

# Master program in Computational Physics, Mathematics and Life Science

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## Master program in Computational Physics, Mathematics and Life Science

We propose a new Master of Science program at the Faculty of Mathematics and Natural Sciences of the University of Oslo. This program is called **Computational Physics, Mathematics and Life Science**, with acronym **CPMLS**

The program is a collaboration between four departments and classical disciplines:

- Department of Biosciences
- Department of Informatics
- Department of Mathematics
- Department of Physics

The program will be administrated by the Department of Physics. The program is based on the highly successful Computational Physics direction under the present Master program in physics at the University of Oslo.

The program is multidisciplinary and all students who have completed undergraduate studies in science and engineering, with a sufficient quantitative background, are eligible. The language of instruction is English.

## Strategic importance

The program will educate the next generation of cross-disciplinary science students with the knowledge, skills, and values needed to pose and solve current and new scientific, technological and societal challenges. The program will lay the foundation for cross-disciplinary educational, research and innovation activities at the Faculty. The program will contribute to building a common cross-disciplinary approach to the key strategic initiatives at the Faculty: Energy, Materials, Life Science, and Enabling Technologies.

A particular strength of physics students have traditionally been their ability to pose and solve problems that combine physical insights with mathematical tools and now also computational skills. This provides a unique combination of applied and theoretical knowledge and skills, which have allows the studies to be of use across field. In this program, we build on and refine this philosophy. The main focus is not to educate computer specialists, but to educate students with specilized knowledge and skills in a field, but with an integrated knowledge of how computational methods are used as part of that field. This requires an education that covers both the subject field — physics, biology, geoscience — with a strong background in computational methods.

## Scientific and educational motivation

**Applications of simulation.** Numerical simulations of various systems in science are central to our basic understanding of nature and technology. The increase in computational power, improved algorithms for solving problems in science as well as access to high-performance facilities, allow researchers nowadays to study complicated systems across many length and energy scales. Applications span from studying quantum physical systems in nanotechnology and the characteristics of new materials or subamotic physics at its smallest length scale, to simulating galaxies and the creation of the universe. In between, simulations are key to understanding cancer treatment and how the brain works, predicting climate changes and this week's weather, simulating natural disasters, semi-conductor devices, quantum computers, as well as assessing risk in the insurance and financial industry. These are just a few topics already well covered at the University of Oslo and that can be topics for a thesis.

**Job market.** A large number of the candidates from the four involved departments get jobs where numerical simulations play a key tool. The proposed program will raise the educational quality in this area, because our candidates need a broader understanding of the possibilities and limitations of computation-based problem solving.

## Multiscale modeling is the big open research question

Today's problems, unlike traditional science and engineering, involve complex systems with many distinct physical processes. The wide open research topic of

this century, both in industry and at universities, is how to effectively couple processes across different length and energy scales. Progress will rely on a multi-disciplinary approach and therefore a need for a multi-disciplinary educational program.

The proposed program will foster candidates with the right multi-disciplinary background and computational thinking for understanding today's simulation technology and its challenges.

### **The new program combines old and new initiatives**

This program builds on the strengths and success of two existing master's programs in Computational Physics (at the Dept. of Physics) and Applied Mathematics and Mechanics (at the Dept. of Mathematics).

A new master's program in Computational Life must anyway be developed to meet coming needs of the scientific community. If successful, it will position the University of Oslo as the leading institution nationally in computational life science. We believe this new program is best developed in close collaboration with already successful computational science programs.

The program in Computational Life Sciences will have a strong link to the Norwegian University of Life Sciences. Further links to NTNU will be developed.

### **Computational Physics at UiO has been a great success**

This initiative has its roots in the highly successful direction called [Computational Physics](#) under the Master program in Physics at the University of Oslo.

This program has educated almost 60 Master of Science students during the last ten years. Over 50% of these students have continued with PhD studies in Physics, Chemistry, Mathematics and now recently Biology connected with the CINPLA project.

Say something about the Applied Math program too...

### **The new program will also host the CSE project**

The new proposed program will also take a leading responsibility in further developments of the highly successful [Computing in Science Education](#) initiative at UiO.

If the program becomes successful, it will naturally lead to new cross-disciplinary research and a need for a new department in computational science.

### **Learning outcomes**

Students of this program learn to use the computer as a laboratory for solving problems in science and engineering. The program offers exciting thesis projects from many disciplines: biology and life science, chemistry, mathematics,

informatics, physics, geophysics, mechanics, geology – you choose your field according to your own interests.

A Master’s degree from this program gives you a methodical training in planning, conducting, and reporting large research projects, often together with other students and university teachers. Projects usually emphasise finding practical solutions, developing an intuitive understanding of the science and the scientific methods needed to solve complicated problems, use of many tools, and not least developing your own creativity and independent thinking. Your thesis work is a scientific project where you learn to tackle a scientific problem in a professional manner.

## Structure and courses

The table here is an example of a suggested path for a Master of Science project, with course work the first year and thesis work the last year.

	10 ECTS	10 ECTS	10 ECTS
4th semester	Master thesis	Master Thesis	Master Thesis
3rd semester	Master thesis	Master Thesis	Master Thesis
2nd semester	Master courses	Master courses	Master courses
1st semester	Master courses	Master courses	Master courses

The program is very flexible in its structure and students may opt for starting with their thesis work from the first semester and scatter the respective course load across all four semesters.

Depending on interests and specializations, there are many courses on computational science which can make up the required curriculum of course work. Furthermore, courses may be broken up in smaller modules, avoiding thereby the limitation of 10 ECTS per course only. Some of these courses are listed below.

## Structure

Here follows a list of suggested courses that students may include in their required course load.

- FYS4150 Computational Physics I
- FYS4411 Computational Physics II
- FYS4460 Computational Physics III
- INF5620 Numerical Methods for Partial Differential Equations
- INF5631 Project on Numerical Methods for Partial Differential Equations
- FYS388 Computational Neuroscience
- STK4520 Laboratory for Finance and Insurance Mathematics

- STK4021 Applied Bayesian Analysis and Numerical Methods
- MAT-INF4130 Numerical Linear Algebra
- MAT-INF4110 Mathematical Optimization
- ECON4240 Equilibrium, welfare and information
- MEK4470 Computational Fluid Mechanics
- MEK4250 Finite Element Methods in Computational Mechanics

The program plans to develop other courses in computational science and its applications, ranging from life science to materials science.

## **Admission**

The following higher education entrance qualifications are needed

- A completed bachelor's degree (undergraduate) comparable to a Norwegian bachelor's degree in one of the following disciplines
  1. Biology, molecular biology, biochemistry or any life science degree
  2. Physics, astrophysics, astronomy, geophysics and meteorology
  3. Mathematics, mechanics, statistics and computational mathematics
  4. Computer science and electronics
  5. Chemistry
  6. Materials Science and nanotechnology
  7. Any undergraduate degree in engineering
  8. Mathematical finance and economy
- The language of instruction is English. An internationally recognised English language proficiency test is required.

## **The program opens up for flexible backgrounds**

While discipline-based master's programs tend to introduce very strict requirements to courses, we believe in adapting a computational thesis topic to the student's background, thereby opening up for students with a wide range of bachelor's degrees. A very heterogeneous student community is thought to be a strength and unique feature of the new program.

## **Study abroad and international collaborators**

As a student at the University of Oslo you may choose to take part of your degree at a university abroad.

Students in this program have a number of interesting international exchange possibilities. The involved researchers have extensive collaborations with other researchers worldwide. These exchange possibilities range from top universities in the USA, Asia and Europe as well as leading National Laboratories in the USA.

## **Career prospects**

Candidates who are capable of modeling and understanding complicated systems in natural science, are in short supply in society. The computational methods and approaches to scientific problems you learn when working on your thesis project are very similar to the methods you will use in later stages of your career. To handle large numerical projects demands structured thinking and good analytical skills and a thorough understanding of the problems to be solved. This knowledge makes you unique on the labor market.

Career opportunities are many, from research institutes, universities and university colleges and a multitude of companies. Examples include IBM, Hydro, Statoil, and Telenor. The program gives you an excellent background for further studies, with a PhD as one possible goal.

The program has also a strong international element which allows you gain important experience from international collaborations in science, with the opportunity to spend parts of the time spent on your thesis work at research institutions abroad.