Suggested title of dissertation:

Modelling collective cell motility

Dissertation supervisor:

Prof Philip K Maini

Description of the proposal:

Collective cell motility occurs in many areas in biology and medicine, including development, wound healing and cancer. Many mathematical models have been proposed to describe this phenomenon. They range from single/coupled reaction-diffusion equations (that account for cell production, diffusion, and directed cell motion, in response to chemical/physical signals), integrodifferential equations (in which the integral kernel is chosen to model non-local signalling), individual (discrete) cell-based models (in which cells are modelled as discrete entities and chemical signals are modelled via a partial differential equation). Despite a great deal of research into this area, there are still many open questions that need to be addressed. A possible focus of this topic is cranial neural crest invasion, which is vital for normal development and also offers insights into how to tackle highly invasive cancers, such as melanoma.

Possible avenues of investigation:

1. Consider a partial differential equation model for collective cell motility on a growing domain and determine, using a combined analytical and numerical study, under what conditions successful invasion can occur. Extend the formulation to include volume exclusion.

2. Formulate an integrodifferential equation model approach to this example.

3. Carry out a detailed numerical investigation of a previously proposed discrete model to understand more fully how different proposed signalling mechanisms lead to different behaviours.

Pre-requisite knowledge:
B5.5 Further Mathematical Biology (essential) (https://courses.maths.ox.ac.uk/node/36417)
B5.2 Applied Partial Differential Equations (essential) (https://courses.maths.ox.ac.uk/node/36395)
B6.1 Numerical Solution of Differential Equations I (useful) (https://courses.maths.ox.ac.uk/node/36448)
B5.1 Stochastic Modelling of Biological Processes (useful) (https://courses.maths.ox.ac.uk/node/36382)
B6.2 Numerical Solution of Differential Equations II (useful) (https://courses.maths.ox.ac.uk/node/36456)

Useful reading:

- J.D. Murray, Mathematical Biology, II: Spatial Models and Biomedical Applications (2003, Springer) Chapters 1, 5.
- L. Dyson, P.K. Maini, R.E. Baker, Macroscopic limits of individual-based models for motile cell populations with volume exclusion, Phys. Rev. E, 86, 031903 (2012).
- K.J. Painter, J.M. Bloomfield, J.A. Sherratt, A. Gerisch, A nonlocal model for contact attraction and repulsion in heterogeneous cell populations, Bull. Math. Biol., 77, 1132-1165 (2015).
- M. Simpson, Exact solutions of linear reaction-diffusion processes on a uniformly growing domain: criteria for successful colonization, PLoS ONE, 10(2): e0117949. doi:10.1371/journal.pone.0117949 (2015).
- A.J. Trewenack, K.A. Landman, A travelling wave model for invasion by precusor and differentiated cells, Bull. Math. Biol., 71, 291-317 (2009).
- R. McLennan, L. Dyson, K.W. Prather, J.A. Morrison, R.E. Baker, P.K. Maini, P.M. Kulesa, Multiscale mechanisms of cell migration during development: theory and experiment, Development, 139, 2935-2944 (2012).

Further references:

- R. McLennan, L.J. Schumacher, J.A. Morrison, J.M. Teddy, D.A. Ridenour, A.C. Box, C.L. Semerad, H. Li, W. McDowell, D. Kay, P.K. Maini, R.E. Baker, P.M. Kulesa, Neural crest migration is driven by a few trailblazer cells with a unique molecular signature narrowly confined to the invasive front, Development, 142, 2014-2025, (2015).

- T. Hillen, K.J. Painter, A users guide to PDE models for chemotaxis, J. Math. Biol., 58, 183-217 (2009).