Full details of the proposed research project

Analysis of some simple mathematical models for epidemics.

Host

Professor John King, Professor of Theoretical Mechanics, School of Mathematical Sciences, Faculty of Science

Description of the proposed project

Epidemic modelling has attained an extremely high public profile during the current pandemic, with concepts intrinsic to such models (notable reproduction numbers and doubling times) entering common usage. Perhaps surprisingly, however, there are aspects of even the simplest relevant models that have not been comprehensively explored by the full range of available mathematical approaches, a number of the possible developments being well-suited to study in the course of an undergraduate research project.

The project aims to implement detailed mathematical investigations of the simplest models for the spread of epidemics. It will, moreover, provide training in a number of the mathematical methodologies effective in such applications, and much more broadly in systems-biology studies. The hypotheses it will explore are that there is more to be understood about even these simple formulations and that their study can provide additional intuition that is of value in interpreting and mitigating spread.

The project will be devoted to the study of ordinary differential equation formulations, initially involving the very well-established SIR (susceptible-infected-removed) and SEIR (susceptible-exposed-infected-removed) models. It will involve the application of a combination of numerical simulations, dynamical-systems approaches and, especially, asymptotic arguments to characterise in detail the dependence of the dynamics on the associated parameter values. Key quantities to be explored include the peak levels of infections and their total numbers over the course of the epidemic. With these results in hand, numerous generalisations will be accessible, notably to explore the effects of non-pharmaceutical interventions, vaccinations and effective anti-virals, the development of new viral strains and the implication of reinfections.

The models to be studied form the building blocks of much more sophisticated formulations that seek greater realism (encompassing structured populations, spatial heterogeneity and stochastic effects, in particular). The motivation for the above work is two-fold, firstly that additional model complexity can sometimes limit intuition, due directly to that complexity, and that developing understanding from the ground up will equip the student subsequently to investigate much more complicated frameworks.

This project would suit a full time student or a student working on a part-time basis over a longer period.

What overall scientific training will the student receive during the project?

The student will gain experience in the formulation of mechanistic mathematical models relevant to medical and biological applications and in a variety of the methods (both computational and analytical) effective in the study of such models. The field currently has, for obvious reasons, an unusually high profile and the project should not only give the student insight into the value of theoretical approaches in such contexts but also experience in seeing the real-world implications of mathematical results that may at first sight appear rather abstract.

A personal statement from John

"Because of the timeliness of the topic, I have recently pursued some preliminary investigations that have convinced me of the scope and potential value of the proposed studies. I believe, moreover, that the work would provide motivation for a student subsequently to apply their developing mathematical skills to problems of considerable real-world relevance as well as training in, and experience of, techniques that are of wide applicability in medical and biological contexts."