LF305-15 Dynamics of Biological Systems

22/23

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 the student to this system level view of the cell and explain the experimental and mathematical approaches used to achieve a system levels 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)

1. Cell (physical and dynamical) properties. Cellular properties: Composition, size, speed, energy, time scales, forces (MA)
2. Cell scales. Functions and scales: Numbers, exponentials, time scales (BM)
3. Mechanistic vs. phenomological models (system dynamics models). Rigorous rules for sloppy calculations and the power of (quantitative) models (OS, BM)
4. 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. Modeling 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)

1. 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:

- Learn about dynamic responses/behavior of cells in terms of metabolism, gene regulation, and signalling.
- Learn about experimental approaches for acquiring quantitative and single-cell data of

cellular systems;
- Learn about building computational/mathematical models that can allow hypotheses to be devised from acquired quantitative data and guide new data collection experiments
- Writing biochemical reactions from pathway diagrams or ODEs
- Acquiring quantitative thinking skills for cellular biology

Indicative reading list

Essential Reading

- Online book on building a quantitative sense for cells: "Biology by the Numbers" by Ron Milo and Rob Phillips
- Select chapters from online book on biological modeling: "Mathematical Modeling in Systems Biology: An Introduction" by Brian Ingalls
- Physical Biology of the Cell (https://www.amazon.co.uk/Physical-Biology-Cell-Rob-Phillips/dp/0815344503)
- Physiology of bacterial cell (https://www.amazon.co.uk/Physiology-Bacterial-Cell-Molecular-Approach/dp/0878936084)
- Klipp, E, Liebermeister, E et al "Systems Biology: A Textbook", Wiley VCH Blackwell (2009), ISBN: 978-35273187742
- Alon, Uri "An Introduction to Systems Biology: Design Principles of Biological Circuits", Taylor and Francis (2006), ISBN: 978-1584886426
  Recommended Reading
- Berg, Howard C "Random Walks in Biology", University Press of California (1993), ISBN: 978-0091000640
- Strogatz, Steven H "Nonlinear Dynamics and Chaos", The Perseus Books Group (2000), ISBN: 978-0738204536
- Ptashne, Mark "A Genetic Switch", Cold Spring Harbour Laboratory Press (2004), ISBN: 978-0879697167
- Murray, James D "Mathematical Biology: An Introduction: Part 1" 3rd , Springer-Verlag (2002), ISBN: 978-0387952239
- Britton, Nicholas F "Essential Mathematical Biology", Springer (2005), ISBN: 978-1852335366
- Kaneko, Kunihiko "Life: An introduction to complex systems Biology" , Springer-verlag (2006), ISBN: 978-364206
- Additional reading material will be assigned for specific lecture and lab sections

Subject specific skills

1. Quantitative thinking skills in the context of cellular systems
2. Gather an appreciation of the systems view of cellular biology and the complexity of biological systems at the cellular level;
3. Gain an appreciation for the role of quantitative data and mathematical modelling in understanding cellular systems;
4. Apply a range of computational and mathematical methods to analyze biological data and model diverse cellular phenomena;

5. Combine experimental and theoretical concepts, literature and ideas.

Transferable skills

1. Work in small groups to tackle complex problems;
2. Communicate with scientists with experimental and/or theoretical backgrounds;
3. Think creatively and beyond traditional discipline boundaries.

Study

Study time

Type	Required
Lectures	20 sessions of 1 hour (13%)
Private study	130 hours (87%)
Total	150 hours

Private study description

130 hrs of self-study and directed reading to prepare for the open book assessment

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 A

	Weighting	Study time
In-Module Test (1) In-module MCQ Test	20%	
In-Module Test (2) In-module MCQ Test	20%	
Open Book Assessment	60%	20 hours

	Weighting	Study time

Final assessment for the module will be on open book assessment. This is an essay based assessment consisting of 4 questions- students need to answer 2. The essays cannot be answered using lecture notes alone- students will need to perform background research and essays will need to be fully referenced.

Assessment group R

	Weighting	Study time
Open Book Assessment	100%	

Final assessment for the module will be on open book assessment. This is an essay based assessment consisting of 4 questions- students need to answer 2. The essays cannot be answered using lecture notes alone- students will need to perform background research and essays will need to be fully referenced.

Feedback on assessment

Pastoral meeting with academic tutor

Availability

Courses

This module is Core for:

- Year 3 of UMDA-CF10 Undergraduate Integrated Natural Sciences (MSci)

This module is Optional for:

- Year 3 of UBSA-C700 Undergraduate 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 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)