

Summer Project 2018 – Jennifer Dingwall

As an undergraduate with a keen interest in pursuing further study, I decided to undertake a summer research project offered by the Mathematics department and facilitated by the ability to reside in college accommodation over the summer vacation. The project, lasting ten weeks, was supervised by Dr Ruiz-Baier and focused on computing reaction diffusion dynamics in poroelastic deforming structures.

Reaction-diffusion systems can explain many phenomena taking place in diverse disciplines such as industrial and environmental processes, biomedical applications or population dynamics. These models allow us to reproduce chaos, spatio-temporal patterns, rhythmic and oscillatory scenarios, and so on. Nevertheless, in most of the applications mentioned above, the reactions do not occur in isolation. The species rather move within, and interact with, a fluid-solid continuum. In this project I studied the interaction between the basic elements that constitute the growth of biological structures (as e.g. bones and teeth). I began by analysing the standard reaction diffusion equations including advection and a source term, whilst I then introduced the notion of poroelasticity to the project. Finally, these two models were coupled together so that diffusion of a chemical could be modelled within a poroelastic medium.

I used many new mathematical techniques to study the properties of the processes involved. Some of these methods included stability analysis and numerical discretisation. This allowed me to actually solve the coupled nonlinear and multidimensional set of equations. I was introduced to a new programming language which will be invaluable when pursuing a further project during my fourth year of studying. I was able to draw conclusions about the effect of varying parameters and boundary conditions of a poroelastic material on pattern formation through these simulations. For example, we discovered that oscillating a poroelastic material volume at a high frequency inhibited the ability of pattern formation, whilst reducing the coupling effect increased the ability of pattern formation. We linked this highly extensible model to a specific biological application, that of the movement of calcium ions in a brain cell, leaving scope for future exploration.

The project contributed to strengthen my research skills, also in view of interdisciplinary activities that involve mathematics, scientific computing, and biology. It provided me with a perfect scenario for gaining further training in rigorous mathematical modelling and numerical methods, working in close collaboration with the project supervisor. Due to the vacation residence offered by Merton, I was able to spend time with friends who also undertook projects in Oxford. It has encouraged me to pursue a PhD following my undergraduate studies and allowed me to interact with many well-respected researchers.