TECHNISCHE UNIVERSITÄT DRESDEN

MSc Physics of Life CMCB

CMCB / Center for Molecular and Cellular Bioengineering

CATALOG OF ELECTIVES– WINTER TERM 2025/2026

One Specialization to be chosen; within the chosen specialization 4 SWS to be completed

Specialization Experimental Biological Physics / Module Advanced Biophysics

Bioenergetics of Self-Organization, Prof. Xingbo Yang

Course work: 2 SWS lecture, 2 SWS seminar, Thursdays 09:20-10:50 & 11:10-12:40

Content:

- The students will learn the basics of cell metabolism and cytoskeleton self-organization
- We will discuss cutting edge techniques to measure cell metabolism in living cells with high spatiotemporal resolution
- We will review novel techniques to model cell metabolism, cytoskeleton and their crosstalk with coarse-grained biophysical models
- In addition, we will discuss research level questions of measuring the energy budget of a cell and explore the impact of spatiotemporal metabolic variations in developmental processes

Requirements: knowledge of calculus and basic programming skills

Number of participants: up to 30 people, minimum 5 students

Biomedical Laser Systems and Optogenetics Prof. Jürgen Czarske, Dr. Robert Kuschmierz

Course work: 2 SWS lecture, Wednesdays 09:20-10:50

Content: Biomedical systems engineering is a multidisciplinary field of engineering and has a direct impact on human well-being. The aim of the lecture Biomedical Laser Systems and Optogenetics is to discuss laser-optical methods and systems for the early detection, diagnosis, therapy and rehabilitation of diseases.

Optogenetics is a combination of methods of optics and genetics. It deals with real-time how holographic laser techniques can be used to control genetically modified cells. Adaptive microscopy using deep neural networks enable 3D imaging into deep tissue layers. Furthermore, of the brain, Brillouin microscopy for contactless sensing with light for cancer diagnosis and needle-thin lensless fiber endoscopes for diagnostics and therapy gentle examinations and stimulations are covered in the lecture.

Requirements: Basic knowledge in optics and photonics is required. Knowledge in sensors, photonic systems and signal processing advised.

Computational Cell Biology – Dr. Ingmar Glauche

Course work: 2 SWS lecture, 2 SWS exercise, Fridays 09:20-10:50 & 11:10-12:40

Content: The course introduces basic modeling techniques relevant to study different phenomena in cell biology, particularly focusing on the mathematics of gene regulation, molecular switches and biological oscillators. The courses approaches many questions from a phenomenological, less theoretical perspective and also aims to advance the student's skills in interdisciplinary communication. The seminar part is designed as an instrument that requires active participation encompassing reading, practicing and presenting.

Digital holography and Image processing - Prof. Jürgen Czarske, Dr. Nektarios Koukourakis

Course work: 1 SWS lecture & 1 SWS exercise, Mondays 11:10-12:40

Content: Computer-aided digital imaging processing (computational imaging) combines elements of classical optics, physics, image processing, mathematics and computer science. The overarching goal in this current research field is to address limitations such as to break the diffraction limitation or to develop new 3D measurement methods. In this lecture, various computer-aided imaging methods are explained using application examples and the essential fundamentals of optics and signal processing are discussed, which are important for understanding the methods.

The following topics will be dealt with: Basics of optics , Basics of holography (analog holography) , Digital holography (off-axis, in-line), Phase Retrieval (Gerchberg Saxton, Transport of Intensity…), Light Field Techniques, Ptychography, Synthetic/coded aperture process, Diffuse tomography, Compressive sensing

Functional Biological Materials - Dr. Yael Politi, Dr. Luca Bertinetti, Dr. Nils Kröger, Dr. Nicole Poulsen,

Course work: 2 SWS lecture, 2 SWS seminar – Mondays 14:00-15:30 (S) & Tuesdays 08:30-10:30 (L); optional: 6 SWS practical

Content: The module will deal with the physical properties, biochemical compositions, biogenesis and assembly of functional biological materials, such as silks, chitin-based materials, wood bone, sea shells and more. mineralized and non-mineralized biological materials and bio-adhesives. Basic physicochemical theories of crystallization, self-assembly and adhesion will be discussed, as well as characterization methods such as x-ray diffraction, vibrational spectroscopy, electron microscopy. The course will establish correlation between hierarchical structure – materials properties and function of biological materials and bio adhesive agents and the mechanisms of their biogenesis.

Requirements: Basic Biology and Biochemistry

Number of participants: minimum 6 students, maximum 20 students

Genomes and Evolution – Prof. Henrik Bringmann

Course work: 3 SWS lecture, Thursdays 10:15-12:30

Content: The students are able to understand the nature of the genome, its architecture, characteristics and variability on a new, integrative level. They are in the position to draw conclusions about the architecture of the genome, its content, as well as the mechanisms of change in evolution.

They understand genome maintenance based on the molecular mechanisms of DNA replication and repair, together with analysis of the molecular mechanisms of recombination that maintains and alters both genomes.

They are in the position to comprehend both prokaryotic and eukaryotic chromatin and master the basics about epigenetic regulation and RNAi. In addition, they have basic knowledge in genetic engineering.

The students have a profound comprehension of the genome and genome engineering, which complements the studies of tissue engineering, bioinformatics and cellular machines. They have an overview of the techniques used in the different fields in genomics.

Requirements: Basic knowledge of molecular and cellular biology and biochemistry

Introduction to Proteomics – Prof. Simon Alberti

Course work: 3 SWS lecture, Thursdays 13:00-15:15

Content: The students have a profound comprehension of protein biochemistry and molecular cell biology. This includes the structure, function and synthesis of proteins, protein complexes, protein assemblies, and the proteome. In addition, basic knowledge of enzymology, metabolism, gene expression and cellular organization is acquired.

The students have an excellent basic knowledge of proteins and their functional roles in cells and tissues. They have an overview of the techniques used in the different fields and can study and comprehend current topics of the scientific literature. The students acquire skills in carrying out lab work in the fields of protein biochemistry and the study of protein function.

Requirements: Basic knowledge of chemistry, physics and mathematics on the high school level. Knowledge of biochemistry and cell biology on the bachelor level.

Literature: Molecular biology of the Cell (Bruce Alberts); Molecular Cell Biology (Darnell)

Molecular Motors – Prof. Stefan Diez

Course work: 2 SWS lecture, 2 SWS seminar, Tuesdays 11:10-14:30

Content: The students will learn about the design principles, the functioning and the application of molecular cytoskeletal motors. In particular, the lecture will concentrate on: (i) structure and dynamics of different filament systems of the cytoskeleton, (ii) motor proteins of the cytoskeleton as high efficient energy transformers, (iii) measurement and prediction of collective effects during the production of force, (iv) sub-cellular mechanosystems with importance for cytokinesis and intracellular transport, (v) cellular motility, and (xii) nanotechnological applications of motor proteins.

Requirements: Basic knowledge in molecular biology, biochemistry, physics and the chemical implication of the single molecule aspect on bachelor level.

Neural data science – Prof. Shervin Safavi

Course work: 2 SWS lecture, 2 SWS exercise

Content: In this course, we will learn various machine-learning methods for analyzing neural data. We will implement basic algorithms and apply them to real data, preparing us to handle real neural data. Such methods are also applicable to a wider range of data.

The course covers the preprocessing of electrophysiological data, from raw signals to fully usable signals (which include spike detection and spike sorting), analysis of spike train, analysis of neural population data, such as multi-array spike and LFP data, as well as advanced topics such as spectral analysis of field potentials, and methods for multi-scale analysis of neural data.

Prerequisite: familiarity with biology, basic machine learning, basic mathematical physics/engineering (e.g. Fourier analysis), basic statistics

Stem Cell Engineering – Prof. Konstantinos Anastassiadis

Course work: 2 SWS lecture, Thursdays 10:30-13:00

Content: The students are provided with an overview of mammalian embryonic development and stem cell biology in general. They study specifically the biology of embryonic stem cells (ESCs), signaling pathways and transcriptional networks as well as differentiation pathways. They learn up to date methods for the genetic manipulation of ESCs and mice. The students get familiar with potential applications of stem cell technologies for regenerative medicine, including inducible reprogramming, disease modeling and gene therapy-strategies.

Requirements: Basic knowledge in Cell Biology, Molecular Biology and Genetics.

The Physics and Biology of Biomolecular Condensates - Dr. Marcus Jahnel, Dr. Ellen Adams, Dr. Lars Hubatsch, Prof. Helmut Schießel, Tuesdays 9:20-10:50 (L) & 11:10-12:40 (S)

Course work: 2 SWS lecture, 2 SWS seminar

Content: Biomolecular condensates are membraneless organelles that form through transient molecular interactions and play a role in many fundamental biological processes – from DNA repair to stress response. In this course, we aim to cover the physics and biology of these dynamic assemblies of biomolecules in equal terms.

Topics we cover include the physics of phase transitions in simple and complex liquids, the kinetics of phase transitions, the emergence of material properties, and the methods to determine the dynamic properties of biomolecular condensates. We will also discuss the combined effect of weak multivalent molecular interactions and protein disorder in shaping these condensates. We aim to build an intuitive understanding of why the physical properties of condensates are necessary to fulfil their biological roles in gene expression, RNA processing, stress response, and interactions with the cytoskeleton. We will discuss the evolution of condensates. We will further learn about the effect of condensates on chemical reactions and how aberrant phase transitions and condensate material properties can be hallmarks of complex diseases such as neurodegeneration, cancer and ageing.

Overall, we want to guide students to think quantitatively about condensate formation, their properties, and how these influence several complex biological processes.

Requirements: Basic understanding of Cell Biology. Basic understanding of thermodynamics. Basic programming experience in Python or Matlab could be beneficial, but we aim to teach all necessary programming skills for the course.

Specialization Theoretical Biological Physics / Module Advanced Theoretical Biophysics

Bioenergetics of Self-Organization, Prof. Xingbo Yang

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The students have a profound comprehension of the genome and genome engineering, which complements the studies of tissue engineering, bioinformatics and cellular machines. They have an overview of the techniques used in the different fields in genomics.

Requirements: Basic knowledge of molecular and cellular biology and biochemistry

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Course work: 2 SWS lecture, 2 SWS seminar, Tuesdays 11:10-14:30

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Prerequisite: familiarity with biology, basic machine learning, basic mathematical physics/engineering (e.g. Fourier analysis), basic statistics

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Overall, we want to guide students to think quantitatively about condensate formation, their properties, and how these influence several complex biological processes.

Requirements: Basic understanding of Cell Biology. Basic understanding of thermodynamics. Basic programming experience in Python or Matlab could be beneficial, but we aim to teach all necessary programming skills for the course.

Structural and Computational Biology – Prof. Maria-Teresa Pisabarro

Course work: 2 SWS lecture, 2 SWS seminar, Mondays 9:00-12:00

Content: This course is addressed to master students with interest in learning how to analyze biological problems from a structural/physico-chemical point of view by applying theoretical computer-aided approaches. Students get introduced to structure-based theoretical concepts used in describing biological systems *in silico*. They are provided with a comprehensive overview on fundamentals, methods and applications in current computational biology/chemistry/biophysics to quantitatively understand the implications of the three-dimensional structure of biomolecules for their stability, dynamics, molecular recognition and function. Students gain insights into the bases needed for computer-based rational bioengineering strategies.

Requirements: This course is addressed to master students in Molecular Bioengineering, Biophysics and Nanobiotechnology with basic knowledge of biology, physics and/or chemistry

Specialization Nanobiotechnology / Module Advanced Nanotechnology

Bioenergetics of Self-Organization, Prof. Xingbo Yang

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Requirements: knowledge of calculus and basic programming skills

Number of participants: up to 30 people, minimum 5 students

Concepts of Molecular Modelling/Computational Materials Science – Prof. Gianaurelio Cuniberti, Dr. Rafael Gutierrez

Course work: 2 SWS lecture, 2 SWS exercise, 2 SWS practical, Tuesdays 09:20-10:50 & Wednesdays 13:00-14:30

Content: The course provides an introduction to various simulation methods to study the structural properties of a broad class of physical systems. Lecture material is further reinforced and discussed in exercise groups. The following topics form the lecture content: Adiabatic approximation, normal modes, basic concepts in statistical physics, molecular dynamics, Monte Carlo method

Requirements: Classical Mechanics, basics of Statistical Physics

Current Topics in Material Science – Prof. Gianaurelio Cuniberti, Florian Pump

Course work: 2 SWS seminar, Fridays 11:10-12:40

Content: Current topics highly relevant for the research in Materials Science (and other disciplines) are discussed in presentations by experts and in talks by the participating students. While the experts give a general overview on different aspects, in their presentations the students go into more detail of selected topics. In addition to the scientific content, invited talks given by experts from science and industry and on soft skills are part of the course concept (e.g. on basics of scientific presenting, publishing and bibliometrics, university rankings, etc.).

Requirements: Basic knowledge of Materials Science and Engineering, Physics, Chemistry

Functional Biological Materials - Dr. Yael Politi, Dr. Luca Bertinetti, Dr. Nils Kröger, Dr. Nicole Poulsen

Course work: 2 SWS lecture, 2 SWS seminar – Mondays 14:00-15:30 (S) & Tuesdays 08:30-10:30 (L); optional: 6 SWS practical

Content: The module will deal with the physical properties, biochemical compositions, biogenesis and assembly of functional biological materials, such as silks, chitin-based materials, wood bone, sea shells and more. mineralized and non-mineralized biological materials and bio-adhesives. Basic physicochemical theories of crystallization, self-assembly and adhesion will be discussed, as well as characterization methods such as x-ray diffraction, vibrational spectroscopy, electron microscopy. The course will establish correlation between hierarchical structure – materials properties and function of biological materials and bio adhesive agents and the mechanisms of their biogenesis.

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Requirements: Basic knowledge in molecular biology, biochemistry, physics and the chemical implication of the single molecule aspect on bachelor level.

Nanooptics – Prof. Lukas Eng

Course work: 2 SWS lecture, Mondays 13:00-14:30

Content: Field of a hertz-dipole, evanescent field, far field, field distribution in focus of linear, circular, radial and azimuthal polarisation, diffraction, principles and applications of the near-field scanning optical microscopy, optical micro-cavity, impact of an optical field in a closed space on the fluorescence properties of a molecule, generation of optical near field on interfaces and through nanostructures: optical aperture, metallic nanoparticles, surface plasmon, optical antennae. The module introduces modern optics on the basis of single molecule detection.

Stem Cell Engineering – Prof. Konstantinos Anastassiadis

Course work: 2 SWS lecture, Thursdays 10:30-13:00, BIOTEC E05/E06

Content: The students are provided with an overview of mammalian embryonic development and stem cell biology in general. They study specifically the biology of embryonic stem cells (ESCs), signaling pathways and transcriptional networks as well as differentiation pathways. They learn up to date methods for the genetic manipulation of ESCs and mice. The students get familiar with potential applications of stem cell technologies for regenerative medicine, including inducible reprogramming, disease modeling and gene therapy-strategies.

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