Mathematical modelling of actin in animals and plants

Supervisory team:
Main supervisor: Dr David Richards (University of Exeter)
Second supervisor: Dr Mike Deeks (University of Exeter)
Prof Harry Mellor (University of Bristol), Dr Imogen Sparkes (University of Bristol), Dr Helen Dawe (University of Exeter)

Collaborators: Prof Kim Hammond-Kosack (Rothamsted Research), Dr Kirsty Wan (University of Exeter)

Host institution: University of Exeter (Streatham)

Project description:
The actin cytoskeleton plays a vital role in animals, plants and fungi. It forms a branched network within cells, which continually changes shape depending on the current requirements. For example, when a plant is attacked by a pathogen, the plant cells remodel their actin cytoskeleton to deliver immune proteins to the site of attack.

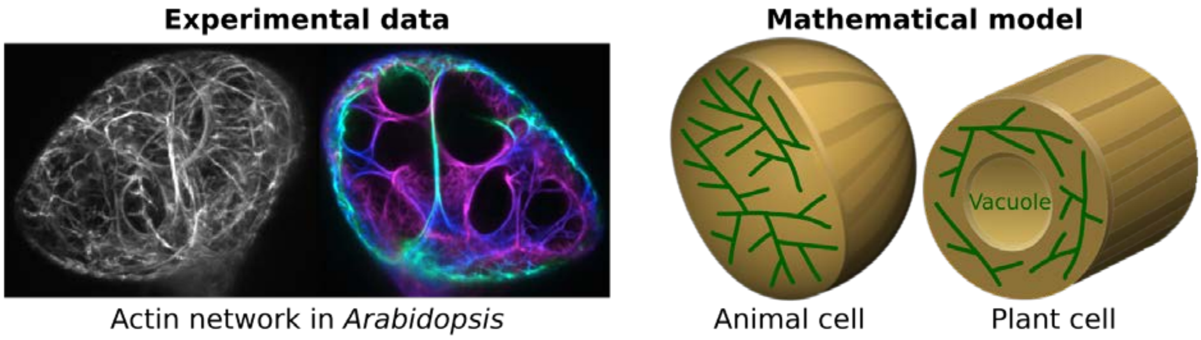
The rules governing how the actin network is formed are still not well-understood. They require a careful balance of filament growth, bundling, shrinking and branching. A particularly fascinating and unexplored question is how conserved these rules are across different organisms, where cells can take radically different sizes and shapes.

For example, animal cells often consist of a single, connected compartment, whereas many plant cells contain a large vacuole that forces the cytoplasm into a thin cylinder near the cell wall (see figure). How do these different geometries affect the shape of the actin network, and how do they influence the rules that govern the network?

Traditional biology tackles problems such as these with a purely experimental approach. However, much quicker progress can be made if mathematical modelling is intimately combined with experiments. This is the program you will follow during this PhD.

You will use a multidisciplinary approach that combines mathematical modelling, computer simulations, microscopy and image analysis. This will allow you to learn a wide range of different skills and techniques, ideal for a future career in academia or elsewhere. You are not expected to already know both mathematical modelling and wet-lab techniques; full training will be provided in both areas during the PhD.

In particular, during this project, you will:
1. Design a mathematical model of the actin network. This will build on our existing model for plants and will involve including filament extension, depolymerisation, branching and capping. These models will then be simulated on a computer using MATLAB or C++.
2. Take microscopy time-lapse images of the 3D shape of the actin network in both animal and plant cells. This will require using a number of state-of-the-art microscopes in both Exeter and Bristol Universities.
3. Develop image analysis software to automatically extract the actin network. This will allow quick, accurate analysis of movies from part 2, which will in turn inform the mathematical modelling in part 1. This interplay between experiment and modelling is a key part of this project and will make for a truly exciting PhD.


Experimental data
Mathematical model
Vacuole
Actin network in *Arabidopsis*
Animal cell
Plant cell