Stochastic Processes in Biology (L16)

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Stochastic processes are applicable to biology across a wide range of scales: from modelling molecules which interact via chemical reactions and diffusion, cells which proliferate, differentiate, die and move using active transport, all the way to modelling large groups of animals which interact and move in space according to complex rules. This course will cover mathematical methods and simulation algorithms for the analysis of such continuous-time stochastic models, including the following topics:

- Chemical reaction networks.
- Slow-fast systems and reduction to effective models.
- Random walks, Brownian motion, and reaction-diffusion processes.
- Metastability and exit problems.
- Interacting diffusion processes and collective behaviour.

For each of the topics, we will introduce the relevant stochastic simulation algorithms and how are they implemented in practice (there will be live coding examples and computational problems in the example sheets). We will also present the corresponding probabilistic descriptions in the form of systems of ODEs (chemical master equations) and PDEs (Fokker–Planck equation, backward Kolmogorov equation). We will highlight the connections between different modelling approaches (deterministic vs stochastic, discrete vs continuous).

Prerequisites

This course assumes basic knowledge of probability, ODEs and PDEs. While the computational component of the course is not assessed, some basic proficiency in programming will be useful.

Literature

1. R. Erban & S. J. Chapman, *Stochastic Modelling of Reaction-Diffusion Processes*. Cambridge University Press, 2019.
2. L. J. S. Allen, *An Introduction to Stochastic Processes with Applications to Biology*. CRC Press, 2010.
3. G. A. Pavliotis, *Stochastic Processes and Applications*. Springer, 2015.
4. C. W. Gardiner, *Handbook of Stochastic Methods*. Springer, 1985.

Additional support

Three examples sheets will be provided, and three associated examples classes will be given. There will be a one-hour revision class in the Easter Term. There will also be one drop-off coding session in the first week.