Study plan in

Physics of biological systems

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA
Dipartimento di Scienze Fisiche, Informatiche e Matematiche

M.Sc. program in Physics – Curriculum Biophysics and applied physics

Overview

This study plan is designed to train students in the investigation of how biologically relevant systems - from **DNA**, to **proteins**, to **entire cells** - work and interact, using both the concepts of physics and **advanced experimental techniques** favoring the quantitative approach. Students following this study plan will be able to understand and develop analytical physical models of biologically relevant systems. Specific examples, where the predictions derived from these models can be experimentally verified, will be considered. At the same time, students will get familiar with experimental advanced techniques, which are exploited to investigate biological systems from the single molecule up to the cellular scale.

Goal

At the end of this program students will be able to understand the physics of some biological systems and to analyse them with analytical models. They will be able to make quantitative investigations and some predictions of simple biological processes. They will learn to use state-of-the art instrumentations for the investigation of biological model systems. They will also learn how it is possible to develop simple tools for the study of biological structures and functions and how to analyse images using state-of-the-art codes for medical physics.

More info and suggestions from

Study plan coordinator
Prof. Andrea Alessandrini

Program director
Prof. Paolo Bordone

Program website
`www.fim.unimore.it/LM/FIS`

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Fist year

Laboratory of nanostructures (D) – F Rossella

The course covers the entire nanotechnology chain, from raw nanomaterials (semiconductor nanowires, 2D materials, nanotubes) to device fabrication (lithography techniques) to electrical and thermal transport measurements and in manufactured nanodevices. Classical and quantum transport experiments will be discussed.

Advanced spectroscopic and imaging methods (D) – R Biagi

X-ray photoemission and absorption spectroscopies are among the most used techniques to characterize properties of materials. Recent technological advances allow to achieve very high spatial (nanometer scale) and temporal (femtosecond scale) resolutions, opening the window to a new universe of phenomena.

Quantum physics of matter (D) – R Magri

An advanced course on matter-light and matter-electron interactions, using quantum linear response theory to discuss elementary excitations of material systems and their spectral features: electronic and phonon excitations, excitons, plasmons, polaritons.

Physics of semiconductors (D) – S D'Addato

A course providing all the necessary ingredients to understand the fascinating physical properties of semiconductors, from their electronic structure description to transport phenomena, and how to exploit them in devices like transistors, or to observe novel states of matter like the quantum Hall liquid.

Nanoscience and quantum materials (D) – E Molinari

Nanosystems are both quantum worlds with astonishingly new properties and the basis of new nanodevices. The course provides a conceptual and practical framework dealing with the physics and description of a set of prototype nanosystems, from nanotubes and graphene structures to nanocrystals, quantum wells, wires and dots.

Laboratory of Quantum Simulation of Materials (D) – A Ruini

Frontal lectures and hands-on tutorial sessions introduce attendees to theoretical/computational techniques for the electronic structure simulation of condensed matter systems. Special emphasis is given to Density Functional Theory, the present state-of-the-art, parameter-free and atomistic scheme for the predictive description of materials.

Synchrotron radiation: basics and applications (R) – S D'Addato

A course on the working principles of synchrotrons and the use of emitted radiation, from description of single ultra-relativistic particles sources to essentials of storage rings, bending magnets, wigglers and undulators, free electron lasers, beam lines. Examples of ensuing popular techniques, as X-ray diffraction, scattering, absorption and X-ray microscopy, are discussed and a visit to to ELETTRA labs in Trieste ends the course.

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Fields of specialization

- Biological physics
- Scanning probe microscopy
- computational modelling of biological systems
- Advanced optical microscopy and optical-tweezers
- Image analysis for medical diagnostics

Opportunities

The multidisciplinary background gained with this study plan is connected to ongoing research activities carried out in collaboration with several research centers in Italy and worldwide, including Univ. of Bologna (Italy), the School of Medicine, Washington University, St Louis (USA), and the Institute for Nanoscience CNR-NANO located in Modena (www.nano.cnr.it) which also contributes to the courses. A specific course allows to aim for a professional future in medical physics. The thesis project will be carried out within one of the groups active in the biophysical research at the Department and/or in collaborating research groups, possibly within the Erasmus program. Students may also opt for the **Double Degree program** and spend the 2nd year on a research project at the Radboud University (NL).

Employment

The acquired skills will enable the attendee to to continue the academic training within a PhD program in Physics, Nanotechnology or Biotechnology, such as the **Graduate School in Physics and Nanoscience** in Modena, or worldwide. This study plan also allows students a smooth entry in many production sectors of a modern economy in an international context, as well as in the health system.

Notes

AStudent may want to include specific courses from the Biology or Engineering programs as free choice courses. Ask the Study plan coordinator for further indications.

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Biological physics with laboratory **(R)** – A Alessandrini, C Cecconi

An introduction to the quantitative analysis of biological processes with the methods of physics and mathematics, together with hands-on experiences using the most advanced biophysical techniques. Students learn how to predict the behavior of some biological phenomena and how to analyze in a quantitative way experimental data.

Chemical physics of biomolecules **(R)** – G Brancolini

A unique, multidisciplinary course to acquire advanced theoretical understanding of chemical physics, with emphasis on biomolecules, colloids and their application to nano-biophysics and nano-medicine.

Medical physics **(R)** – G Guidi

A course which provides the attendees with a basic knowledge of some of the principal diagnostic techniques making use of ionizing and non-ionizing radiation in humans from a physical (technical) point of view.

Second year

Advanced quantum mechanics **(D)** – M Gibertini

A self-contained course addressing several aspects of quantum mechanics relevant to modern developments of physics, from condensed-matter theory to particle physics and their fundamental interactions. Emphasis will be given to the concept of Berry phase, the path integral formulation, and scattering theory.

Nano-mechanics **(F)** – A Rota

An experimental insight on the methods, procedures and apparata used in advanced research to investigate mechanical properties of materials at the nanoscale, with detailed case studies. Experiments on nano-objects are carried out in the lab, aiming at defining their intrinsic tribological properties and their macroscopic effect.

Numerical algorithms for signal and image processing **(F)** – S Bonettini

A course to introduce the basic properties of Fourier transform as a tool for signal analysis, from continuous to discrete settings. Applications to signal and image filtering and compression will be presented also with some laboratory activity in the Matlab environment.

Legend: (M) mandatory course for this curriculum; (D) chosen within distinctive (*caratterizzanti*) courses; (R) chosen within related (*affini*) courses; (F) selected as a free choice course

This study plan is a suggested set of courses, chosen within the curriculum, to ensure an in-depth professional training combined with the broad spectrum of skills required to modern scientists. Mandatory, distinctive and related courses provide the natural background of this study plan. However, the study plan can also be tailored to the students' scientific interests. Ask the study plan coordinator for further indications.