Research Interests

My research interests center on mathematics applied to real-world problems, specifically within the biological sciences. These efforts often lead to both interesting mathematical results and helpful biological insights. Brief descriptions of these projects can be found below. Fuller descriptions can be found on my website: http://www.math.lsa.umich.edu/~ gammack.

At Michigan I have sought out undergraduates to do Independent Studies with me. An Independent Study is a research project worth between 1 and 4 credits. Currently, I am supervising a mathematics undergraduate student who came up with the idea of modeling the spread of fungus. While this model is in very early stages, the same student worked with me last year on the cellular reaction to Anthrax exposure. He developed an interesting model combining the effects of Anthrax on the body and the initial immune response. As the model was large, analytical progress is hard and therefore we have been using Matlab to investigate the effects of various parameters.

Previously, I had two independent study students who wanted to work with me on the *atherosclerosis* project, discussed below. Rather than study the specific model, they wanted to learn and understand some of the techniques involved. Therefore, I introduced them to differential geometry and perturbation methods and demonstrated how these could be applied in fluid mechanics.

1 Patterning in the root epidermis of *Arabidopsis*

The motivation for this project is to understand how patterns of root-hair and non-hair cells form in the *Arabidopsis* plant. The actual mechanism for this is dependent on a variety of gene networks and on positional cues that the cortical cell imposes on the epidermal cells.

At present we are trying to establish reasonable parameter values for the model. This includes examining the forms of the reaction terms. In addition I am supervising an independent study student who is working on this project. She is investigating the homogeneous steady states of the nonlinear system with the aim of further focussing in on the correct parameter regime.

2 Flow in Coronary Arteries

Heart disease, and in particular *atherosclerosis* is responsible for a third of all deaths in the Western World. Atherosclerotic plaques, the precursor of full blown disease, are located at regions of low wall shear stress in coronary arteries.

I modelled Newtonian fluid flows in pipes with non-uniform curvature and torsion. The equations are derived by describing a pipe with a fixed radius and a centreline that varies with its arc-length. Using a rotating coordinate system, analytical and computation solutions were found and the effects of both steady and unsteady pressure gradients have been studied. Additionally, I have studied particle tracking in helical pipes. In this model it was shown that helicity can, in certain circumstances, produce increased longitudinal transport.

3 *Mycobacterium* tuberculosis (Mtb) infection

Tuberculosis is the number one cause of death by infectious disease in the world with approximately 3 million deaths per year. The immune response to Mtb infection is the formation of multicellular spheroidal lesions, called granulomas.

I have developed two new models of Mtb infection incorporating macrophage phagocytosis and intracellular bacteria replication. The first model uses a system of reaction-advection-diffusion equations and the method of internal states to model the initial reponse to infection. The second model is a metapopulation model.

4 Tumour Biology

The tumour suppressor gene, p53, plays an important role in tumour development. Under low levels of oxygen (hypoxia), wild-type p53 cells undergo apoptosis (cell death) whereas mutant p53 cells may survive and stimulate angiogenic growth factors that promote tumour vascularization.

My research has focussed on how mutations in the p53 gene affect tumour growth. Using an ODE approach I examined how a mixed population of wild-type and mutant cells are effected by alternating rounds of hypoxia and normoxia (normal oxygen levels).

5 Tissue Vascularization

The formation of spatial patterns and the mechanisms which create them are among the most crucial issues in developmental biology. For example, this occurs in: the formation of new blood vessels; embryonic growth; and many other system. Vast ranges of pattern and structure in animals are a consequence of a homogeneous mass of dividing cells and while much progress has been made in the understanding of these basic mechanisms the definitive details of any single pattern forming mechanism remains unknown. There exist many mechanisms which are thought to play a role in the formation of cellular patterns and studies have focused on two main views of pattern generation.