Syllabus

Principles and Applications of Systems Biology

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September 2024

Assistants

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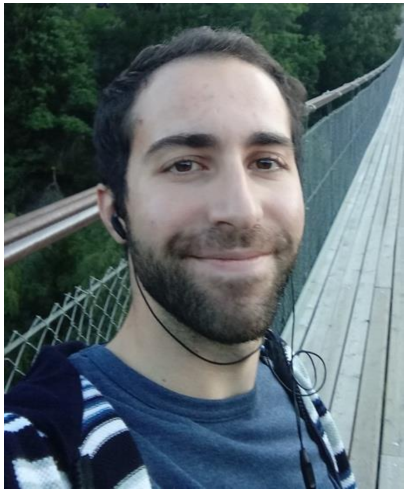

Omid Oftadeh

Syllabus (approximate)

Date	Lecture	Exercise
14.09	Introduction to Systems Biology	-
20.09	FBA, Objective functions, Growth trade off (FAB1) Phenotypic phase plane, alternative flux distributions (FBA2),	-
27.09	Practical (Software; Simulation exercises)	Q/A MATLAB,Python
04.10	Thermodynamics flux balance analysis, and GCM (TFA2)	Q/A
11.10	Data integration of Stoichiometric models	Q/A
18.10	Data integration of Stoichiometric models	
01.11	Enzyme kinetics/Large-scale modelling + Kinetic modeling of cancer metabolism	Q/A
08.11	Large-scale modelling + Kinetic modeling of cancer metabolism / Data (Maria)	Q/A
15.11	Sigma / Signal transduction systems	Q/A
22.11	Stochastic and Spatial effects on the intracellular level // ME-models (Omid)	Q/A
29.11	ME-models (cont'd if needed) / Communities	
06.12	Work on projects	
13.12	*Work on projects/Final Presentations*	
20.12	*Final Presentations*	

Brief course description

The course introduces and develops the key concepts from **systems biology** and **systems engineering** in the context of **complex biological networks**.

The lectures elaborate on **techniques** and **methods** to **model** and **analyze** complex biological problems.

(*Focus on Metabolism – and some signaling!*)

Examples and projects apply the model-based and systems engineering integration and analysis of big data from biological systems.

TOPICS

- Mathematical and computational analysis of metabolic reaction networks
- Analysis of metabolomics and bioenergetics data in the context metabolic networks
- Mathematical and computational analysis of protein expression
- Methods and technologies for the analysis of signaling networks
- Computational models of microbial communities
- Interpretation and analysis of single cell data
- Mathematical modeling of spatial effects in biological systems

METHODS

- Metabolic Flux balance analysis (FBA)

  (**Linear programming**)

- Thermodynamics based flux balance analysis (TFA) of

  metabolic networks

  (**Mixed-integer linear programing).**

- Kinetic models

  (**Ordinary differential equations**)

- Metabolic control analysis

  (**Local and global sensitivity analysis**)

- Stochastic simulation algorithm (SSA) and

  Particle based simulation methods

  (**Stochastic simulation**)

- Parameter estimation for biological systems

  (**System identification methods**)

RECOMMENDATIONS

The building of working groups will make it possible for people with partial knowledge in these fields to contribute depending on their formation.

COURSES

SV courses:

- Dynamical systems in biology BIO-341
- Numerical analysis MATH-251

ChemE courses:

- Dynamics and kinetics CH-310
- Biochemical engineering ChE-311
- Bioreactor modelling and simulation ChE-320
- Numerical methods ChE-312

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Important concepts to start the course

- For the computational exercises, MATLAB® and PYTHON will be the platforms of choice.
- An introductory session on the platforms and software used is part of the course.

Learning Outcomes

By the end of the course, the student must be able to:

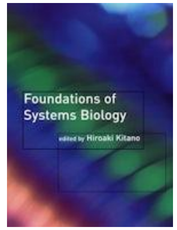
- Formulate mass balances of reaction networks
- Solve mass balance equations using linear programing solvers
- Construct kinetic models of biological reactions
- Create and analyze stochastic models of biological reactions
- Analyze papers on modeling and analysis of biological networks
- Assess / Evaluate alternative methods for the study of biological networks

Transversal skills

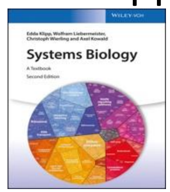
- Plan and carry out activities in a way which makes optimal use of available time and other resources.
- Access and evaluate appropriate sources of information.
- Summarize an article or a technical report.
- Demonstrate the capacity for critical thinking
- Negotiate effectively within the group.

Literature

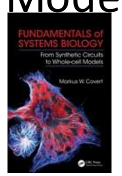
- Foundations of System Biology, Edited by Hiraoki Kitano. MIT Press 2001 (classic reading)



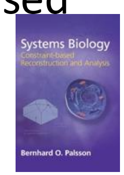
- Systems Biology, a textbook, Edda Klipp



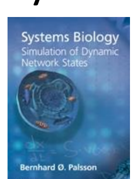
- Fundamentals of Systems Biology: From Synthetic Circuits to Whole-Cell Models, by Markus Covert



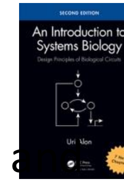
- Systems Biology : Constraint-Based Reconstruction and Analysis



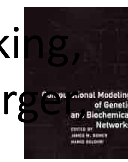
- Systems Biology: Simulation of Dynamic Network States



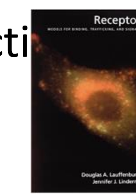
- An Introduction to Systems Biology: Design Principles of Biological Circuits, by Uri Alon. Chapman and Hall/CRC 2006



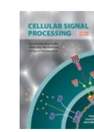
- Computational Modeling of Genetic and Biochemical Networks, by James M. Bower and Hamid Bolouri. Bradford 2004



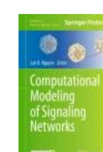
- Receptors: Models for Binding, Trafficking, and Signaling by Douglas A. Lauffenburger Jennifer Linderman



- Cellular Signal Processing: An Introduction to the Molecular Mechanisms of Signal Transduction



- Computational Modeling of Signaling Networks



Grading

- Project based evaluation:
    - Analyze and reproduce the results of a paper (A paper will be assigned to each group)
- TAs will be available to solve the questions during exercise sessions
- One grade per group
- Final presentation 100%

Groups and Project presentations

- Groups:
  - 3-4 People
  - Send one e-mail per group to david.liaskos@epfl.ch
    with the full names of all group members <u>until the 27th Sep</u>
  - If you are not part of a group by that time, we will assign you to a group

- Project presentation:
  - After forming a group, a paper will be assigned to you
  - Goal: Replicate the key results from the article
  - Propose extensions to the work presented