MS202-15 Cellular Decision Making

24/25

Department
: Warwick Medical School

Level
: Undergraduate Level 2

Module leader
: Timothy Saunders

Credit value
: 15

Module duration
: 10 weeks

Assessment
: 100% coursework

Study location
: University of Warwick main campus, Coventry

Description

Introductory description

This module focuses on how complex biological systems can make decisions. For example, the body must respond to changes in the local environment quickly and reliably. The approach taken here is to use mathematical modelling to understand how networks and feedback can generate precise responses, such as switching and pulse generation. Relatedly, we will develop the students ability to perform estimation and quick calculations relevant to biological systems.

The module will be compulsory for second year Integrated Natural Science (INS) students. The module builds on the ethos of INS, with a clear emphasis on solving problems by drawing freely from the methods and mindsets of more than one discipline. The module will be open to SLS students who want to expand their quantitative and mathematical skills. No prerequisites are required, though students without knowledge of calculus will need to do some prescribed pre-module reading and exercises.

Module aims

The module will focus primarily on mathematical methods to analyse data, and model interactions and spatial patterns. The students will be equipped to extract quantitative information from images, derive network information and mathematical models to describe multidimensional patterns and complex multi-species interactions. The module provides an important view on understanding biological systems that is quite distinct from most other approaches covered in UG modules in

SLS and WMS.

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.

Block 1: Numbers in biology – learning to estimate
Back-of-envelope calculations
Scales in biology
Number patterns in biology

Block 2: Law of mass action and application to simple gene networks
Michaelis-Menten simple derivation
Thresholds for generating gene response
Concept of steady-state
Non-dimensionalisation

Block 3: Generating simple circuits with genes
Simple gene network – feedforward
Positive feedback switch
Effects of noise on switching

Block 4: Timing in gene networks
Multiple thresholds for generating timing sequence
Pulse generation
Basic intro to generating biological oscillators

Block 5: Interpretation of spatial information by gene networks
Morphogen gradients and positional information
Interpreting morphogens through gene networks

Project: Extracting and analysing quantitative imaging data
Students given imaging data, e.g. butterfly wing images. In groups of around four, implement segmentation via available software packages, e.g. ilastik. Generate figures from quantitative data. Individually write short reports on imaging data, emphasising statistical analysis.

Learning outcomes

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

- Utilise software packages for analysing imaging data (written report)
- Understand fundamental concepts underlying biological networks, including feedback, hysteresis, and robustness
- Comprehend concepts underlying networks and their representation
- Apply model fitting approaches to experimental data (written report)
- Apply statistical knowledge to estimate uncertainties in analysis (written report)
- Apply statistical techniques to a variety of biological data
- Generate and interpret graphs of biological data

Indicative reading list

There is no necessary book, though we recommend
An Introduction to Systems Biology by Uri Alon
Numbers in Biology by Rob Philips

Interdisciplinary

Utilises concepts from mathematics, physics and computer science to tackle problems related to biology.

Subject specific skills

Knowledge of key methods in network analysis, simple dynamic modelling, data handling and analysis. Knowledge of approaches to model linear and multidimensional gradients resulting in cellular decision making and robust pattern formation. Knowledge how to use tools to extract quantitative data from images and analyse the data.

Transferable skills

Students will be able to demonstrate integrated thinking across the Sciences. They will learn to work as a team to tackle a problem. They will learn how to structure a longer project over 10 weeks.

Study

Study time

Type	Required
Lectures	5 sessions of 1 hour (3%)
Project supervision	5 sessions of 1 hour (3%)
Practical classes	10 sessions of 2 hours (13%)
Private study	92 hours (61%)
Assessment	28 hours (19%)
Total	150 hours

Private study description

Reviewing lecture material prior to practical classes.
Reading literature, particularly Systems Biology by U Alon.
Going through practical class material afterwards to embed learning and to cover any questions missed.
Working on project in groups initially and then individually to prepare data for the report.

Costs

No further costs have been identified for this module.

Assessment

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

Assessment group A

	Weighting	Study time
Block 2 Problem Set	10%	3 hours
Using plotting to understand different scenarios of gene behaviour		
Block 3 Problem Set	10%	3 hours
Detailed analysis of switching behaviour		
Block 4 Problem Set	10%	3 hours
Exploring behaviour of an oscillating circuit		
Block 5 Problem Set	10%	3 hours
Using non-dimensionalisation to understand general behaviour of mathematical models of biology		
Quantitative approaches to biological imaging data	35%	15 hours
Students given imaging data, e.g. butterfly wing images In groups of four, implement segmentation via available software packages, e.g. ilastik Generate figures from quantitative data Individually write short reports on imaging data, emphasising statistical analysis		
Mathematical approaches to understanding biological networks	25%	1 hour
The one-hour in-class test will take place at the end of the last Practical Class. It will consist of short maths problems related to understanding biological networks.		

Feedback on assessment

Students will receive back their marked Problem Sets (except no. 5) prior to the in-class test. Worked solutions will be provided where appropriate. The project will have 5 1-hour classes available where students can come for feedback on their progress.

Availability

Pre-requisites

Students without calculus knowledge should do precourse reading as prescribed by the lecturer

Courses

This module is Core for:

- Year 2 of UMDA-CF10 Undergraduate Integrated Natural Sciences (MSci)