to critically assess electrophysiological experiments.
- are able to connect neurobiological concepts and signal with methods for their quantitative analysis.
- can design and perform guided paw movement training of a rat. In particular, the student will know the elements of basic rat behavior, and how to tune naïve behavior to a controlled behavior.
- can modify algorithms in a standard scripting language to guide the paw movements with real-time sensory feedback.

- can use this acquired knowledge, insights and skills to read, understand and critically discuss scientific publications in the experimental neurosciences.

Zu erbringende Prüfungsleistung

none

Zu erbringende Studienleistung

- Preparation for the practical parts using the course script,
- Regular participation according to § 13, para. 2 of the framework examination regulations Master of Science
- Attendance of the course days (100%).

Literatur

The following literature is recommended for independent preparation and follow-up of the course contents:
- Johnston, Wu: Foundations of Cellular Neurophysiology, MIT Press, Chapt. 1-6, 14, 15
- Wishaw & Kolb: The laboratory rat. Oxford University press, Chapter 14-15.
- Course script, primary literature and academic reviews as provided at the beginning of the course

Bemerkung / Empfehlung

In diesem Modul werden gelegentlich Ratten oder Mäuse verwendet. Die Ratten und Mäuse stammen aus eigener Forschungszucht.

Dabei handelt es sich um eine Wirbeltierverwendung der Kategorie C4: Adulte Wirbeltiere, die für die Forschung gezüchtet und getötet werden und für die Lehre mitgenutzt werden (typischerweise bei Mitarbeit von Studierenden an aktuell laufenden Forschungsprojekten). .

Begründung für diese Verwendung: In diesem Modul ist die Arbeit mit adulten Wirbeltieren erforderlich, da nur mit diesem authentischen Material die für Biolog:innen relevanten praktischen Fertigkeiten (Präparation, Entnahme von Organen, Studium des Aufbaus) erworben werden können. In diesen Fällen ist es aufgrund der notwenigen Tierart nicht möglich, auf für den Verzehr gezüchtete Tiere zurückzugreifen, da diese Tiere in der Regel nicht Bestandteil des Nahrungsrepertoirs von Menschen ist. Damit für die Lehre nicht zusätzliche Tiere produziert werden müssen, werden in diesen Fällen Tiere, die für die Forschung gezüchtet und getötet werden, auch für die Lehre mit verwendet.

Verwendbarkeit des Moduls

M.Sc. Biology, elective module in the Major Neuroscience
M.Sc. Neuroscience

Name des Moduls	Nummer des Moduls
WM-30 Neurophysiology: Measuring Neuronal Activity Dynamics and Plasticity in vitro	09LE03M-WM-30
Veranstaltung	
Neurophysiology in vitro	
Veranstaltungsart	Nummer
Übung	09LE03Ü-WM-30_0001

ECTS-Punkte	9,0
Arbeitsaufwand	270 Stunden
Präsenzstudium	135 Stunden
Selbststudium	135 Stunden
Semesterwochenstunden (SWS)	9,0
Mögliche Fachsemester	2
Angebotsfrequenz	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	Pflicht
Lehrsprache	englisch

Inhalte

The course covers electrophysiological and behavioral aspects of neuroscience. Electrophysiological recordings are performed in acute brain slices of the hippocampus and in cell cultures of cortical neurons to teach widely used methods by recording and analyzing the activity and properties of individual neurons and networks. Behavioral experiments are conducted with adult rats. The course is an intense exercise using advanced techniques of neurophysiological and behavioral research, emphasizing independent use of high-tech equipment and critical analysis and interpretation of own research data.

Specifically, participants will perform
- Intracellular recordings using the patch clamp technique,
- Extracellular recordings using microelectrode arrays,
- Measure fundamental properties of neurons and networks,
- Analyze the properties of synaptic potentials,
- Measure local field potentials in different tissue configurations,
- Visualize activity dynamics in brain slices,
- Assess synaptic plasticity in paired pulse facilitation and long-term potentiation paradigms. Observations of naïve and trained rat behavior.
- Modifications of control software to adapt to the performance of the animals.
- Analyses of the recorded behavioral data.

The results obtained will be presented in the style of a conference workshop among the participants.

Lern- und Qualifikationsziele der Lehrveranstaltung

The students
- are able to prepare and document immunocytochemical stains of brain slices
- can name neuronal subtypes in the hippocampus, fiber tracts and their connectivity and explain their functions, respectively
- can record and analyze electrical activity in individual neurons and networks with tools used in current research.
- are able to assess the electrophysiological properties of individual neurons, synaptic properties and network dynamics with the corresponding experimental paradigms and techniques.

- can stimulate neurons and neural tissue for different paradigms
- are able to present in speech and writing the concepts, implementations and interpretation of electrophysiological experiments in scientific style using own data.
- are able to critically assess electrophysiological experiments.
- are able to connect neurobiological concepts and signal with methods for their quantitative analysis.
- can design and perform guided paw movement training of a rat. In particular, the student will know the elements of basic rat behavior, and how to tune naïve behavior to a controlled behavior.
  can modify algorithms in a standard scripting language to guide the paw movements with real-time sensory feedback.
- can use this acquired knowledge, insights and skills to read, understand and critically discuss scientific publications in the experimental neurosciences.

Zu erbringende Prüfungsleistung

none

Zu erbringende Studienleistung

- Preparation for the practical parts using the course script,
- Regular participation according to § 13, para. 2 of the framework examination regulations Master of Science

Literatur

The following literature is recommended for independent preparation and follow-up of the course contents:
- Johnston, Wu: Foundations of Cellular Neurophysiology, MIT Press, Chapt. 1-6, 14, 15
- Wishaw & Kolb: The laboratory rat.Oxford University press, Chapter 14-15.
- Course script, primary literature and academic reviews as provided at the beginning of the course

Teilnahmevoraussetzung laut Prüfungsordnung

s. Modulebene

Lehrmethoden

The course will be taught in the form of
- Interactive presentations,
- Individual work on electrophysiological and behavioral setups
- group work
- lab visits to research laboratories,
- tutoring during practical sessions and data analysis
- seminar presentations
- colloquia

The following media will be used:
- scripts for practical sessions,
- electrophysiological research equipment,
- lab equipment for histology
- Powerpoint presentations,
- several software toolboxes for data analysis and visualization,
- data from neurophysiological recordings.

Detailed Module Descriptions

Focus Area 2: Computational Neuroscience

Name of module	**Number of module**
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Biological Learning, Control and Decision Making	
Event type	Number
Lecture + exercise	09LE03V-NE-2-T1.2

ECTS-Points	9
Workload	270 h
Attendance	78 h
Independent study	192 h
Hours of week	6
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	English

Contents

Building on prior knowledge in neuroscience and mathematical methods, this course covers the computational neuroscience and modeling of biological learning, control and decision making. Topics include:

- Biological movement control
- Sensorimotor learning and motor adaptation
- Reinforcement learning in neuroscience
- Bayesian models in action and perception
- Recurrent neural networks of learning and control

Several of the methods and models covered in this course are related to developments in artificial intelligence and machine learning and thus, connections between models of brain function and AI will be a topic of discussion in this course.

The course consists of interactive lectures and accompanying exercises.

Qualification

The students acquire the competence to

- summarize models of biological learning, control and decision making
- link mathematical models with biological phenomena arising in systems neuroscience, using theory and computer simulations
- understand the fundamental tradeoff between biological detail and mathematical abstraction and evaluate its consequences
- explain the steps necessary to develop and validate models of behaviour their underlying neural mechanisms
- explain the gain in understanding biological mechanisms arising from the study of mathematical models and critically discuss the limits of mathematical modeling

- implement, simulate and analyse models and methods of biological learning, control and decision making
- compare models of different levels of abstraction

Examination achievement
Written exam (70 minutes duration)
Course achievement
Presentation of selected exercise solutions

Compulsory requirement
None
Recommended requirement
■ Basic knowledge in the biological foundations of neuroscience ■ Basic knowledge of quantitative methods ■ Enjoying mathematical modelling ■ Quantitative Methods and Statistics course ■ Python programming ■ Scientific Programming in Python course
Teaching method
Lectures, exercises and discussion Presentation and discussion of exercise solutions

Name of module	**Number of module**
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Quantitative Methods 2	
Event type	Number
Lecture + exercise	09LE03V-NE-2-T1.3

ECTS-Points	9.0
Workload	270 h
Attendance	75 h
Independent study	195 h
Hours of week	5.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	English

Contents

- Examples of probability distributions
- PCA,SVD
- Tuning curves and likelihoods, probabilistic decoding, Cramer Rao bound and Fisher Information
- Model identification: Linear filters (Fourier theory) Generalized Linear Models
- Learning and Regression
- Perceptrons and Patterns
- Support Vector Machines and Kernel trick
- Shannon Information and independence

Qualification

The students can

- answer detailed questions about the lecture contents
- explain the mathematical foundations of the introduced analysis concepts
- apply the analysis concepts to simple neuroscience problems
- generalize the presented methods to new problem variants
- explain the limitations of the presented analysis methods
- implement the analysis concepts from the lecture in python.
- reproduce mathematical derivations and proofs shown in the lecture
- apply the analysis concepts to small data sets

Examination achievement
Written exam (70 minutes duration)

Course achievement
■ Attendance of the lecture is voluntary, but highly recommended. ■ Regular participation in exercises
Literature
■ Spikes; Bialek, de Ruyter van Steveninck, Rieke, Garland ■ Introduction to Theoretical Neurobiology I; Tuckwell ■ Information Theory, Inference and Learning Algorithms; McKay ■ Advanced Data Analysis in Neuroscience: Integrating Statistical and Computational Models; Durstewitz ■ Pattern Recognition & Machine Learning; Bishop
Compulsory requirement
None
Recommended requirement
Quantitative Methods, enjoying mathematics
Teaching method
■ Presentation of lecture notes ■ Solving problem sheets together ■ Discussion of homework in tutorials ■ Homework problems require both programming (Python) and mathematical analysis

Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Current Topics in Computational Neuroscience	
Event type	Number
course	09LE03S-NE-2-T11
Faculty	
Fakultät für Biologie	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	15 h
Independent study	75 h
Workload	90 h

Content

In this seminar, current topics in computational neuroscience will be presented and discussed. While the final list of seminar topics is updated each semester and selected before the organization meeting, the following list comprises some topics that have been part of this seminar previously:

- Dynamics of spiking neuronal networks
- Models of sensory networks, sensory processing and perception
- Functional and structural plasticity of neurons and networks
- Models of learning and memory
- Models of sleep and memory consolidation
- Models of brain dysfunction and brain diseases
- Models of movement control
- Models of decision making
- Biophysics of single neurons and networks

Qualification

The students

- have advanced knowledge about several recent research findings in the field of computational neuroscience
- have the competence to extract the important findings from a research publication and present them in a meaningful and well-structured scientific presentation in English
- have the competence to give an oral presentation about an advanced research topic from the field of computational neuroscience.

Examination achievement

None

Course achievement
Active participation in the seminar (including the initial organization meeting). Oral presentation of one of the seminar topics.
Compulsory requirement
Recommended requirement
Participation in all lectures of the focus area Computational Neuroscience
Teaching method
Oral presentation by the student; individual instruction how to present an advanced seminar topic, including feedback after the presentation; guidance how to lead a scientific discussion in front of the group; numerical reproduction of essential research findings

↑

Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Maschinelles Lernen / Machine Learning - Lecture	
Event type	Number
lecture course	11LE13V-1153
Organizer	
Institut für Informatik, Professur für Maschinelles Lernen	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Hours of week	3.0
Recommended semester	2
Frequency	only in the winter term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	45
Independent study	120
Workload	180 Stunden

Content
Characterization of supervised, unsupervised and reinforcement learning, concept learning, decision trees, neural networks, probabilistic methods, committee techniques, reinforcement learning.
Learning target
This course provides you with a good theoretical understanding and practical experience about the basic concepts of machine learning. You shall be enabled to implement a number of basic algorithms, understand advantages and drawbacks of single methods and know typical application domains thereof. Furthermore, you should be able to use (Python) software libraries in order to work on novel data analysis problems. The course will prepare you to dive deeper into advanced methods of ML, e.g. deep learning, recurrent networks, reinforcement learning, hyperparameter optimization, and into specific application domains such as image analysis, brain signal analysis, robot learning, bioinformatics etc., for which specialized courses are available.
Examination achievement
Oral examination with a duration of 35 minutes
Course achievement
see excercise
Literature
Duda, Hart and Stork: Pattern Classification Christopher Bishop: Pattern Recognition and Machine Learning Hastie, Tibshirani and Friedman: The Elements of Statistical Learning

Mitchell: Machine Learning
Murphy: Machine Learning – a Probabilistic Perspective
Criminisi et. al: Decision Forests for Computer Vision and Medical Image Analysis
Schölkopf & Smola: Learning with Kernels
Goodfellow, Bengio and Courville: Deep Learning
Michael Nielsen: Neural Networks and Deep Learning

In addition, literature for every section of the course is announced during these sections.

Compulsory requirement

keine | none

Recommended requirement

We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory.

We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof.

We recommend basic knowledge of optimization and of the scikit-learn Python library.

Teaching method

For in-class lectures:

Despite the large lecture rooms, a teacher-centered style shall be enriched as much as possible by measures like:

- interactive question and answer rounds
- discussions in sub-groups, reporting to the large group
- cross-teaching
- problem-oriented teaching e.g. via data analysis competition
- repetition of important concepts in slightly altered contexts.

For virtual lectures:

- flipped classroom teaching with videos provided
- Q&A sessions to discuss the videos' content
- Cross-teaching via Ilias forum
- problem-oriented teaching e.g. via data analysis competition
- repetition of important concepts in slightly altered contexts.

Target group

Advanced BSc., MSc. students and PhD students

↑

Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Maschinelles Lernen / Machine Learning - Exercises	
Event type	Number
excercise course	11LE13Ü-1153
Organizer	
Institut für Informatik, Professur für Maschinelles Lernen	
Faculty	
Technische Fakultät	

ECTS-Points	.
Hours of week	1.0
Recommended semester	2
Frequency	only in the winter term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	15

Content
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods to gain experience in practical applications.
Examination achievement
see Lecture
Course achievement
Passing an oral or written examination.
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Neuroprothetik / Neuroprosthetics - Seminar	
Event type	Number
seminar	04LE50V-5318
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Hours of week	3.0
Recommended semester	4
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	39 hours
Independent study	51 hours
Workload	90 hours

Content

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson‘s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

Examination achievement

Written documentation and oral presentation. The module grade is based on the written documentation (50%) and the oral presentation (50%).

Course achievement

None

Literature

- Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE

- Dagnelie, G., Ed. (2011). Visual Prosthetics: Physiology, Bioengineering, Rehabilitation: Physiology, Bioengineering and Rehabilitation, Springer
- DiLorenzo, D. J. and J. D. Bronzino, Eds. (2008). Neuroengineering Boca Raton, CRC Press
- Akay, M. (2007). Handbook of Neural Engineering, IEEE Press, Wiley
- Dornhege, G., et al., Eds. (2007). Toward Brain-Computer Interfacing. Neural Information Processing Series. Cambridge, MA, MIT Press
- Horch, K. W. and G. S. Dhillon (2004). Neuroprosthetics - Theory and Practice. Singapore-London, World Scientific Publishing

Compulsory requirement
None
Recommended requirement
High level knowledge in mathematics and natural sciences

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Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
lecture course	11LE50V-5249
Organizer	
Institut für Mikrosystemtechnik, Systemtheorie, Regelungstechnik und Optimierung	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Hours of week	6.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	78 hours
Independent study	102 hours
Workload	180 hours

Content
■ Introduction: Dynamic Systems and Optimization ■ Rehearsal of Numerical Optimization ■ Rehearsal of Parameter Estimation ■ Discrete Time Optimal Control ■ Dynamic Programming ■ Continuous Time Optimal Control ■ Numerical Simulation Methods ■ Hamilton-Jacobi-Bellmann Equation ■ Pontryagin and the Indirect Approach ■ Direct Optimal Control ■ Differential Igebraic Equations ■ Periodic Optimal Control ■ Real-Time Optimization for Model Predictive Control
Examination achievement
Written exam (180 minutes)
Course achievement
see exercise
Literature
1. Manuscript "Numerical Optimal Control" by M. Diehl and S. Gros 2. Biegler, L.T., Nonlinear Programming, SIAM, 2010

Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

↑

Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
excercise course	11LE50Ü-5249
Organizer	
Institut für Mikrosystemtechnik, Systemtheorie, Regelungstechnik und Optimierung	
Faculty	
Mathematisches Institut-VB Technische Fakultät	

ECTS-Points	.
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english

Content
Theoretical and computer exercises accompany the lecture to deepen the understanding
Examination achievement
Course achievement
Successful participation/solution of at least 50% of the weekly exercise sheets
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

↑

Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals - Lecture	
Event type	Number
lecture course	11LE50V-5312
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	26 hours
Independent study	64 hours
Workload	90 hours

Content
The course starts with an introduction to the basic principles of the measurement of neurophysiological signals mainly EEG and MEG. Despite a basic technical introduction of the measurement systems an overview about physiological and pathological patterns and rhythms in brain signal is given. Pattern recognition in the diagnostics of patients suffering from epilepsy is one core topic of the module. Long term recordings of EEG in epilepsy diagnostic create a high demand for automatic EEG analysis procedures. Three different types of events are at the moment in the focus for automatic detection strategies. a) Epileptic seizures, which are the core syndrome of the disease. Automatic detection may facilitate the review of long term recordings tremendously. b) Short high amplitude peaks in EEG and MEG called spikes contribute to the diagnoses of epilepsy and give information related to the localization of the seizure onset region in focal epilepsy. c) Oscillatory activity in the frequency range between 80 Hz and 600 Hz gives according to recent result probably more specific information about the seizure origin area than spikes. Signal processing and pattern recognition strategies are presented and how they can be applied to the patterns of interest in epilepsy diagnostic. In detail following strategies will be presented: a) Heuristics b) Template matching c) Wavelet transformation d) Hilbert transformation e) Background and target modelling f) Artificial neural networks

A second focus of the module is related to the localization of generators of neuronal activity based on EEG and MEG measurements. The introduction starts with the presentation of the Maxwell equations and the common simplifications as they are applied in EEG and MEG source localization. Localization includes two basic components, the forward simulation and an inverse parameter estimation procedure. Concepts of the following forward models representing the physical properties of the head are presented: a) Spherical model b) Boundary element model c) Finite element model Main types of focal and distributed inverse models will form the contents of the inverse part of the source localization procedure. Exemplary application examples will show the complete processing chain from measurements and image acquisition to localization results.
Examination achievement
Oral exam (30 minutes)
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Elective Subjects (Focus Area: Computational Neuroscience)	09LE03MO-NE-2-2021
course	
Simulation of Biological Neuronal Networks	
Event type	Number
excercise course	09LE03Ü-NE-2-T2
Faculty	
Fakultät für Biologie	

ECTS-Points	3.0
Hours of week	3.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	45 h
Independent study	45 h
Workload	90 h

Content
This course covers the fundamentals of simulating networks of single-compartment spiking neuron models. We start from the concept of a point neuron and then introduce more complex topics such as phenomenological models of synaptic plasticity, connectivity patterns and network dynamics.
Qualification
The course is based on introductory lectures using slides (provided for download) and whiteboard in the computer pool. The task is to individually implement NEST programs, starting with simple tasks and later executing small project. The intense interaction with tutors enhances the learning experience. The students acquire the competence to ■ link mathematical models with biological phenomena arising in systems neuroscience, both using theory and computer simulations; ■ implement and simulate simple neuronal network models using modern tools and methods of scientific programming (based on Python and NEST); ■ implement simple programs for data analysis and apply them to simulated data; ■ appreciate and explain the gain in understanding biological mechanisms arising from the study of mathematical models of neuronal systems and their simulation on a computer; ■ critically discuss the limits of mathematical modeling and numerical methods in computational neuroscience.
Examination achievement
None
Course achievement
Regular attendance, active participation and self-guided study; successful completion (50% correct) of all assignments and/or projects.

Literature
See http://www.nest-initiative.org/ for some general information and an online tutorial on the BNN simulator NEST.
Compulsory requirement
None
Recommended requirement
Basic knowledge in the biological foundations of and quantitative methods in neuroscience
Teaching method
Practical exercises in devising, executing and analyzing numerical simulations of neuronal networks. Introductory lectures to cover the neuroscience background.

↑

Detailed Module Descriptions

Focus Area 3: Neurotechnology

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Lecture	
Event type	Number
lecture course	11LE50V-5301
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	39 hours
Independent study	51 hours
Workload	90 hours

Content
The course introduces different aspects of the recording of bioelectrical signals starting with the nerve and including amplifier design. It presents the most important medical diagnosis methods in the field of bioelectrical signals. In detail, the following topics will be covered: ■ Origin of bioelectrical signals ■ Electrochemistry of electrodes ■ Acute and chronic applications of electrodes ■ Recording and amplification of bioelectrical signals ■ Interference and artefacts ■ Bioelectrical signals of peripheral nerves and the muscle ■ Electrical signals of the heart (ECG) ■ Cardiac pacemakers and implantable defibrillators ■ Technical safety of medical devices Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.
Examination achievement
Oral examination (30 minutes)
Course achievement
See exercise
Literature
Actual copies of the slides will be delivered accompanying to the lectures.

Literature:
German
1. Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005

English
1. Bronzino, Joseph D. (Hrsg.): The Biomedical Engineering Handbook, Volume 1 (and 2), Second Edition. Boca Raton: CRC Press 2000 / Heidelberg: Springer-Verlag, 2000
2. Enderle, John, Blanchard, Susan, Bronzino, Joseph (Hrsg.): Introduction to Biomedical Engineering, Second Edition. Burlington, San Diego, London, Elsevier, 2005

Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Exercises	
Event type	Number
excercise course	11LE50Ü-5301
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	.
Hours of week	1.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english

Content
Examination achievement
See lecture
Course achievement
The exercises are considered passed if 50% of maximum points will be achieved in each of the three tests that are written in the exercises with prior notice.
Compulsory requirement

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Neuroprothetik / Neuroprosthetics - Seminar	
Event type	Number
seminar	04LE50V-5318
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Hours of week	3.0
Recommended semester	4
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	39 hours
Independent study	51 hours
Workload	90 hours

Content

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson‘s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

Examination achievement

Written documentation and oral presentation. The module grade is based on the written documentation (50%) and the oral presentation (50%).

Course achievement

None

Literature

- Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE

- Dagnelie, G., Ed. (2011). Visual Prosthetics: Physiology, Bioengineering, Rehabilitation: Physiology, Bioengineering and Rehabilitation, Springer
- DiLorenzo, D. J. and J. D. Bronzino, Eds. (2008). Neuroengineering Boca Raton, CRC Press
- Akay, M. (2007). Handbook of Neural Engineering, IEEE Press, Wiley
- Dornhege, G., et al., Eds. (2007). Toward Brain-Computer Interfacing. Neural Information Processing Series. Cambridge, MA, MIT Press
- Horch, K. W. and G. S. Dhillon (2004). Neuroprosthetics - Theory and Practice. Singapore-London, World Scientific Publishing

Compulsory requirement
None
Recommended requirement
High level knowledge in mathematics and natural sciences

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Biomedical microsystems	
Event type	Number
lecture course	11LE50V-7900
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	.
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	60
Independent study	120
Workload	180 hours

Content
The course presents exemplary applications of microsystems in biomedical engineering, discusses challenges and illustrates solutions to meet the requirements of biocompatibility, biostability and reliability in clinical applications. In detail, the following topic will be covered: ■ Introduction to Biomedical Microdevices ■ Medical Devices: Legal Framework and Classification ■ Glaucoma Monitoring Implant ■ Neual Implants to Restore Vision ■ Neural Implants to Record from the Brain ■ Sensors in Cardiac Pacemakers ■ Imaging Pills ■ Spectroscopic Billirubin Measurement ■ Trends for Intelligent Endoprostheses ■ Stability and Functionality Implantable MEMS ■ Packaging and Housing Concepts ■ Data and Energy Transmission in (Micro-)Implants Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.
Examination achievement
Written examination

Course achievement
see exercises
Literature
Actual copies of the slides will be delivered accompanying to the lectures. Literature: ■ G. A. Urban (ed.) BioMEMS. Dordrecht: Springer 2006.
Compulsory requirement
none

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Biomedical microsystems	
Event type	Number
excercise course	11LE50Ü-7900
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	.
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english

Content
Examination achievement
The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.
Course achievement
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Major Concepts in Cognitive Neurosciences	
Event type	Number
lecture course	09LE03V-WM-05_0001
Faculty	
Fakultät für Biologie	

ECTS-Points	3.0
Hours of week	4.3
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	
Language	english
Attendance	60 Stunden
Independent study	30 Stunden
Workload	90 Stunden

Content

Topics of the lectures given by various teachers are intentions, methods, and results of diverse fields of research that together contribute to our understanding of the relationship between cognition and the structure and physiology of brains.
Topics contain:

- Brain evolution
- Cognitive Psychology
- Neuroplasticity
- Perception
- Brain-machine interfaces
- Imaging methods
- Animal cognition
- Clinical neuroscience
- Neurophilosophy

Qualification

- Students can name major stages of human brain evolution.
- They can explain and differentiate several levels of neuroplasticity.
- They can name major benefits and limits of computational concepts for understanding cognitive functions.
- They identify similarities and differences between human and animal cognition.
- They can give examples of logical complications faced by the cognitive neurosciences.

Examination achievement

none

Course achievement

none

Literature
The following literature is recommended for independent preparation and follow-up of the course contents: ■ Tim Shallice, Richard P. Cooper: The organization of mind. Oxford Univ. Press 2011 ■ Kenneth M. Heilman, Edward Valenstein (Eds.): Clinical neuropsychology. 4th ed., Oxford Univ. Press 2003.
Compulsory requirement
s. Modulebene
Teaching method
Lectures will be given as Power-Point presentation, including multimedia elements, backed by slide handouts. Intermitting discussions will be encouraged and coached.
Target group
■ M.Sc. Biology ■ M.Sc. Bioinformatics & Systems Biology ■ M.Sc. Neuroscience ■ Diploma Biology

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Methods in Cognitive Neurosciences	
Event type	Number
excercise course	09LE03Ü-WM-05_0002
Faculty	
Fakultät für Biologie	

ECTS-Points	2.0
Hours of week	0.5
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	6 Stunden
Independent study	54 Stunden
Workload	60 Stunden

Content
■ demonstration of key methods in the cognitive neurosciences ■ participation in experiments as subjects.
Qualification
The students can: ■ identify major components and regions of human brain anatomy. ■ explain EEG recordings, name the necessary equipment for it, and assess its fields of application. ■ explain the principles of an MRI measurement and identify reasonable fields of application. ■ plan and conduct experiments in teams, respect competencies of others and contribute their own skills constructively.
Examination achievement
keine
Course achievement
■ 100% active participation in 2 of 3 practical courses ■ writing a lab report each about the experimental procedures done or seen.
Literature
The following literature is recommended for independent preparation and follow-up of the course contents: ■ Lennart Heimer: The human brain and spinal cord. 2nd ed., Springer Verlag, New York 1994.
Compulsory requirement
s. Modulebene

Teaching method
Students will be given hands-on experience of key-methods used in the cognitive neurosciences.
Target group
■ M.Sc. Biology ■ M.Sc. Bioinformatics & Systems Biology ■ Diploma Biology

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Selected Topics in Cognitive Neurosciences	
Event type	Number
seminar	09LE03S-WM-05_0003
Faculty	
Fakultät für Biologie	

ECTS-Points	4.0
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	30 Stunden
Independent study	90 Stunden
Workload	120 Stunden

Content
■ Two seminar blocks will be held for students to learn and discuss original papers about the cognitive neurosciences in general and about brain and language specifically. ■ The students will learn how to read and evaluate original research reports. ■ They will understand how to structure and present complex issues of current research. ■ They will participate in scientific discussions and learn how to deal with controversies
Qualification
Students present and discuss specific scientific terms and concepts, observing the fundamental distinction between data and their interpretation.
Examination achievement
keine
Course achievement
■ 100% active participation in two seminar blocks ■ Two seminar presentations of data and concepts contained in original literature
Literature
To be distribute during the preparatory session.
Compulsory requirement
s. Modulebene
Teaching method
Seminars will be given by each student as media-supported Power-Point presentations.

Target group
■ M.Sc. Biology ■ M.Sc. Bioinformatics & Systems Biology ■ Diploma Biology

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation - Lecture	
Event type	Number
lecture course	11LE50V-5306
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	3
Frequency	only in the winter term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	30 hours
Independent study	60 hours
Workload	90 hours

Content
The lecture introduces biological-medical as well as physico-technical aspects during electrical stimulation of nerves and muscles. The following topics will be covered: ■ Overview of the history of electrical stimulation ■ Anatomy and physiology of nerves and muscles ■ Description of electrical excitation of nerve cells ■ Electrical fields and electrochemical processes at electrodes ■ Methods of selective nerve stimulation ■ Effects of chronic electrical stimulation of nerve and muscle ■ Limits of safe electrical stimulation ■ System theory and control aspects in neural prosthetics ■ Simulatoin of nerve excitation ■ Design of stimulators for electrical stimulation ■ Characteristic parameters for different applications in electrical stimulation. The learning targets and objectives will be summarized at the end of each lecture and a comprehensive summary will take place at the end of the course to repeat the most important objectives and facilitate preparation of the oral examinations.
Examination achievement
Oral exam (30 minutes)
Course achievement
None
Literature
Actual copies of the slides will be delivered accompanying to the lectures.

Literature: ■ Horch, K.W., Dhillon, G.S. (Hrsg.): Neuroprosthetics – Theory and Practice. (Series on Bioengineering & Biomedical Engineering – Vol. 2) ■ River Edge: World Scientific Computing, 2004
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Lecture	
Event type	Number
lecture course	11LE50V-5313
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	3
Frequency	only in the winter term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	45 hours
Independent study	45 hours
Workload	90 hours

Content
In the lecture Implant Manufacturing Technologies, knowledge and methods for the development of electrically active implants such as pacemakers or hearing prostheses (cochlear implants) are taught. Materials, components, systems and legal frameworks are presented. Clinically established (neuro-) implants as well as novel developments, which are still in the research phase, will be presented and critically discussed. The following topics will be covered during the lecture: ■ Overview of active implants & neuroprostheses in clinical and research settings. ■ Definitions and classification of electrically active implants ■ Biocompatibility testing and biostability (corrosion and degradation) ■ Electrodes ■ Design of electrically active implants (components, interfaces) ■ Silicone as material for encapsulation ■ Materials for hermetically sealed housings ■ Connections and joining techniques ■ Requirements for implant development and production (risk management, FMEA, production rooms, documentation) ■ Thin-film technology in implant development ■ Manufacturing of microimplants using the example of a BION Finally, the learning content will be repeated together with the students in order to facilitate the preparation for the examination.
Examination achievement
Written examination (90 minutes)

Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Exercises	
Event type	Number
excercise course	11LE50Ü-5313
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	.
Hours of week	1.0
Recommended semester	3
Frequency	only in the winter term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english

Content
Examination achievement
See lecture
Course achievement
None
Compulsory requirement

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Maschinelles Lernen / Machine Learning - Lecture	
Event type	Number
lecture course	11LE13V-1153
Organizer	
Institut für Informatik, Professur für Maschinelles Lernen	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Hours of week	3.0
Recommended semester	2
Frequency	only in the winter term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	45
Independent study	120
Workload	180 Stunden

Content
Characterization of supervised, unsupervised and reinforcement learning, concept learning, decision trees, neural networks, probabilistic methods, committee techniques, reinforcement learning.
Learning target
This course provides you with a good theoretical understanding and practical experience about the basic concepts of machine learning. You shall be enabled to implement a number of basic algorithms, understand advantages and drawbacks of single methods and know typical application domains thereof. Furthermore, you should be able to use (Python) software libraries in order to work on novel data analysis problems. The course will prepare you to dive deeper into advanced methods of ML, e.g. deep learning, recurrent networks, reinforcement learning, hyperparameter optimization, and into specific application domains such as image analysis, brain signal analysis, robot learning, bioinformatics etc., for which specialized courses are available.
Examination achievement
Oral examination with a duration of 35 minutes
Course achievement
see excercise
Literature
Duda, Hart and Stork: Pattern Classification Christopher Bishop: Pattern Recognition and Machine Learning Hastie, Tibshirani and Friedman: The Elements of Statistical Learning

Mitchell: Machine Learning
Murphy: Machine Learning – a Probabilistic Perspective
Criminisi et. al: Decision Forests for Computer Vision and Medical Image Analysis
Schölkopf & Smola: Learning with Kernels
Goodfellow, Bengio and Courville: Deep Learning
Michael Nielsen: Neural Networks and Deep Learning

In addition, literature for every section of the course is announced during these sections.

Compulsory requirement

keine | none

Recommended requirement

We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory.

We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof.

We recommend basic knowledge of optimization and of the scikit-learn Python library.

Teaching method

For in-class lectures:

Despite the large lecture rooms, a teacher-centered style shall be enriched as much as possible by measures like:

- interactive question and answer rounds
- discussions in sub-groups, reporting to the large group
- cross-teaching
- problem-oriented teaching e.g. via data analysis competition
- repetition of important concepts in slightly altered contexts.

For virtual lectures:

- flipped classroom teaching with videos provided
- Q&A sessions to discuss the videos' content
- Cross-teaching via Ilias forum
- problem-oriented teaching e.g. via data analysis competition
- repetition of important concepts in slightly altered contexts.

Target group

Advanced BSc., MSc. students and PhD students

↑

Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Maschinelles Lernen / Machine Learning - Exercises	
Event type	Number
excercise course	11LE13Ü-1153
Organizer	
Institut für Informatik, Professur für Maschinelles Lernen	
Faculty	
Technische Fakultät	

ECTS-Points	.
Hours of week	1.0
Recommended semester	2
Frequency	only in the winter term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	15

Content
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods to gain experience in practical applications.
Examination achievement
see Lecture
Course achievement
Passing an oral or written examination.
Compulsory requirement
none
Recommended requirement
none

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Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
lecture course	11LE50V-5249
Organizer	
Institut für Mikrosystemtechnik, Systemtheorie, Regelungstechnik und Optimierung	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Hours of week	6.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english
Attendance	78 hours
Independent study	102 hours
Workload	180 hours

Content
■ Introduction: Dynamic Systems and Optimization ■ Rehearsal of Numerical Optimization ■ Rehearsal of Parameter Estimation ■ Discrete Time Optimal Control ■ Dynamic Programming ■ Continuous Time Optimal Control ■ Numerical Simulation Methods ■ Hamilton-Jacobi-Bellmann Equation ■ Pontryagin and the Indirect Approach ■ Direct Optimal Control ■ Differential Igebraic Equations ■ Periodic Optimal Control ■ Real-Time Optimization for Model Predictive Control
Examination achievement
Written exam (180 minutes)
Course achievement
see exercise
Literature
1. Manuscript "Numerical Optimal Control" by M. Diehl and S. Gros 2. Biegler, L.T., Nonlinear Programming, SIAM, 2010

Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

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Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Numerical Optimal Control in Science and Engineering	
Event type	Number
excercise course	11LE50Ü-5249
Organizer	
Institut für Mikrosystemtechnik, Systemtheorie, Regelungstechnik und Optimierung	
Faculty	
Mathematisches Institut-VB Technische Fakultät	

ECTS-Points	.
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	core elective
Language	english

Content
Theoretical and computer exercises accompany the lecture to deepen the understanding
Examination achievement
Course achievement
Successful participation/solution of at least 50% of the weekly exercise sheets
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses. Numerical Optimization (NUMOPT), Modelling and System Identification (MSI), Systems and Control Bachelor or Master lectures.

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Name of module	Number of module
Elective Subjects (Focus Area: Neurotechnology)	09LE03MO-NE-3-2021
course	
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals - Lecture	
Event type	Number
lecture course	11LE50V-5312
Organizer	
Institut für Mikrosystemtechnik, Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	2
Frequency	only in the summer term
Pflicht/Wahlpflicht (P/WP)	compulsory
Language	english
Attendance	26 hours
Independent study	64 hours
Workload	90 hours

Content
The course starts with an introduction to the basic principles of the measurement of neurophysiological signals mainly EEG and MEG. Despite a basic technical introduction of the measurement systems an overview about physiological and pathological patterns and rhythms in brain signal is given. Pattern recognition in the diagnostics of patients suffering from epilepsy is one core topic of the module. Long term recordings of EEG in epilepsy diagnostic create a high demand for automatic EEG analysis procedures. Three different types of events are at the moment in the focus for automatic detection strategies. a) Epileptic seizures, which are the core syndrome of the disease. Automatic detection may facilitate the review of long term recordings tremendously. b) Short high amplitude peaks in EEG and MEG called spikes contribute to the diagnoses of epilepsy and give information related to the localization of the seizure onset region in focal epilepsy. c) Oscillatory activity in the frequency range between 80 Hz and 600 Hz gives according to recent result probably more specific information about the seizure origin area than spikes. Signal processing and pattern recognition strategies are presented and how they can be applied to the patterns of interest in epilepsy diagnostic. In detail following strategies will be presented: a) Heuristics b) Template matching c) Wavelet transformation d) Hilbert transformation e) Background and target modelling f) Artificial neural networks

A second focus of the module is related to the localization of generators of neuronal activity based on EEG and MEG measurements. The introduction starts with the presentation of the Maxwell equations and the common simplifications as they are applied in EEG and MEG source localization. Localization includes two basic components, the forward simulation and an inverse parameter estimation procedure. Concepts of the following forward models representing the physical properties of the head are presented: a) Spherical model b) Boundary element model c) Finite element model Main types of focal and distributed inverse models will form the contents of the inverse part of the source localization procedure. Exemplary application examples will show the complete processing chain from measurements and image acquisition to localization results.
Examination achievement
Oral exam (30 minutes)
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

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