Module Handbook

Bachelor Degree Programme

Biomedical Sciences

(English)

as of 30.05.2024

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0. Principles of course structure

Course is organised by the Faculty of Natural Sciences (FNW)

Teaching contribution come from Medicine (FME), Physics (FNW), Psychology (FNW) and Informatics (FIN).

All compulsory courses taught in English. A small number of optional courses may be offered in German. Language teaching in Scientific English is offered.

In Year 1, examinations in English OR German dependent on individual choice.

Semesters 1-3: all students cover core course.

> Main principles of biomedical sciences taught in blocks; integrated teaching in lecture, practicals and tutorials/seminars for smaller groups underpin each core modules.

Semester 4: Specialisation

Semester 5: Lab rotations or semester abroad

Semester 6: Bachelor thesis

YEAR 1

WiSe – ORGANIZING PRINCIPLES		SuSe – FROM CELLS TO ORGANS	
Molecular Cell Biology	Genes & Genetics	Cell Physiology	Development & Evolution
QUANTITATIVE FOUNDATIONS		QUANTITATIVE EXTENSIONS	
Scientific English + Skills I What is life?		Scientific English + Skills II Evo-Devo	

YEAR 2

WiSe - ORGANISMS		SuSe - SPECIALISATIONS
NERVOUS SYSTEM	IMMUNE SYSTEM	I. NEUROSCIENCE
QUANTITATIVE APPLICATIONS		II. IMMUNOLOGY
Scientific English + Skills III Behaviour		III. CELLULAR FUNCTIONS

Semester 5: Internship semester / semester abroad
LAB ROTATIONS OR SEMESTER ABROAD

Semester 6: Bachelor thesis.
BACHELOR THESIS
Data science
Scientific ethics
Communicating Science
Journal club 1
Journal club 2
Soft skills (e.g. teaching skills, peer mentoring, journalistic writing, rhetoric, etc.)
Sidetracks (selected courses from other curricula): e.g. Philosophy

1 Bachelor degree programme Biomedical Sciences, compulsory modules

1.1 Molecular Cell Biology

Study programme:
Bachelor in Biomedical Sciences

Modules:
Molecular Cell Biology (PF)

Module aims:
This section of the course introduces the chemical basis for biological processes including the basic processes of biochemistry and metabolism, protein translation and protein degradation. Students will become familiar with the specialized molecules that make up cells and organisms, understand the principles that determine the structure of biological macromolecules and acquire an understanding of how principles of organic and physical chemistry underlie the behaviour of biological systems.

Content and learning outcomes:

Protein structure / chemistry

Aims:
- to provide an overview of the most important functional groups of organic chemistry and their acid-base properties and the reactions that are of most importance in biochemistry, such as hydrolysis.
- to provide a first overview on protein translation
- to provide an overview of protein chemistry and structure;
- to illustrate how protein structure is related to function (e.g. enzymes, cytoskeleton proteins, nuclear proteins) or dysfunction (e.g. point mutations, aggregates);
- to introduce principles of protein folding;

Objectives:
By the end of this lecture series students should understand the amino acids and their various unique properties;
- the basis for regular secondary structure;
- the forces that stabilise protein tertiary structure and that define protein folding;
- the molecular basis of cooperative oxygen binding to haemoglobin;
- the differences between structural and functional proteins.

Cell structure and biochemistry of membranes

Aims:
- to understand the basic architecture of membranes
- to introduce the varied composition of the membrane and its unique role in living organisms;
- to explain the central importance of proteins that are embedded within the membrane.

Objectives:
By the end of this lecture series students should understand

- the basic structural properties of cells and organelles;
- the structure and properties of lipids and their role in membranes;
- how individual components influence membrane properties;
- the basic structure of membrane proteins.

Energy metabolism

Aims:

- to introduce the structure of proteins, lipids, carbohydrates, and nucleic acids;
- to understand the metabolism of the major macromolecular classes;
- to introduce the concepts of catabolic and anabolic metabolism, and how the pathways of energy yield and storage are connected and vary in different pathophysiological states;
- to understand the integration of carbohydrate, lipid, protein, and nucleic acid metabolism on the whole animal;
- to introduce the principles of metabolic regulation.

Objectives:

By the end of this lecture series students should be able to

- discuss mechanisms of energy provision and energy storage;
- describe the major pathways of metabolism and how they are inter-related and regulated.

Teaching formats

Lecture (3 SWS), exercise (2 SWS), lab exercise (2 SWS)

Examinations

written exam 120 min (K120; pass / fail) in English or German

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 1
Language: English

Time investment:

Face-to-face: 98h (=7 SWS)
Independent study: 202h
Total: 300h (=10 CP)

Module coordinators:

Fred Schaper (FNW)

Recommended literature:

Molecular Biology of the Cell (7.ed.) Alberts, Heald, Johnston, Morgan, Raff (2022) ISBN 978-0393884852
Biochemistry (10. ed.) Berg, Gatto, Hines, Tymoczkoi, Stryer (2023) ISBN: 978-1319498504

1.2 Genes and Genetics

Study programme:
Bachelor in Biomedical Sciences

Modules:
Genes and Genetics (PF)

Module aims:

DNA and RNA structure/chemistry

Aims:

- to provide insight to the chemistry of Nucleotides, DNA and RNA;
- to discuss the conformations of DNA and RNA;
- to relate the structures of DNA and RNA to biological information transfer.

Objectives:
By the end of this lecture series students should understand

- the chemical structure and modifications of DNA and RNA;
- the structural properties and organisation of DNA and RNA;
- the mechanisms of DNA replication, transcription and translation

Genes

Aims:

- to gain basic knowledge of the structural and functional gene organisation;
- to acquire an understanding of genetic programs and epigenetic mechanisms, and their interaction with cellular signals;
- to develop concepts of gene x environment interactions in development and adulthood;
- to understand principles of mutagenesis, genetic variability, repair and genetic pathology.

Objectives:
By the end of this module students will be able to

- present nucleic acid structures and their organisation principles;
- explain transcriptional and translational regulation of gene function in detail;
- understand exemplified genetic programs of cell and tissue development;
- interpret findings of molecular investigations of gene functions at the cellular and tissue level.

Gene technology

Aims:

- to acquire an understanding of the principles in genetic technology research;
- to master the standard technologies of genetic analysis and manipulation;
- to become acquainted with important technology developments, such as Crispr/Cas9, next generation sequencing, etc.
- to gain insight into in silico genetic work, available data sources and their use.

Objectives:
By the end of this module students will be able to

- analyse results of genetic analyses at the population level;
- apply genetic knowledge to an individual's adaptive responding to environmental stimuli as well as to pathology;
- implement state-of-the art gene technology to analyse biological questions

- interpret findings from genetic models and design models and experiments to address biological functions and pathologies.

Teaching formats
Lecture (3 SWS), exercise (2 SWS), lab exercise (2 SWS)

Examinations
written exam 120 min (K120 pass / fail) in English or German

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 1
Language: English

Time investment:
Face-to-face: 98h (=7 SWS)
Independent study: 202h
Total: 300h (=10 CP)

Module coordinators:
Oliver Stork (FNW)

Module contributors:
Martin Zenker (FME), Andrea Kröger (FME)

Recommended literature:

General: Lewin XII, Genes
Watson, Molecular Biology of the Gene, 7th ed.

1.3 Quantitative Foundations

Study programme:
Bachelor in Biomedical Sciences

Modules:
Quantitative Foundations (PF)

Module aims:

This module will introduce students to quantitative concepts, methods, and levels of description of cellular and organismal structure and function. To this end, students will be introduced to selected topics in mathematics, physics, physical chemistry, biophysics, and computation, insofar as they are pertinent to biological systems. During this semester students will learn to address biological questions with quantitative tools and develop quantitative intuition at microscopic, mesoscopic, and macroscopic scales.

Content and learning outcomes:

Aims:

- to acquire the basics of geometry, calculus, and linear algebra;
- provide basic skills in programming and computer-based analysis and visualization;
- to gain an understanding of the principles of drug action on cells and on the body;
- to provide a basic knowledge of the physics of static systems at micro-, meso- and macroscopic scales.

Objectives:
By the end of this lecture series students should be able to:

- apply differential and integral calculus and linear algebra to biological systems;
- discuss and apply principles of thermodynamics and physical chemistry to cells and organs;
- discuss and apply principles of mechanics to cellular structures (e.g., skeleton, membranes, macromolecules);
- discuss and apply the principles of fluid dynamics, diffusion, rate equations, molecular motors, and biological electricity;
- write customized programmes and data visualizations in Python.

Lectures & Tutorials:
Mathematical & Statistical Foundations, 2 SWS
1. Quantities and Units
2. Numbers and Equations
3. Tables, Graphs and Functions
4. Shapes, Waves and Trigonometry
5. Differentiation
6. Integration
7. Calculus
8. Matrices and vector spaces
9. Vector calculus
10. Line, surface and volume integrals

Physics, physical chemistry & biophysics, 2 SWS
1. Energy: equilibrium, minimization, spring

2. Free energy, Gibbs calculus of equilibrium
3. Entropy, Boltzmann distribution, Entropy of a gas
4. Osmotic energy, membranes
5. Ion channels/cooperative binding
6. Random Walks & Structure of Macromolecules
7. Introduction into classical mechanics & Newton's laws
8. Electrostatics of Salt solutions
9. Beam Theory for cells/skeletons
10. DNA packing, cytoskeleton

Teaching formats

Lectures:
24 x 1h (always 1h Lecture paired with 1h Lab course)

Lab course: in the form of practicals/seminars/tutorials:
24 x 1h Students work through selected application examples

Examinations
written exam 90 min (K90 pass / fail) in English or German

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 1
Language: English

Time investment:
Face-to-face: 56h (= 4 SWS)
Independent study: 94h
Total: 150h (= 5 CP)

Module coordinators:
Claus-Dieter Ohl (FNW), W2 Neuronal Computation (FNW)

Recommended literature:

Biophysics
- Philipps, Konder, Theriot, Garcia (2012) Physical Biology of the Cell, Taylor & Francis, 2nd Ed.
- Philip Nelson (2015) Biological Physics, Updated Version, W. H. Freeman

Mathematics
- Aitken, Broadhurst, Hladky (2012) Mathematics for Biological Scientists, Garland Science
- Holmes, Huber (2019) Modern Statistics for Modern Biology, Cambridge UP
- Robeva, Kirkwood, Davies, Farhy, Johnson, Kovatchev, Straume (2008) An Invitation to Biomathematics, Academic Press
- Riley, Hobson (2011) Essential Mathematical Methods for the Physical Sciences, Cambridge UP

Programming
- Jesse M. Kinder, Philip Nelson (2018) A Student's Guide to Python for Physical Modeling: Updated Edition, Princeton University Press Revised ed. edition (January 30, 2018).

1.4 Scientific English + Skills I

Study programme:
Bachelor in Biomedical Sciences

Modules:
Scientific English + Skills I (PF)

Module aims:

This module will introduce students to scientific writing in English. Using examples from the course, students will be introduced to note taking and essay writing. A second pillar of this module is aimed to develop the skill set to read scientific literature effectively and engage in scientific discourse in the form of a book club. The latter part can be undertaken in English or German

Content and learning outcomes:

Scientific English I

Aims:
to teach the fundamentals of scientific communication and essay writing

- scientific note taking in English
- scientific essay writing in English
- reading scientific literature

Objectives:
By the end of this lecture series students should be able to:

- take notes in a lecture or when reading a scientific text. Notes that reflect the key themes and points of the material
- write a well-structured essay on a scientific question.
- confidently read scientific literature
- summarize scientific literature

Bookclub: What is life/Was ist Leben?

- Engaging in scientific discourse

Teaching formats
Seminar (exercise) in English (3 SWS)

- focus on note taking and essay writing
- weekly discussion of key themes and books across life sciences and humanities (German or English)

Examinations
Extended essay (homework) (HA) pass/fail in English or German

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 1
Language: English (part in German, optional)

Time investment:
Face-to-face: 42h (= 3 SWS)
Independent study: 108h
Total: 150h (=5 CP)

Module coordinators: Kristine Krug (FNW), Sanja Bauer Mikulovic (LIN)
Recommended literature (suggestions, will vary based on student selection): • Erwin Schrödinger, "What is Life?", 1967/2012, Canto Classics. • James Watson, "The Double Helix", 1965/2001, Touchstone Reprint. • Ernst Mayr "What Evolution Is: From Theory to Fact", 2002, Science Masters. • Jacques Monod "Chance and Necessity", 1997, Penguin Science Press. • Charles Darwin, "The Origin of Species", 1853/2003, 150th Anniversary Edition, Signet. • Kathleen Donohue, ed., "Darwin's finches: Readings in the Evolution of a Scientific Paradigm", 2011, U Chicago Press. • Stephen Jay Gould, "The Richness of Life", 2007, Vintage. • P Anderson "More is Different", Science, 1972 • Edward O. Wilson, 1990, "The ants", Harvard University Press. • Eric Kandell, "In Search of Memory", 2007, Norton & Co. • Richard Dawkins, "The Selfish Gene", 1976/2016, 40th Anniversary Edition, Oxford UP. • Denis Noble, "The Music of Life: Biology Beyond Genes", 2006, Oxford UP. • Nick Lane, "Oxygen", 2016, OUP Landmark Science, or "The Vital Question", 2016, Norton & Co. • Robert Sapolsky, "Why Zebras don't get Ulcers", 2004, St. Martin's Press. • Colin Tudge, "The Secret Life of Trees", 2007, Broadway Books. • Michael Tomasello "A natural history of human thinking", 2014, Harvard UP.]

1.5 Cell Physiology

Study programme:
Bachelor in Biomedical Sciences

Modules:
Cell Physiology (PF)

Module aims:
This block will introduce students to essential concepts regarding the relationship between cellular structure and function, including cell-to-cell communication. It will also provide knowledge of the key experiments that have led to our present understanding of this subject. During this thread students will grow to understand that cell function is intimately linked to cell structure. In addition, students will study how cells perform specialised functions and will be introduced to a variety of inter- and intra-cellular signaling mechanisms used by cells.

The module will also address the structure and function of different mammalian organ systems. Students will learn about the specific cell types and their functionality in organ systems as different as muscle, liver, skin and lung. They will understand the internal organisation principles of these particular organs and how cellular differentiation and interaction serves the overall organ functions. Students will moreover learn about the regulation of organ function in response to environmental stimuli and internal needs.

Aims:
- to introduce the application of basic physicochemical principles to the understanding of cell function;
- to gain an understanding of the principles of drug action on cells and on the body;
- to provide a basic knowledge of the functions performed by different cell types; including musculo-skeletal, endocrine, excitable tissues.
- to provide an elementary knowledge of the structure and physiological properties of nerve and muscle cells, their resting states and responses to stimulation
- to provide an introduction to the pharmacology of the nervous system.
- to gain basic knowledge of the structure and function of mammalian organs
- to obtain an overview of cellular subtypes and their differentiation according to organ need
- to acquire an understanding of the internal organisation principles of different organs
- to understand principles of regulation of cell and organ functions in the context of homeostasis

Objectives:
By the end of this lecture series students should be able to

- describe the structure and properties of biological membranes, including membrane potentials, ion channels, and ion transport mechanisms;
- explain the initiation and propagation of impulses in nerve and muscle, junctional transmission, and the contractile process in muscle;
- discuss the actions of drugs on the functioning of peripheral nerve fibres, the skeletal neuromuscular junction, the autonomic nervous system and the tissues it innervates;
- explain how important parameters of cell function can be measured and be able to assess these variables in a meaningful way;
- have acquired an understanding of basic concepts in cellular neuroscience:
  ion channels and transporters, resting and action potentials, Nernst & Goldman equations, cable properties of neurites, the role of myelin, chemical synaptic transmission, excitation and inhibition, temporal and spatial integration of synaptic inputs, synaptic plasticity.

- to present the internal organisation of different organ systems
- to explain the cellular specifications in different organs
- to understand the role of specific organ systems in organismal processes
- to interpret parameters of metabolic, structural and physiological change in organ function

Teaching formats
Lecture (3 SWS), exercise (2 SWS), lab exercise (2 SWS)

Examinations
written exam 120 min (K120) in English or German

Semesters offered: every summer semester
Duration: 1 semester
Recommended semester: 2
Language: English

Time investment:
Face-to-face: 98h (=7 SWS)
Independent study: 202h
Total: 300h (=10 CP)

Module coordinators:
Kristine Krug (FNW), Sanja Bauer Mikulovic (LIN)

Module contributors:
Volkmar Lessmann (FME), Ralf Mohrmann (FME), Markus Rothermel (FME)

Recommended literature:

General:

- The Physiology of Excitable Cells; Aidley, D; Cambridge University Press (4th edition 1998) ISBN: 978-0521574211
- From Neuron to Brain. Martin AR, Brown DA, Diamond ME, Cattaneo A et al. (6th edition, 2021) Oxford University Press.
- Rang and Dale's Pharmacology; Rang H, Dale M, Ritter J & Flower R Churchill Livingstone (8th edition 2015) ISBN: 978-0702053634
- Medical Physiology: A Cellular and Molecular Approach Boron, W & Boulpaep, E Elsevier Saunders (3rd revised edition 2016) ISBN: 978-1455743773

1.6 Development & Evolution

Study programme:
Bachelor in Biomedical Sciences

Modules:
Development & Evolution (PF)

Module aims:
This course will introduce students to the principal mechanisms that regulate the ontogenetic and phylogenetic development of a complex organism. We start from single cells and will explain how body axes are established and how body organs, an embryo and finally an adult organism are formed. We will also explain how the development of an individual phenotype is programmed by gene x environment interaction and how this interaction influences the development of health and disease. The course will also provide knowledge about the basic principles of evolution, explain the differences between micro- and macro-evolution and introduce students to concepts of brain evolution. Evolution, or "descent with modification," refers to the changes in the proportions or properties of organismal populations over time and is often considered to be the central unifying concept of all biological sciences. This course will cover the fundamental processes that drive these changes, and students will learn how to apply evolutionary principles to modern science and medicine.

Aims:
- to understand the formation of the early body plan and the underlying induction mechanisms
- to explain mechanisms of cell differentiation, organogenesis and morphogenesis
- to understand the mechanisms of fetal (perinatal) programming and the "Developmental Origins of Health and Disease (DOHaD)"
- to explain the meaning of epigenetics as mediator of developmental processes
- to understand the basic principles of brain development
- to introduce and compare the concepts of phylogenesis vs. ontogenesis
- to give an overview about basic principles of micro- and macro-evolution
- to provide a basic overview about the phylogenesis of the nervous system and to introduce concepts of brain evolution in vertebrates
- to introduce the mechanisms that underly evolutionary adaptation, including genetic variation, mutation, sexual selection, and heritability
- to explore the processes of natural selection, gene flow, genetic drift, and speciation
- to understand how evolution shapes biodiversity
- to provide insight into human health and disease from an evolutionary perspective

Objectives:
By the end of this lecture students should be able to

- to explain the basic mechanisms of developmental biology
- to understand how single cells develop into a complex organism
- to describe how environmental challenges can influence developmental processes and thereby influence the development of health and disease
- to understand the basic principles of brain development and describe the functional maturation of neuronal networks
- to understand and critically discuss the basic principles of evolution and to explain the difference between micro- and macro-evolution
- to describe the major stages and principles of vertebrate brain evolution

- to acquire an understanding of population genetics and how they are affected by evolutionary mechanisms and the environment
- to examine and interpret information from phylogenetic trees and cladograms
- to discuss the origins and evolution of humans as a species

Lectures:

- Formation of the early body plan – induction mechanisms
- Cell differentiation
- Organogenesis
- Morphogenesis
- Fetal (perinatal) programming and the Developmental origins of health and disease (DOHaD)
- Epigenetic mechanisms
- Developmental disorders
- Neuronal development, Development of the brain
- Principles of Evolution
- Phylogenesis of the nervous system and evolution of the vertebrate brain
- Adaptation and natural selection
- Molecular evolution
- Population genetics
- Speciation and classification
- Human evolution

Teaching formats

Lecture (3 SWS), exercise (2 SWS), lab exercise (2 SWS)

Examinations

written exam 120 min (K120) in English or German

Semesters offered: every summer semester
Duration: 1 semester
Recommended semester: 2
Language: English

Time investment:
Face-to-face: 98h (=7 SWS)
Independent study: 202h
Total: 300h (=10 CP)

Module coordinators:
Jörg Bock (FNW), New W2 (Development) (FNW)

Recommended literature:

General:
- Barresi & Gilbert,Developmental Biology, 2023, Oxford University Press; ISBN 9780197574591

Specific:
- Epigenetics, Development, Ecology and Evolution. (2022) Editor Luis María Vaschetto Alta Gracia, Córdoba, Argentina. Springer Verlag. ISBN 978-3-031-13770-9 ISBN 978-3-031-13771-6.

1.7 Quantitative Extensions

Study programme:
Bachelor in Biomedical Sciences

Modules:
Quantitative Extensions (PF)

Module aims.
This module will introduce students to quantitative concepts, methods, and levels of description of cellular and organismal structure and function. To this end, students will be introduced to selected topics in statistics, physics of dynamical systems, physical chemistry, and biophysics, and deepen their computation skills, insofar as they are pertinent to biological systems. During this thread students will learn to address biological questions with quantitative tools and develop quantitative intuition at microscopic, mesoscopic, and macroscopic scales.

Content and learning outcomes:

Aims:

- to introduce statistical modeling, testing, and inference in the context of modern methods;
- to develop their skills in programming and computer-based analysis and visualization;
- to gain an understanding of the principles of drug action on cells and on the body;
- to provide a basic knowledge of the physics of dynamic systems at micro-, meso- and macroscopic scales.

Objectives:
By the end of this lecture series students should be able to:

- develop and apply statistical models and tests for discrete, continuous, and multivariate situations;
- discuss and apply principles of thermodynamics and physical chemistry to cells and organs;
- discuss and apply the principles of fluid dynamics, diffusion, rate equations, molecular motors, and biological electricity;
- write even complex customized programmes and data visualizations in Python

Lectures & tutorials:

Statistics: 2 SWS
1. Generative models for discrete data
2. Statistical modeling
3. Mixture models
4. Clustering
5. Statistical testing
6. Multivariate analysis
7. High-throughput count data
8. Multivariate analysis for heterogeneous data
9. Networks and trees
10. Image data
11. Principal components
12. Supervised learning

Biophysics, dynamical systems: 2 SWS
1. Vesicles and equilibrium shape of organelles, cells
2. Hydrodynamics of water
3. Blood flow & centrifugation
4. Low Reynolds number flow
5. Diffusion as a passive transport & Einstein Relation
6. Diffusion limited chemical reactions
7. Chemical description of biological dynamics and the rate equations
8. Molecular translational & rotational motors
9. Rectified Brownian motion
10. Polymerisation and translocation
11. Biological Electricity: Charge State of the cell
12. Membrane permeability & ion channels

Teaching formats

Lectures:
24 x 1 h (always 1h lecture paired with 1h Lab course)

Lab course: in the form of practicals/seminar/tutorials:
24 x 1 h Students work through selected application examples

Examinations
written exam 90 min (K90) in English or German

Semesters offered: every summer semester
Duration: 1 semester
Recommended semester: 2
Language: English

Time investment:
Face-to-face: 56h (= 4 SWS)
Independent study: 94h
Total: 150h (=5 CP)

Module coordinators:
Claus-Dieter Ohl (FNW), W2 Neuronal Computation (FNW)

Recommended literature:

Biophysics
- Philipps, Konder, Theriot, Garcia (2012) Physical Biology of the Cell, Taylor & Francis, 2nd Ed.
- Philip Nelson (2015) Biological Physics, Updated Version, W. H. Freeman

Mathematics
- Aitken, Broadhurst, Hladky (2012) Mathematics for Biological Scientists, Garland Science
- Holmes, Huber (2019) Modern Statistics for Modern Biology, Cambridge UP
- Robeva, Kirkwood, Davies, Farhy, Johnson, Kovatchev, Straume (2008) An Invitation to Biomathematics, Academic Press
- Riley, Hobson (2011) Essential Mathematical Methods for the Physical Sciences, Cambridge UP

Programming
- Jesse M. Kinder, Philip Nelson (2018) A Student's Guide to Python for Physical Modeling: Updated Edition, Princeton University Press Revised ed. edition (January 30, 2018).

1.8 Scientific English + Skills II

Study programme: Bachelor in Biomedical Sciences
Modules: Scientific English + Skills II
Module aims: This module will introduce students to scientific writing in English. Using examples from the course, students will be introduced to experimental notes and lab report writing. A second pillar of this module is aimed to develop the skill set to read scientific literature effectively and engage in scientific discourse in the form of a book club. The latter part can be undertaken in English or German
Content and learning outcomes: **Scientific Writing II** **Aims:** to teach the fundamentals of lab report writing • how to take experimental notes • keeping a lab-book • structure of a lab report in English to teach fundamentals of assessing and communicating about research ethics • intro to ethics of research with humans • intro to ethics of research with animals **Objectives:** By the end of this lecture series students should be able to: • take and organize experimental notes • be able to structure a basic lab-book • write a lab report **Bookclub: Evolution-Development / Evo-Devo (optional German/English)** Weekly discussion of key themes and books across life sciences and humanities • engaging in scientific discourse
Teaching formats Seminar (exercise) (3 SWS) Scientific Writing II - Seminar in English focussing on lab report writing and scientific discussions Evolution-Development / Evo-Devo (optional German/English) (German or English) - weekly discussion of key themes and books across life sciences and humanities
Examinations Extended essay (homework) (HA) + presentation (R)
Semesters offered: every summer semester **Duration:** 1 semester **Recommended semester:** 2

Language: English (part in German, optional)
Time investment: Face-to-face: 42h (= 3 SWS) Independent study: 108h Total: 150h (=5 CP)
Module coordinators: New W2 (Development) (FNW)
Recommended literature (suggestions, will vary based on student selection): • Erwin Schrödinger, "What is Life?", 1967/2012, Canto Classics. • James Watson, "The Double Helix", 1965/2001, Touchstone Reprint. • Ernst Mayr "What Evolution Is: From Theory to Fact", 2002, Science Masters. • Jacques Monod "Chance and Necessity", 1997, Penguin Science Press. • Charles Darwin, "The Origin of Species", 1853/2003, 150th Anniversary Edition, Signet. • Kathleen Donohue, ed., "Darwin's finches: Readings in the Evolution of a Scientific Paradigm", 2011, U Chicago Press. • Stephen Jay Gould, "The Richness of Life", 2007, Vintage. • P Anderson "More is Different", Science, 1972 • Edward O. Wilson, 1990, "The ants", Harvard University Press. • Eric Kandell, "In Search of Memory", 2007, Norton & Co. • Richard Dawkins, "The Selfish Gene", 1976/2016, 40th Anniversary Edition, Oxford UP. • Denis Noble, "The Music of Life: Biology Beyond Genes", 2006, Oxford UP. • Nick Lane, "Oxygen", 2016, OUP Landmark Science, or "The Vital Question", 2016, Norton & Co. • Robert Sapolsky, "Why Zebras don't get Ulcers", 2004, St. Martin's Press. • Colin Tudge, "The Secret Life of Trees", 2007, Broadway Books. • Michael Tomasello "A natural history of human thinking", 2014, Harvard UP.

1.9 Nervous System

Study programme: Bachelor in Biomedical Sciences
Modules: Nervous System (PF)
Module aims: This course describes sensory receptors and the pathways and mechanisms by which sensory information is processed by the brain and the physiological foundations of behaviour. It discusses the neural coding of sensory information, processing of sensory attributes related to perception and computational models of perception. It also considers how muscle generates movement, and how those movements are controlled and coordinated by the brain and spinal cord. We introduce methods for studying the brain and principles of brain function in the context of understanding cognitive processes such as perception, attention, and memory. This module will introduce students to the autonomic nervous system. A basic understanding of the complex world of hormones will be given. All major aspects of humoral signalling will be addressed. The students will understand the regulation of hormone production and release and how hormones interact at the functional level. **Aims:** • to understand the properties of reflexes at all levels of the nervous system; • to give an overview of the functions of sensory systems, including the somaesthetic, visual, and auditory systems and associated sensations including pain; • to introduce the student to the key motor structures of the central nervous system and their roles in controlling, coordinating and planning actions; • to introduce the scientific study of mental processes; • to explain core methods in neuroscience; • to provide basic understanding of elements of human cognition such as perception, attention, and memory; • to gain basic knowledge on the autonomic nervous system • to acquire an understanding of the humoral action and network of the organism • to identify potential intervention strategies to interfere in humoral (dis)regulation **Objectives:** By the end of this lecture and practical class series you should • be able to recognize and identify a number of fundamental neuroanatomical structures and features, such as white and gray matter, spinal cord, brainstem, midbrain, cortex, cerebellum, basal ganglia, hippocampus & limbic system, meninges, blood-brain barrier, ventricles & cerebrospinal fluid. • have acquired an understanding of basic concepts in sensory neuroscience including knowledge of: o visual: optics of the eye, retina, retinotopy, centre-surround receptive fields, colour opponency, optic chiasm, lateral geniculate nucleus, optic radiation, primary visual cortex, orientation tuning, extrastriate visual areas; o auditory: function of the outer, middle and inner ear, coding in the auditory nerve, frequency tuning, auditory brainstem processing, binaural interactions, inferior colliculus and medial geniculate nucleus, auditory cortex, tonotopy;

    - somatosensory: cutaneous receptors, proprioceptive receptors, dorsal column pathway, dorsal column nuclei, anterolateral pathway, ventroposterior lateral thalamic nuclei, somatosensory cortex, somatosensory homunculus;
- be familiar with the fundamentals of some key motor pathways and structures:
    - spinal reflex arcs, motor cortex & cortico-spinal tract, motor loop through the basal ganglia, cerebellum
- begin to appreciate the biological underpinnings of cognition:
    - mechanisms of memory formation, sleep and wakefulness, emotional drive and the limbic system, compulsion and addiction
- be able to describe and explain the essentials of different experimental approaches to studying the nervous system and their strengths and limitations:
    - extracellular and intracellular recordings, electrical and pharmacological stimulation, optogenetics, lesion studies, histology, brain imaging
- understand the basic structure and function of the autonomic nervous system and its relationship to interoception
- understand the humoral hypothalamus and hypophysis stress axis
- interconnect steroid functions with metabolic and stress signalling
- explain pathologies as a result of humoral disfunctions

Lectures:

- sensory systems:
    - transduction, neuronal codes, central processing
    - visual system (eye, pathways, cortex),
    - somatosensory (peripheral receptors, cortical processing)
    - hearing (ear, subcortical processing, cortex)
    - motor systems
    - muscle spindle, peripheral pathways, animal models
- motor systems:
    - Basal Ganglia
    - Cerebellum
    - parietal cortex
    - motor cortical areas
- introduction to behaviour (psychophysics, animal behaviour)
- neural basis of cognition
- the autonomic nervous system
- interoception
- ACTH axis, stress and metabolism
- steroid hormones, synthesis and action
- thyroid hormones and metabolism
-

Teaching formats
Lecture (3 SWS), exercise (2 SWS), lab exercise (2 SWS)

Examinations
written exam 120 min (K120)

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 3
Language: English

Time investment: Face-to-face: 98h (= 7 SWS) Independent study: 202h Total: 300h (= 10 CP)
Module coordinators: Constanze Lenschow (FNW)
Recommended literature: *Principles of Neural Science.* Kandel, ER, Koester JD, Mack SH, Siegelbaum SA (6th edition, 2021) *From Neuron to Brain.* Martin AR, Brown DA, Diamond ME, Cattaneo A et al. (6th edition, 2021) Oxford University Press. *Carpenter's Neurophysiology: A Conceptual Approach* Massey D, Cunniffe N, Noorani I (6th edition 2022) *Cognitive Neuroscience: The Biology of the Mind* Gazzaniga, M, Ivry, G & Mangun, R, W. W. Norton & Co (5th edition 2018)

1.10 Immune System

Study progamme:
Bachelor in Biomedical Sciences

Modules:
Immune System (PF)

Module aims:
This course will provide basic knowledge about the players of the immune system and the host defense mechanisms against invading pathogens. Students will be taught the different types of immune cells of the innate and the adaptive arm of the immune system and will be introduced into their development, selection processes and communication capabilities. The module will provide basic knowledge about various sensing and signaling mechanisms that allow cells of the immune system to discriminate between “self” and “dangerous”. Part of this module will be also to introduce the students into main effector mechanisms of these cells during innate and adaptive immune responses and how they are regulated and terminated. This will be accomplished by an introduction into immunological standard methods used to study immune cell sensing, signaling and effector function experimentally.

Aims:
- to introduce the different types of immune cells of the innate and adaptive immune system and immune organs
- to give an overview about immune cells development, selection and communication
- to provide a basic understanding of sensing and signalling mechanisms allowing the discrimination between “self” and “danger”
    - to explain effector mechanisms of innate and adaptive immune cells such as:
    - effector mechanisms of the innate immune system: phagocytosis, oxidative burst, cytotoxicity
    - effector mechanisms of the adaptive immune system: antigen-specific cytotoxicity, effector functions of T helper cells
    - humoral mechanisms of host defence: complement system, antibody functions
- to provide insight into the regulation and termination of immune responses and inflammation

Objectives:
By the end of this module all students will

- have acquired a basic knowledge about the different types of immune cells of the innate and adaptive immunity, their development, selection and effector functions
- be able to explain the mechanisms of sensing and signalling that enable immune cells to discriminate between “self” and “danger” and their mechanisms of communication required for efficient pathogen clearance
- be familiar with different effector mechanisms of immune cells be able to describe experimental approaches that are frequently used to study immune cell sensing, signalling and effector functions

Teaching formats

Lecture (3 SWS), exercise (2 SWS), lab exercise (2 SWS)

Lectures:
- Immune cells:
    - Innate immune cells

- Adaptive immune cells
- Immune organs

- Understanding the immune system as a dynamic organ scanning interfaces to the environment:
    - Immune cell communication
    - Migration, chemotaxis, extravasation
    - Maintenance of barrier integrity
- The challenge of discriminating between “self” and “danger”:
    - Sensing and signalling mechanisms of the innate immune system
    - Sensing and signalling of the adaptive immune system
    - Antigen processing and presentation
    - Selection of antigen-specific cells and self-tolerance
- Effector mechanisms of host defence:
    - Innate effector mechanisms
    - Antigen-specific and innate mechanisms of cytotoxicity
- Regulation and Termination of immune responses and inflammation:

Lab course:
- Hands-on workshops introducing immunological methods:
    - Immune cell isolation, enrichment, and culture
    - Immune cell activation and measurements of Ca^{2+}influx
    - Western Blot
    - Flow cytometry
    - Live cell imaging / immunohistochemical or immunofluorescence staining of tissue sections

Seminars:
in groups of 20-30 students (students present and discuss lecture topics)

Examinations
written exam 120 min (K120)

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 3
Language: English

Time investment:
Face-to-face: 98h (=7 SWS)
Independent study: 202h
Total: 300h (=10 CP)

Module coordinators:
Anne Dudeck (FME), Sascha Kahlfuß (FME), Thomas Schüler (FME)

Module contributors:
Prof. A. Dudeck, Prof. S. Kahlfuß, Prof. A. Müller, Prof. A. Reinhold, Prof. D. Reinhold, Dr. Kliche, Prof. L. Simeoni, Prof. T. Schüler

Recommended literature:

Basic Immunology. Abbas, AK, Lichtman, AH, Pillai, S. (6thedition 2019) ISBN:978-0323549431
Janeway’s Immunobiology. Murphy K, Weaver C. (9thedition 2016) ISBN: 978-0815345848

1.11 Quantitative Applications

Study progamme: Bachelor in Biomedical Sciences
Modules: Quantitative Applications (PF)
Module aims: Computational assignments, supported by tutorials, with selected application examples, chosen to integrate, deepen and consolidate quantitative concepts and methods. The weekly tutorial meetings serve to introduce assignments, to offer assistance in completing assignments, and to provide a forum for students to present their results. **Application examples, 2 SWS** 1 Processes that change with time (discrete and continuous dynamics, integration, differentiation) 2 Complex dynamics (dynamical systems, phase plane) 3 Genetics (discrete stats, binomial, multinomial) 4 Quantitative genetics and statistics (normal distribution) 5 Blood glucose (distributions, whitening, signal detection) 6 Septicaemia in neonates (distributions, moments, whitening) 7 Cooperative binding (reaction kinetics, dynamical systems) 8 Ligand binding (least-squares and linear algebra) 9 Endocrinology and Hormone pulsatility (filtering, convolution, deconvolution) 10 Endocrine networks (dynamical systems in 3D) 11 Circadian rhythms (Fourier methods) 12 Circadian rhythm & microarray (Linear algebra, cluster analysis, customized least-squares) **Application example, 2 SWS** 1. Linear & nonlinear springs (Taylor approximation, potential, energy) 2. Ligand-Receptor binding using statistical mechanics and mass action 3. Monod-Wyman-Changeux Model for cooperative binding (partition function) 4. Molecular dynamics simulation of an ideal gas through forces and momentum conservation 5. Single molecule measurement techniques (force spectroscopy) 6. Coulomb's law of various charge distributions (div/grad, Gauss law) 7. Energy in DNA looping & virus configurations (shapes of virus and the nucleus) 8. Life at low Reynolds numbers (micro swimmer) 9. Simulate and compare 1d, 2d and 3d diffusion based transport 10. Rate Equations and Eigenvalues/Eigenvectors 11. Kinesin as a motor protein (dynamics, energy balance) 12. Action potential and cable equation (model and solutions) **Objectives:** By the end of this module all students will • A quantitative understanding and competency in applying the above concepts and operations to biological problems
Teaching formats **Lectures:** 24 x 1 h (always 1h lecture paired with 1h Lab course)

Lab course: in the form of practicals/seminar/tutorials:
24 x 1 h Students work through selected application examples

Examinations
written exam 90 min (K90)

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 3
Language: English

Time investment:
Face-to-face: 56 h (= 4 SWS)
Independent study: 244 h
Total: 300h (= 10 CP)

Module coordinators:
W2 Neuronal Computation (FNW), Claus-Dieter Ohl (FNW)

Recommended literature:

Biophysics

- Philipps, Konder, Theriot, Garcia (2012) Physical Biology of the Cell, Taylor & Francis, 2nd Ed.
- Philip Nelson (2015) Biological Physics, Updated Version, W. H. Freeman

Mathematics

- Aitken, Broadhurst, Hladky (2012) Mathematics for Biological Scientists, Garland Science
- Holmes, Huber (2019) Modern Statistics for Modern Biology, Cambridge UP
- Robeva, Kirkwood, Davies, Farhy, Johnson, Kovatchev, Straume (2008) An Invitation to Biomathematics, Academic Press
- Riley, Hobson (2011) Essential Mathematical Methods for the Physical Sciences, Cambridge UP

Programming

- Jesse M. Kinder, Philip Nelson (2018) A Student's Guide to Python for Physical Modeling: Updated Edition, Princeton University Press Revised ed. edition (January 30, 2018).

1.12 Scientific English + Skills III

Study programme: Bachelor in Biomedical Sciences
Modules: Scientific English + Skills III (PF)
Module aims: This module will introduce students to structure, write and conduct scientific presentations in English and engage in scientific discourse. Using examples from the course, students will be composing and presenting their own scientific presentations. A second pillar of this module is aimed to develop the skill set to read scientific literature effectively and engage in scientific discourse in the form of a book club. The latter part can be undertaken in English or German
Content and learning outcomes: **Scientific Writing III** **Aims:** to teach the fundamentals of scientific presentations • structure a scientific presentation • write a scientific presentation • present a scientific talk **Objectives:** By the end of this lecture series students should be able to: • understand the structure of different scientific presentations • put together and give a scientific presentation • engage in structured scientific arguments **Book club: Behaviour/Verhalten** **Aims**: Weekly discussion of key themes and books across life sciences and humanities **Objectives**: • engage in scientific discourse
Teaching formats Seminar (exercise) (3 SWS) Scientific Writing III – seminar in English: scientific presentations in English Behaviour/Verhalten- Weekly discussion of key themes and books across life sciences and humanities (English or German)
Examinations Extended essay (homework) (HA) + Presentation (R)
Semesters offered: every summer semester **Duration:** 1 semester **Recommended semester:** 3 **Language**: English (part in German, optional)

Time investment:
Face-to-face: 42h (= 3 SWS)
Independent study: 108h
Total: 150h (=5 CP)

Module coordinators:
Constanze Lenschow (FNW)

Recommended literature (suggestions, will vary based on student selection):

Erwin Schrödinger, "What is Life?", 1967/2012, Canto Classics.
James Watson, "The Double Helix", 1965/2001, Touchstone Reprint.
Ernst Mayr "What Evolution Is: From Theory to Fact", 2002, Science Masters.
Jacques Monod "Chance and Necessity", 1997, Penguin Science Press.
Charles Darwin, "The Origin of Species", 1853/2003, 150th Anniversary Edition, Signet.
Kathleen Donohue, ed., "Darwin's finches: Readings in the Evolution of a Scientific Paradigm", 2011, U Chicago Press.
Stephen Jay Gould, "The Richness of Life", 2007, Vintage.
P Anderson "More is Different", Science, 1972
Edward O. Wilson, 1990, "The ants", Harvard University Press.
Eric Kandell, "In Search of Memory", 2007, Norton & Co.
Richard Dawkins, "The Selfish Gene", 1976/2016, 40th Anniversary Edition, Oxford UP.
Denis Noble, "The Music of Life: Biology Beyond Genes", 2006, Oxford UP.
Nick Lane, "Oxygen", 2016, OUP Landmark Science, or "The Vital Question", 2016, Norton & Co.
Robert Sapolsky, "Why Zebras don't get Ulcers", 2004, St. Martin's Press.
Colin Tudge, "The Secret Life of Trees", 2007, Broadway Books.
Michael Tomasello "A natural history of human thinking", 2014, Harvard UP.]

2. Compulsory choice modules (WPF)
2.1 Neuroscience

Study programme:
Bachelor in Biomedical Sciences

Modules:
Neuroscience (WPF)

Module aims:

In the fourth semester, students can choose two of three specialist options. The aim of this module is to get a more in depth understanding of advanced topics and current research in neuroscience. Teaching will be delivered in a combination of:

- Lectures/Seminars for all students taking the option (15-20 students per lecture/seminar)
- Tutorials out of a choice of 25 topics. Students will receive a reading list and prepare an essay for the tutorial (5 students per tutorial)
- Students will write an extended essay (homework / “Hausarbeit”) in a research topic of their choice. They will receive 3 Tutorial hours with a specialist in the field to (i) discuss the topic, (ii) discuss the literature included, (iii) discuss questions arising.
- Practical classes will include “lab visits”, each student can choose 3 research groups from a list, which will organise one-day “lab visits”, where they get an insight into current research and methods on campus. Students prepare a short presentation (10 min + 5 min questions) on one of the lab visits, which will be presented at the end of the semester for all students and lab hosts in this specialisation.

Aims:

- Functional Neuroanatomy
  - Microscale: Neurons and glia - structure to function
  - Mesoscale: Local brain circuits: tracing and functional interactions
  - Macroscale: Imaging the connectome
- Cognitive & Behavioral Neuroscience
  - Perception
  - Learning
  - Memory
- Pathobiology and pathophysiology of the nervous system
  - Dementia
  - Psychiatric disorders (Schizophrenia, Bipolar, Depression)
  - Developmental disorders (Autism, ADHD)
- Neuroscience methods (P)
  - Neurophysiological recordings
  - MR imaging
  - Computational modelling

Objectives:
By the end of this lecture series students will

- have a deep understanding on the functional anatomy of the mammalian nervous system
- will have a good grasp of fundamental research in central areas of cognitive and behavioural neuroscience
- understand the symptoms and neuropathology of a range of psychiatric and developmental disorders

- be able to describe and critically discuss the advantages and disadvantages on key neuroscience methods

Teaching formats

Lecture (4 SWS), seminar (exercise) (2 SWS), practical (1 SWS), lab courses (lab exercise) (2 SWS)

Examinations
Written exam 120 min (K120)

Semesters offered: every summer semester
Duration: 1 semester
Recommended semester: 4
Language: English

Time investment:
Face-to-face: 126h (= 9 SWS)
Independent study: 324h
Total: 450h (= 15 CP)

Module coordinators:
Kristine Krug (FNW), Jörg Bock (FNW), N.N.

Module contributors:
Anne Maas (FNW)

Recommended literature:
Cognitive Neuroscience: The Biology of the Mind Gazzaniga, M, Ivry, G & Mangun, R, W. W. Norton & Co (5th edition 2018)

Review articles and selected original research articles.

2.2 Immunology

Study programme:
Bachelor in Biomedical Sciences

Modules:
Immunology (WPF)

Module aims:

The specialization course Immunology will provide the students with more complex information about the molecular sensing and signalling mechanisms of innate and adaptive immune cells. A special focus of the first part of this module will be to deepen the understanding of innate and adaptive effector mechanisms in immune responses against bacteria, viruses or parasites. In the second part of this module special emphasize will be on immune cell selection and different mechanisms of self-tolerance. As the dysregulation of these processes provide the basis for most of the immune related diseases including autoimmune diseases, immunodeficiencies and hyperreactivities, students will now be able to translate and apply their knowledge about basic principles of the immune system to understand complex immune-pathologies. All lectures in this module will be accompanied by seminars and interactive POL (problem-oriented learning) courses, in which the students will learn the patho-mechanisms of infectious diseases, autoimmune diseases, hyperreactivities and immunodeficiencies by means of exemplary clinical cases. This will be accomplished by lab visits, in which the students will use their knowledge about immunological standard methods acquired in the first module to now take part in and experience lab routine of different labs and how they address specific scientific questions.

Aims:
- to provide detailed knowledge about sensing and signalling processes
- to explain mechanisms of host defence against infection by bacteria, viruses or parasites
- to provide understanding of immune dysregulation resulting in immune related diseases, including autoimmune disease, immunodeficiencies and hyperreactivities
- to give insights into the complexity of immune responses and patho-mechanisms based on exemplary clinical cases
- to give an overview about clinical intervention strategies

Objectives:
By the end of this lecture series students will

- have acquired a more detailed understanding of innate and adaptive sensing strategies and signalling pathways
- be familiar with different effector mechanisms of host defence against
    - bacteria
    - viruses
    - parasites
- be able to explain the selection process of antigen-specific cells and various mechanisms of self-tolerance
- have a basic understanding about the dysregulation of immune responses and immune-related disorders, including autoimmune diseases, immunodeficiencies and hyperreactivity responses
- be able to describe some strategies of clinical immunology to intervene or enhance immune responses

Teaching formats Lecture (4 SWS), seminar (exercise) (2 SWS), practical (1 SWS), lab courses (lab exercise) (2 SWS)
Examinations written exam 120 min (K120)
Semesters offered: every summer semester **Duration:** 1 semester **Recommended semester:** 4 **Language**: English
Time investment: Face-to-face: 126h (= 9 SWS) Independent study: 324h Total: 450h (=15 CP)
Module coordinators: Thomas Schüler (FME), Sascha Kahlfuß (FME), Anne Dudeck (FME) **Module contributors:** Prof. A. Dudeck, Prof. S. Kahlfuß, Prof. A. Müller, Prof. A. Reinhold, Prof. D. Reinhold, Dr. Kliche, Prof. L. Simeoni, Prof. T. Schüler
Recommended literature: Review articles and selected original research articles.

2.3 Molecular & Cellular Functions

Study programme:
Bachelor in Biomedical Sciences

Modules:
Molecular & Cellular Functions (WPF)

Module aims:
The specialization course Molecular and Cellular Functions offers students the opportunity to gain a deep insight into cellular functions using the example of apoptosis and cellular signal transduction. In addition to the underlying molecular mechanisms, a focus is placed on regulatory aspects. In this context, fundamental principles of systems biology approaches are presented.

Content and learning outcomes:

Signal transduction and Systems Biology
Aims:

- to introduce the molecular mechanisms of signal transduction
- to provide an overview on basic mechanisms and components of signal transduction
- to elaborate basic regulatory principles of signal transduction
- to present the concept of signal modules
- to provide a detailed insight into special signal transduction pathways
- to present biochemical methods for analysing signal transduction cascades
- to introduce an overview of the research field of systems biology
- to discuss basic concepts of systems biology
- to analysis network motifs
- to present regulation and control mechanisms in cellular systems and organisms
- to elaborate structure and dynamics of network motifs
- to quantify cellular signalling events

Objectives:
By the end of this lecture series:

- students know the basic molecular mechanisms of signal transduction in eukaryotes and can recognize signal modules.
- they are familiar with the principles of the regulation of signalling cascades.
- students are able to familiarize themselves with new issues in the field of systems biology and apply possible solutions.
- students will be familiar with control loop structures and network motifs of signal transmission pathways in biological systems as well as their representation and will be able to read the dynamics of signal processing from simple network structures.
- students will have the competence to quantify cellular signalling events.
- students will understand the importance of interdisciplinary research in the field of life sciences.

Systems pharmacology and programmed cell death
Aims:

- to introduce the three main types of programmed cell death (PCD): apoptosis, regulated necrosis and autophagy
- to explain the molecular mechanisms of apoptosis
- to introduce recently discovered types of PCD: ferroptosis, necroptosis and others

- to present biochemical methods for analysing signal transduction cascades in PCD
- to discuss the role of PCD regulation in the pathology of cancer, neurodegeneration, autoimmune diseases and metabolic syndromes
- to outline pharmacological targeting of apoptotic and non-apoptotic cell death pathways
- to present mathematical modelling of apoptosis
- to discuss how mathematical modelling can explain life and death decisions in the cell and support the development of new therapeutic approaches

Objectives:
At the end of the lecture series students

- will have basic knowledge of modern concepts of cell death;
- will be able to distinguish between different modes of cell death at the molecular and cellular level
- will have a basic understanding of pharmacological targeting
- will have a background in the systems biology of apoptosis

Regulatory Biology

Aims:

Regulatory networks and cellular sensors control and regulate practically all life processes in different ways. After attending the lecture, students will know which types of molecular networks of cellular signal processing and regulation are known, how they are constructed, according to which functional principles they work and how complex networks are investigated conceptually and experimentally.

Objectives:
At the end of the lecture series students will know about

- the importance of regulatory networks in microorganisms, plants and animals
- basic operations of biological regulation: reception, amplification, integration, adaptation, feedback, switching, logical links using the example of chemotaxis in Escherichia coli
- methods for the experimental analysis of the structure and dynamics of cellular signal processing networks
- light-regulated signal chains and basics of photo-biochemistry
- dynamics of cellular signal processing using the example of Halobacterium phototaxis; stochastic phenomena as the cause of individual behaviour
- fundamentals of signal transduction, membrane receptors, adapter proteins
- molecular mechanisms of carcinogenesis and metastasis
- from gene to function: experimental methods
- Petri nets: Modelling and simulation of cellular signalling processes; reverse engineering
- the mechanisms of cellular reprogramming of mammalian cells
- the regulation of the cell cycle
- sporulation of Physarum polycephalum as a genetic model system of cell differentiation and cellular reprogramming

Teaching formats
Lecture (4 SWS), exercise (2 SWS), practical course (1 SWS), lab courses (lab exercise) (2 SWS)

Examinations
written exam 120 min (K120)

Semesters offered: every summer semester
Duration: 1 semester
Recommended semester: 4
Language: English

Time investment:
Face-to-face: 126h (= 9 SWS)
Independent study: 324h
Total: 450h (= 15 CP)

Module coordinators:
Fred Schaper (FNW), Inna Lavrik (FME), Wolfgang Marwan (FNW)

Recommended literature:

1] Biochemistry of Signal Transduction and Regulation, G. Krauss, 5th ed., Wiley-VCH ISBN 978-3-527-33366-0
[2] Signal Transduction, I.M. Kramer, 3nd ed., Academic Press, ISBN 978-0123948038
[3] Cellular Signal Processing, F. Marks, U. Klingmüller, K. Müller-Decker, Garland Science, ISBN 978-0-8153-4215-1
[4] An Introduction to Systems Biology, U. Alon, 2nd ed., Chapman & Hall/CRC, ISBN 978-1-4398-3717-7

3.0 Internship semester

Study programme:
Bachelor in Biomedical Sciences

Module:
Internship semester / semester abroad (PF)

Module aims:

LAB ROTATION (1 + 2) OR SEMESTER ABROAD

Aims:
The students will be introduced to the research in a laboratory. They will be introduced to new techniques and work on a short project, which they will write up in a lab report.

Objectives:
By the end of this lecture series students will have detailed understanding of:

- Cutting edge lab techniques
- The research process in a research group
- Structuring a short research project
- Conducting experiments
- Writing up a short research project

Alternatively, the student can take a semester abroad, either for research experience or carrying out course work. These arrangements have to be pre-approved by the examination committee for accreditation.

Teaching formats

Seminar (exercise) (3 SWS), practical (3 SWS), lab courses (lab exercise) (6 SWS)
For each of two lab rotations.

Examinations
Lab rotation report (experimental work)
For each of two lab rotations.

Semesters offered: every winter semester
Duration: 1 semester
Recommended semester: 5
Language: English

Time investment:
Face-to-face: 168 h (= 12 SWS)
Independent study: 282h
Total: 450h (=15 CP)
For each of two lab rotations.

Module coordinators:
N.N.

Recommended literature:

4.0 Bachelor degree programme Biomedical Sciences, Expansion compulsory choice modules
4.1 Data Science

Study programme: Bachelor in Biomedical Sciences
Modules: Data Science (WPF)
Module aims: The students will be taught principles about how to curate and analyse research data. This course would introduce the students to the key scientific libraries and packages that exist for data analysis in Python, e.g. Numpy, SciPy, Pandas etc. Moreover, this course would also be designed to teach state-of-the-art computational frameworks and tools that are widely used in field of scientific computing, e.g. Jupyter notebooks, GitHub etc. As machine learning approaches are transforming almost all sectors, including programming. Artificial intelligence (AI) based coding assistants like ChatGPT have become powerful tools to generating programming code in an efficient manner, thereby saving time for implementing ideas into algorithms. Teaching students how to use these AI based tools for writing code and data analysis could be an interesting component of this course. **Objectives**: By the end of this lecture series students will have detailed understanding of: • Data storage and curation • Key scientific libraries and data analysis tools • Basics of Machine learning approaches • Using AI-based coding assistants efficiently and correctly
Teaching formats Lecture (1 SWS), seminar (exercise) (2 SWS)
Examinations Extended essay (homework) (HA) (Pass / Fail)
Semesters offered: every summer semester **Duration:** 1 semester **Recommended semester:** 6 **Language**: English
Time investment: Face-to-face: 42 h (= 3 SWS) Independent study: 108h Total: 150h (= 5 CP) For each of two lab rotations.
Module coordinators: W2 (Neuronal Computation) (FNW)
Recommended literature:

4.1 Scientific Ethics

Study programme: Bachelor in Biomedical Sciences
Modules: Scientific Ethics (WPF)
Module aims: General aspects of integrity in research conduct will be discussed. The students will also learn about the ethics of conducting animal and human research. What approaches are used to evaluate cost and benefits of research. There will be an introduction into how to write an application for ethics approval related to the students' own bachelor research project or a chosen example. **Objectives**: By the end of this lecture series, students will have detailed understanding of: • Principles of ethics and integrity when conducting research • Key ethical aspects of research with animals and humans • The basic processes of seeking ethical approval for a research project in Germany
Teaching formats Lecture (1 SWS), seminar (exercise) (2 SWS)
Examinations Extended essay (homework) (HA) (Pass / Fail)
Semesters offered: every summer semester **Duration:** 1 semester **Recommended semester:** 6 **Language**: English
Time investment: Face-to-face: 42 h (= 3 SWS) Independent study: 108h Total: 150h (= 5 CP)
Module coordinators: Kristine Krug (FNW) **Module contributors:** Guest speakers will be invited for individual seminars.
Recommended literature:

4.3 Communicating Science

Study programme: Bachelor in Biomedical Sciences	

Study programme:
Bachelor in Biomedical Sciences

Module:
Communicating Science (WPF)

Module aims:

The students will be learning about communicating science to lay audiences. They will learn how to:

- write a lay summary of their research project
- write a press release of their research project
- give a 3-minute elevator pitch on their research project to a non-scientist
- plan and record a short podcast or a short video on a science topic of their choice for a general audience OR prepare a presentation/experiment for the "Lange Nacht der Wissenschaft"
- plan and prepare a short talk to a scientific audience about their research project

Objectives:
By the end of this lecture series students will have detailed understanding of:

- how to assess their audience's needs when communicating sciences
- different approaches to communication science to non-specialists
- how to prepare a scientific presentation about their own research

Teaching formats

Lecture (1 SWS), seminar (exercise) (2 SWS)

Examinations
Extended essay (homework) (HA) (Pass / Fail)

Semesters offered: every summer semester
Duration: 1 semester
Recommended semester: 6
Language: English

Time investment:
Face-to-face: 42 h (= 3 SWS)
Independent study: 108h
Total: 150h (= 5 CP)
For each of two lab rotations.

Module coordinators:
New W2 Development (FNW)

Recommended literature:

4.4 Journal Club 1 + 2

Study programme: Bachelor in Biomedical Sciences
Module: Journal club (WPF)
Module aims: The students will be learning how assess and discuss original research papers. There will be usually two Journal club modules offered, which cover different areas of biomedical science, e.g. Neuroscience, Cell Biology, Immunology etc. It is recommended, that one should be in the wider area of the student's bachelor thesis. **Objectives**: By the end of this lecture series students will have detailed understanding of: • where to find and how to extract relevant information from research papers • how to critically assess original research papers • how to present key information from research papers to support a scientific argument.
Teaching formats Lecture (1 SWS), seminar (exercise) (2 SWS)
Examinations Extended essay (homework) (HA) (Pass / Fail)
Semesters offered: every summer semester **Duration:** 1 semester **Recommended semester:** 6 **Language**: English
Time investment: Face-to-face: 42 h (= 3 SWS) Independent study: 108h Total: 150h (= 5 CP) For each of two lab rotations.
Module coordinators: Constanze Lenschow (FNW)
Recommended literature:

Appendix to Module Handbook (Anhang zum Modulhandbuch)

	Compulsory modules (Pflichtfächer)	CP						Teaching format (Lehrformat)				Examination schedule (Prüfungsplan)		
	Modules (Module)	***WiSe*** 1. Sem.	***SuSe*** 2. Sem.	***WiSe*** 3. Sem.	***SuSe*** 4. Sem.	***WiSe*** 5. Sem.	***SuSe*** 6. Sem.	***VL***	***Ü***	***P***	***LÜ***	***CP***	***LN***	***PL***
1. Sem.	**Molecular Cell Biology**	10						3 SWS	2 SWS		2 SWS	10	x	K120#
	Genes and Genetics	10						3 SWS	2 SWS		2 SWS	10	x	K120#
	Quantitative Foundations	5						2 SWS	1 SWS		1 SWS	5	x	K90#
	Scientific English + Skills 1	5							3 SWS			5		HA#
2. Sem.	**Cell Physiology**		10					3 SWS	2 SWS		2 SWS	10	x	K120
	Development + Evolution		10					3 SWS	2 SWS		2 SWS	10	x	K120
	Quantitative Extensions		5					2 SWS	1 SWS		1 SWS	5	x	K90
	Scientific English + Skills 2		5						3 SWS			5		HA+R
3. Sem.	**Nervous System**			10				3 SWS	2 SWS		2 SWS	10	x	K120
	Immune System			10				3 SWS	2 SWS		2 SWS	10	x	K120
	Quantitative Applications			5				2 SWS	1 SWS		1 SWS	5	x	K90
	Scientific English + Skills 3			5					3 SWS			5		HA+R
4. Sem.	**1. compulsory choice module* (Wahlpflichtfach*)**				15			4 SWS	2 SWS	1 SWS	2 SWS	15	x	K120
	2. compulsory choice module* (Wahlpflichtfach*)				15			4 SWS	2 SWS	1 SWS	2 SWS	15	x	K120
5. Sem.	**1. Lab rotation (Laborrotation)** — **or semester abroad (alternativ: Auslands-semester)**					15			3 SWS	3 SWS	6 SWS	15		EX
	2. Lab rotation (Laborrotation)					15			3 SWS	3 SWS	6 SWS	15		EX
6. Sem.	**3 x Expansion WPFs***						15					15		
	Bachelor Thesis **Kolloquium**						12 3					15		EX/M
	Sum CP:	**30**	**30**	**30**	**30**	**30**	**30**					**180**		

*Compulsory choice modules must be selected from the module handbook (*Wahlpflichtfächer sind aus dem jeweils gültigen Modulhandbuch auszuwählen)

Appendix to Module Handbook (Anhang zum Modulhandbuch)

	Compulsosry choice modules (Wahlpflichtfächer)	CP						Teaching format (Lehrformat)				Examination schedule (Prüfungsplan)		
	Modules (Module)	***WiSe*** 1. Sem.	***SuSe*** 2. Sem.	***WiSe*** 3. Sem.	***SuSe*** 4. Sem.	***WiSe*** 5. Sem.	***SuSe*** 6. Sem.	***VL***	***Ü***	***P***	***LÜ***	***CP***	***LN***	***PL***
Angebot 4. Sem.	**Neuroscience**				15			4 SWS	2 SWS	1 SWS	2 SWS	15	x	K120
	Immunology				15			4 SWS	2 SWS	1 SWS	2 SWS	15	x	K120
	Molecular & Cellular Functions				15			4 SWS	2 SWS	1 SWS	2 SWS	15	x	K120

	Expansion Compulsory choice modules (Expansion Wahlpflichtfächer)	CP		Teaching format (Lehrformat)				Examination schedule (Prüfungsplan)		
	Module	***WiSe***	***SuSe***	***VL***	***Ü***	***P***	***LÜ***	***CP***	***LN***	***PL***
Angebot 6. Semester	**Data Science**		5	1 SWS	2 SWS			5		HA#
	Soft Skills / Sidetracks		5	1 SWS	2 SWS			5		R/HA/K#
	Scientific Ethics		5	1 SWS	2 SWS			5		HA#
	Communicating Science		5	1 SWS	2 SWS			5		R#
	Journal Club 1		5		3 SWS			5		R#
	Journal Club 2		5		3 SWS			5		R#

Legend and Glossary:

CP	Credit Points (Kreditpunkte)	M	oral exam (mündliche Prüfung)	Ü	exercise (Übung)
EX	experimental work (experimentelle Arbeit)	P	practical (Praktikum)	VL	lecture (Vorlesung)
HA	extended essay (homework) (Hausarbeit)	PL	examination (Prüfungsleistung)	WiSe	winter semester (Wintersemester)
K	written exam (Klausur)	R	presentation (Referat)	WPF	compulsory choice module (Wahlpflichtfach)
LN	prerequiste for exam (Prüfungsvorleistung)	SuSe	summer semester (Sommersemester)	x	mandatory (erforderlich)
LÜ	lab exercise (Laborübung)	SWS	semester hours per week (Semesterwochenstunden)	#	pass/fail (bestanden/nicht bestanden)