

## Engineering Tripos Part IIB, 4G1: Mathematical biology of the cell, 2022-23

### Module Leader

[Dr Thierry Savin](#) [1]

### Lecturers

[Dr T Savin, Dr T O'Leary](#) [2]

### Timing and Structure

Michaelmas term. 16 lectures (including 2 examples classes). Assessment: Coursework 100%

### Aims

The aims of the course are to:

- introduce to sub cellular processes and the role of thermal fluctuations
- shift from the classical biology approach to a more physical description
- illustrate mathematical/computing approaches to study regulatory networks and biomolecular dynamics
- provide background knowledge on stochastic processes

### Content

The course covers topics in stochastic processes and statistical mechanics with application to examples from biology. No background in biology is assumed.

#### Introduction (Savin)

- Cells are a very well organized machinery
- But molecular processes are subject to fluctuations, i.e. stochasticity
- How is it possible?

#### Mathematical formalism (Savin)

- Probabilities & Random Variables
- Stochastic Processes
- Master Equation, Fokker-Plank Equation

#### Regulation of gene expression (O'Leary)

- Gene expression analysis
- Stochastic gene expression
- Stochastic simulations

#### Cell structural organization (Savin)

- Biomolecules (DNA, cytoskeleton)
- Statistical physics for biology
- Polymer mechanics

- Transport processes in cells

## Coursework

| Coursework                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Format                                             | Due date<br>& marks                                          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------------|
| <p><b>Coursework activity #1: Analysis of noise in prokaryotic gene expression</b></p> <p>Cells often express genes in low copy numbers, leading to substantial variability in protein. In this coursework you will build a simple model of gene expression, analyse it mathematically and simulate a stochastic version of the model.</p> <p><u>Learning objective:</u></p> <ul style="list-style-type: none"> <li>• understand how to estimate fluctuation size in a stochastic system and limitations of analytic estimates;</li> <li>• be able to implement stochastic simulations;</li> <li>• interpret biological data and predictions that simulations yield.</li> </ul>                                           | <p>Individual report</p> <p>Anonymously marked</p> | <p>Posted Fri week 10<br/>Due Fri week 11</p> <p>30/60</p>   |
| <p><b>Coursework activity #2: Modelling DNA's mechanical response</b></p> <p>The mechanical properties of DNA and other biological filaments are important factors for cell functions. In this coursework you will simulate a DNA molecule using a bead-spring chain model undergoing thermal fluctuations, and compare your results with the theory and existing experimental data.</p> <p><u>Learning objective:</u></p> <ul style="list-style-type: none"> <li>• understand models and Brownian dynamics of biological polymer;</li> <li>• code and carry out the simulations; statistically analyse the data;</li> <li>• interpret the simulations output in comparison with theory and experimental data.</li> </ul> | <p>Individual report</p> <p>Anonymously marked</p> | <p>Posted Fri week 11<br/>Due Fri two weeks</p> <p>30/60</p> |

## Booklists

Please see the [Booklist for Group G Courses](#) [3] for references for this module.

## Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [4].

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#### **Links**

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[2] <mailto:ts573@cam.ac.uk>, [tso24@cam.ac.uk](mailto:tso24@cam.ac.uk)

[3] <https://www.vle.cam.ac.uk/mod/book/view.php?id=364101&chapterid=56061>

[4] <https://teaching24-25.eng.cam.ac.uk/content/form-conduct-examinations>