M4457

Optogenetic cell control, Advanced Microscopy & Quantitative Imaging

Optogenetische Zellkontrolle, forgeschrittene Mikroskopie und quantitative Bildanalyse

Coordinator (responsible lecturer)
Prof. Dr. Matias Zurbriggen (matias.zurbriggen@uni-duesseldorf.de)

Lecturers
Prof. Dr. Matias Zurbriggen, Jun.-Prof. Dr. Mathias Beller, Dr. Stefanie Weidtkamp-Peters

Module organization
Prof. Dr. Matias Zurbriggen (matias.zurbriggen@uni-duesseldorf.de), Jun.-Prof. Dr. Mathias Beller (matias.beller@hhu.de, Dr. Stefanie Weidtkamp-Peters (stefanie.weidtkamp-peters@hhu.de)

Work load	Credit points	Contact time	Self-study	Duration
420 h	14 CP	300 h	120	1 semester

Course components	Frequency	Group size
Practical Course: 18 SWS Lectures: 3 SWS	Each summer semester	12 students

Learning outcomes/skills
Optogenetics: The students are able to describe and apply the fundamental concepts and strategies of optogenetics in prokaryotic and eukaryotic biological systems. They can implement these approaches for the understanding and control of cellular processes.
The students can design optogenetic molecular switches and implement them in mammalian cell culture and plant cells. The students are able to work precisely and without supervision with measuring equipment, laboratory instruments and process quantitative information with the appropriate software.

Microscopy: The students will be able to independently perform advanced fluorescence microscopic techniques from sample preparation to data analyses in order to solve relevant biological questions. Using molecular biology techniques, the students can independently prepare samples that they analyze afterwards and evaluate in detail using advanced techniques like confocal and super-resolution microscopy. The students get to know the theoretical basis of fluorescence and its describing parameters. They can explain and compare the pros and cons of the different fluorescent techniques, e.g. the super-resolution techniques SIM (Structured Illumination Microscopy) and STED (stimulated emission depletion) microscopy. The students will be able to apply these techniques to solve different relevant biological questions and analyze and judge the results of their experiments.

Quantitative Imaging: The students will be able to independently perform experiments in multiwell plates to analyse the quantitative impact of small molecule treatments and RNA interference gene knock-down on cellular phenotypes. The cell samples will be imaged using automated fluorescence microscopy. Subsequently, the CellProfiler software will be used to identify and quantify cellular parameters via image segmentation and object recognition. Numeric data will be subsequently processed with different strategies involving the Python programming language or integrated, graphical analysis platforms (KINME).

Forms of teaching
Lectures with exercises (including wet-lab bench work), and seminar/presentation

Contents

Lectures:

Optogenetics: Molecular mechanisms and principles of optogenetics. Photobiology. Classical optogenetics: opsins and neurobiology. Second optogenetics wave: light control over intra- and extracellular processes. Design of synthetic molecular optoswitches Biomedical applications of optogenetics: understand, prevent and treat diseases. Opotgenetics in fundamental research: quantitative understanding and control of signaling processes. Readout systems and mathematical modelling.

Microscopy: In the lectures the basics of light and fluorescence microscopy and their application in relevant biological questions are taught. This includes the chemical and physical fundamentals of fluorescence, the properties of fluorescence and how these are determined. Additionally, the setup of fluorescence microscopes and the different fluorescence microscopy techniques are discussed. The students will get to know different techniques which employ fluorescence reporters in order to characterize the behaviour of proteins and biomolecules in living and fixed cells. Due to the content of the lectures, the students are supposed to understand and apply the theoretical fundamentals of these techniques to planning and performing of experiments during the practical part of the course.

Quantitative Imaging: In the lectures, the students will be introduced to the principles of phenotypic screening, quantitative image analysis and image segmentation. Further, basic knowledge in the statistical analysis of large-scale biological data will be taught. The lecture is supposed to provide the foundation allowing the students to understand and perform the planning of the experiments, analyse the imaging data and present their results with appropriate data visualizations.

Exercises and practical course:

Optogenetics: Understand and control cellular processes. Application of optogenetics in mammalian cells. Engineering of optogenetic molecular tools. Readout systems to monitor cellular processes. Mathematical modelling and characterisation of activity of molecular optoswitches. Generation and analysis of quantitative datasets.

Microscopy: The students will learn how to use a confocal laser scanning microscope (CLSM), a super-resolution microscope (SIM, STED), and an automated microscopy system in order to independently record images and z-stacks of fixed and live cells. The students will analyse the acquired data using the appropriate software. Imaging data shall be prepared in a way that conclusions about the cellular diversification in a population of cells and concerning the protein localization in different cell types can be drawn; live cell experiment data shall allow conclusions about e.g. interaction and mobility of proteins.

Quantitative Imaging: The students will learn how to operate an automated screening microscope system and perform experiments in a high-throughput format. Using RNA interference and/or small molecules in combination with Drosophila tissue culture cells, cellular function will be disturbed and the resulting phenotypes recorded by automated microscopy. Automated image analysis will be used to quantify these phenotypic read-outs, and different software will be used to analyse and visualize the data.

Requirements for admission

Accepted to the master programs in Biology, Biochemistry

Type of examination

1) Skill area knowledge (70% of the grade): written or oral examination on the content of the

lecture and the practical course (2) Skill area documentation (15% of the grade): protocol (presentation of subject, execution, evaluation and discussions of scientific experiments) (3) Skill area scientific presentation (15% of the grade): preparation, presentation and discussion of a subject related publication/seminar. Writing of a one-page summary
Requisites for the allocation of credit (1) Regular attendance and active participation in the classes and the practical course. Submission of a protocol complying with the requirements of scientific documentation (2) Pass of exam (3) Oral presentation in a seminar with an accompanying handout. (4) The final grade is calculated from the mark of the written exam (70% of final grade) and the description of the analyses, performance of experiments and the scientific presentation (30% of the grade).
Relevant for following study programmes/major (only MSc programme) M.Sc. Biology M.Sc. Biology international; M.Sc. Biochemistry Major (only M.Sc. biology)
Compatibility with other curricula M.Sc. biochemistry
Significance of the mark for the overall grade The mark given will contribute to the final grade in proper relation to its credits. M.Sc. biology 14/72 CP M.Sc. biology international 14/54 CP
Course language English. Examination in English; German on demand
Additional informationen Registration: Central registration office (PD Dr. Schumann) or per e-mail to matias.zurbriggen@uni-duesseldorf.de