# Engineering Tripos Part IIB, 4G1: Mathematical biology of the cell, 2019-20

## 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 |
| --- | --- | --- |
| | | & marks |
| **Coursework activity #1: Analysis of noise in prokaryotic gene expression**<br><br>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.<br><br>Learning objective:<br><br>- understand how to estimate fluctuation size in a stochastic system and limitations of analytic estimates;<br>- be able to implement stochastic simulations;<br>- interpret biological data and predictions that simulations yield. | Individual report<br><br>Anonymously marked | Posted Fri we<br>Due Fri week<br><br>30/60 |
| **Coursework activity #2: Modelling DNA's mechanical response**<br><br>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.<br><br>Learning objective:<br><br>- understand models and Brownian dynamics of biological polymer;<br>- code and carry out the simulations; statistically analyse the data;<br>- interpret the simulations output in comparison with theory and experimental data. | Individual report<br><br>Anonymously marked | Posted Fri w<br>Due Fri two w<br><br>30/60 |

## 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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