

LF305-15 Dynamics of Biological Systems

26/27

Department

Life Sciences

Level

Undergraduate Level 3

Module leader

Orkun Soyer

Credit value

15

Module duration

10 weeks

Assessment

Multiple

Study location

University of Warwick main campus, Coventry

Description

Introductory description

This module will introduce students to the "systems dynamical" nature of cells. We will introduce students to this system-level view of the cell and explain the experimental and mathematical approaches used to achieve a system-level understanding of cellular function. The module will also outline how a detailed understanding of system dynamics enables researchers to engineer novel biological systems for the first time, in a synthetic biology approach.

Module aims

- Acquiring a more quantitative/physical view of cells
- Understanding 'design principles' of cellular systems involved in gene regulation, signalling and metabolism
- Understanding (system) dynamics of cellular systems (e.g. bistability, oscillations)
- Understanding physical properties and limits of cellular systems (thermodynamics, mechanical forces, electrical properties)

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

Quantitative skills in cell biology (4 lectures)

Cell (physical and dynamical) properties. Cellular properties: Composition, size, speed, energy, time scales, forces (MA)

Cell scales. Functions and scales: Numbers, exponentials, time scales (BM)

Mechanistic vs phenomenological models (system dynamics models). Rigorous rules for sloppy calculations and the power of (quantitative) models (OS, BM)

Model choice (Occam's razor level), model fitting (very basic), optimisation, model-expw cycle. Dynamics and stability (BM, OS)

Cell metabolism (5 lectures) 5. Free energy of binding and the mass action rule (OSS) 6. Enzyme kinetics and writing differential equations to model a biochemical system (ODE models) (OSS) 7. Modelling metabolism (ODE and FBA models) (OSS) 8. Metabolic control: carbon source hierarchy, diauxic shifts and overflow metabolism (biologically relevant case) (OSS) 9. Metabolic oscillations (biologically relevant case) (OSS)

Cellular signalling (4 lectures) 10. Ligand binding, allostery, Hill function (basic numbers/processes) (BM) 11. Signal amplification and ultrasensitivity (MAPK type cascade) (BM) 12. Two-component cascades (BM) 13. Chemotaxis (biologically relevant case) (OSS, BM)

Gene regulation 1 (3 lectures) 14. Ribosome binding and principles of gene regulation, Simple gene regulation models and network motifs, e.g. self-regulating TF (feedback loop) (MA) 15. Excitatory dynamics in the context of competency / differentiation (biologically relevant case) (MA) 16. Limit cycle oscillation (MA)

Gene regulation 2 (3 lectures) 17. Low numbers in gene regulation and intro to stochastic modelling (DH) 18. Chemical master equation and how to construct stochastic models (DH) 19. 1- and 2-state models of gene expression and how it experimentally tested (DH)

Advanced topics of interest: Maximum likelihood, model choice (link back to beginning), parameter sampling, experiment-model cycle.

Learning outcomes

By the end of the module, students should be able to:

- Understand and develop the concepts of “systems dynamics” and “dynamical responses” in the context of cellular metabolism, gene expression, and signalling.
- Apply and utilise these concepts and associated tools to the understanding of cellular behaviours arising from metabolic regulation, gene regulatory networks, and intracellular signalling processes.
- Evaluate experimental approaches used to generate quantitative and single cell data, including consideration of their strengths, limitations, and appropriate applications in cellular systems biology.
- Construct and apply computational and mathematical models of cellular processes to generate testable hypotheses from quantitative data and justify their use in guiding experimental design. Translate pathway diagrams into biochemical reaction schemes and

- ordinary differential equation (ODE)–based models, and interpret their dynamic behaviour.
- Apply quantitative reasoning skills to analyse, interpret and draw conclusions from temporal, multi-scale, or integrated datasets describing cellular biological systems.

Indicative reading list

[Reading lists can be found in Talis](#)

[Specific reading list for the module](#)

Subject specific skills

Quantitative thinking skills in the context of cellular systems

Gain an appreciation of the systems view of cellular biology and the complexity of biological systems at the cellular level;

Gain an appreciation for the role of quantitative data and mathematical modelling in understanding cellular systems;

Apply a range of computational and mathematical methods to analyse biological data and model diverse cellular phenomena;

Combine experimental and theoretical concepts, literature and ideas.

Transferable skills

Work in small groups to tackle complex problems;

Communicate with scientists with experimental and/or theoretical backgrounds;

Think creatively and beyond traditional discipline boundaries.

Study

Study time

Type	Required
Lectures	20 sessions of 1 hour (13%)
Private study	127 hours 30 minutes (85%)
Assessment	2 hours 30 minutes (1%)
Total	150 hours

Private study description

127.5 hrs of self-study and directed reading to prepare for the closed-book examination

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

Assessment group B

	Weighting	Study time	Eligible for self-certification
In-class examination	50%	1 hour	No
In-person locally-timetabled in-class examination			
Closed-book end-of-year examination	50%	1 hour 30 minutes	No
In-person locally-timetabled closed-book end-of-year examination.			

This will be a written assessment that may take the form of problem-solving and/or data analysis.

Assessment group R3

	Weighting	Study time	Eligible for self-certification
Closed-book examination	100%		No
In-person locally-timetabled closed-book examination			

Feedback on assessment

Pastoral meeting with academic tutor

[Past exam papers for LF305](#)

Availability

Courses

This module is Optional for:

- UBSA-C700 Undergraduate Biochemistry
 - Year 3 of C700 Biochemistry
 - Year 3 of C700 Biochemistry

- ULFA-C1A2 Undergraduate Biochemistry (MBio)
 - Year 3 of C1A2 Biochemistry
 - Year 3 of C700 Biochemistry
- Year 4 of ULFA-C702 Undergraduate Biochemistry (with Placement Year)
- Year 3 of ULFA-C1A6 Undergraduate Biochemistry with Industrial Placement (MBio)
- UBSA-3 Undergraduate Biological Sciences
 - Year 3 of C100 Biological Sciences
 - Year 3 of C100 Biological Sciences
 - Year 3 of C102 Biological Sciences with Cell Biology
 - Year 3 of C103 Biological Sciences with Environmental Resources
 - Year 3 of C104 Biological Sciences with Microbiology
 - Year 3 of C105 Biological Sciences with Molecular Genetics
 - Year 3 of C107 Biological Sciences with Virology
- Year 3 of ULFA-C1A1 Undergraduate Biological Sciences (MBio)
- Year 4 of ULFA-C113 Undergraduate Biological Sciences (with Placement Year)
- Year 3 of ULFA-C1A5 Undergraduate Biological Sciences with Industrial Placement (MBio)
- UBSA-C1B9 Undergraduate Biomedical Science
 - Year 3 of C1B9 Biomedical Science
 - Year 3 of C1B9 Biomedical Science
 - Year 3 of C1B9 Biomedical Science
- ULFA-C1A3 Undergraduate Biomedical Science (MBio)
 - Year 3 of C1A3 Biomedical Science
 - Year 3 of C1B9 Biomedical Science
- Year 3 of ULFA-C1A7 Undergraduate Biomedical Science with Industrial Placement (MBio)
- ULFA-CB18 Undergraduate Biomedical Science with Placement Year
 - Year 4 of CB18 Biomedical Science with Placement Year
 - Year 4 of CB18 Biomedical Science with Placement Year
 - Year 4 of CB18 Biomedical Science with Placement Year
- Year 3 of ULFA-B140 Undergraduate Neuroscience (BSc)
- Year 3 of ULFA-B142 Undergraduate Neuroscience (MBio)
- Year 3 of ULFA-B143 Undergraduate Neuroscience (with Industrial Placement) (MBio)
- Year 4 of ULFA-B141 Undergraduate Neuroscience (with Placement Year) (BSc)