Faculty of Science

FYTN12, Theoretical Physics: Systems Biology - Models and Computations, 7.5 credits

Teoretisk fysik: Systembiologi - modeller och beräkningar, 7,5 högskolepoäng

Second Cycle / Avancerad nivå

Details of approval

The syllabus was approved by Study programmes board, Faculty of Science on 2014-10-07 to be valid from 2014-10-07, spring semester 2015.

General Information

The course is an elective course for second-cycle studies for a Degree of Master of Science (120 credits) in physics, particularly for the specialisation in biological physics and computational biology.

Language of instruction: English

Main field of studies	*Depth of study relative to the degree requirements*
Physics	A1F, Second cycle, has second-cycle course/s as entry requirements

Learning outcomes

The overall aim of the course is to give the student basic knowledge of the most important computational methods in systems biology. The student shall be given experience in implementing and applying the methods on relevant biological problems.

Knowledge and understanding

After completion of the course the student shall be able to connect biology, mathematics and physics to:

- formulate and interpret equations for biochemical systems from a description in terms of simple chemical reactions,

- formulate and interpret equations for transcription and translation of genes and mRNA,
- design mathematical models at the level of cell populations,
- describe similarities between the models on concentration and population level, including the assumptions that are usually made in the models,
- describe when it is appropriate to model a biological system by means of ordinary differential equations,
- describe when it is appropriate to use stochastic simulations instead of deterministic, and what assumptions underlie the choice.

Competence and skills

On completion of the course the student shall be able to:

- implement a mathematical model by means of existing software libraries for ordinary differential equations and expand such a model to several interacting cells,
- implement the Gillespie algorithm for stochastic simulations,
- estimate the values of model parameters from experimental data based on reasonable biological and statistical assumptions including error estimation (sensitivity analysis),
- formulate model equations taking into account how well the parameters can be determined,
- implement different cost functions to fit a model to data and use optimization methods to find good parameter values.

Course content

- Translation between biology and mathematics: Formulation of equations that describe biochemistry, transcription and translation based on various assumptions. Michaelis-Menten kinetics, Hill coefficients and the Shea-Ackers model for transcription.
- Population models and spatial models: Formulation of equations that describe how cell populations evolve. Interaction between identical systems based on their spatial arrangement.
- Simulations: Deterministic versus stochastic simulations of mathematical models. Weaknesses, strengths and applicability of ordinary differential equations and stochastic simulations.
- The Gillespie algorithm for stochastic simulations: Naive implementation and possible optimisations for large systems.
- Cost functions: Different strategies to compare simulations with experimental data.
- Optimization methods: Overview of methods to fit models to data. Local optimisation, thermodynamic methods and genetic algorithms.
- Sensitivity analysis: Estimation of the uncertainty in determined parameter values. Strategies to achieve robustness.

Course design

The teaching consists of lectures and programming projects. The projects are based on examples from the scientific literature, where a computational method has been applied on a biological problem.

Assessment

The examination takes place with written hand-in assignments, individual presentations of the programming projects and an oral test.

Subcourses that are part of this course can be found in an appendix at the end of this document.

Grades

Marking scale: Fail, Pass, Pass with distinction.
To pass the entire course, a passed oral test and passed programming assignments is required. The final grade is determined by combining the results on the different parts of the examination.

Entry requirements

Admission to the course requires knowledge equivalent to FYTN03 (Computational physics), FYTN05 (Theoretical biophysics) and English B. Knowledge in programming in Java, Python, C++ or another programming language is needed for the programming assignments.

Subcourses in FYTN12, Theoretical Physics: Systems Biology - Models and Computations

Applies from V15

1401 Project presentations, 3,0 hp
Grading scale: Fail, Pass, Pass with distinction
1402 Oral examination, 4,5 hp
Grading scale: Fail, Pass, Pass with distinction