IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Modeling and simulations of collective behaviour by self-propelled particulate fluids**	
Project Number	IMURA0328	
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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?
(*Feel free to nominate more than one. For more information, see www.iitbmonash.org)*

1. Advanced computational engineering, simulation and manufacture
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

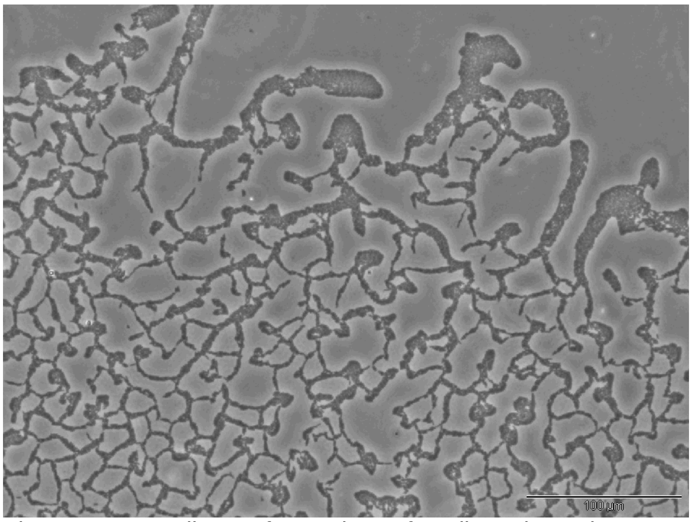

Fig. 1: An expanding surface colony of motile pathogenic bacteria: Finger-like rafts of cells co-operatively and rapidly spread over surfaces, such as tissue surfaces. The structures that thus form are reminiscent of patterns observed in flows of ordinary immiscible fluids in thin films. [Image courtesy Dr C. B. Whitchurch, i3 Institute, University of Technology Sydney]

The Research Problem

Many biological systems involve coherent motion of large populations of self-propelled particles. The collective motion looks remarkably like viscous fluids, but unlike ordinary fluids, these are "self-propelled". Can we use **mathematical modeling and computational fluid and solid mechanics** to provide fresh insight into complex biological and medical questions?

Project Aims

Our goal is to **develop mechanobiological models and simulations** for systems such as advancing surface swarms of bacteria. The project consists of the following broad steps:

- setting up simple models inspired by fluid mechanics to understand the shapes and structures that are observed in these systems (see Fig. 1 above);
- develop particle-level simulations of dense collections of self-propelled;
- develop methods for analyzing experimental data obtained by tracking cell positions and orientations, so that we can compare with modeling and simulation results.

Expected Outcomes

One of the problems that this study will investigate is the morphology and dynamics of bacterial biofilms. Our insights may suggest novel mechanical strategies to control the spread of bacterial infections in medical implants.

This is a challenging project in the emerging and highly interdisciplinary field of computational bioengineering, and is aimed at advancing fundamental understanding as well as developing new computational techniques. **The project requires a strong background in mathematics, computation and programming. The work will involve numerical analysis, discretization of partial differential equations, linear and nonlinear stability analysis, probability and statistics, etc. The project also involves understanding the physics of mechanical behaviour and flow properties of complex materials such as liquid crystals.**

This is an ideal stepping-stone to either an academic or industrial career in advanced fluid computation, especially in micro/nano fluidics and bioengineering. **Prospective applicants should note that THIS IS NOT AN EXPERIMENTAL PROJECT and there is no scope for microbiological, biochemical, bioinformatics experiments.**

How will the project address the Goals of the above Themes?

The models and simulations developed in this study address Goal 1. The subject of these simulations are stem cells – this addresses Goal 6.

Additional costs and equipment

This is a computational project; all programs will be developed in-house or use software already available at supercomputing facilities in IITB and Monash. No other equipment or consumables are required. The student will be required to spend an extended period of time at Monash University. This may require about $11,000 which will be sourced from funds available to Dr. Ranganathan at Monash.

Capabilities and Degrees Required

- Undergraduate degree in chemical/mechanical engineering or physics/mathematics
- Strong undergraduate performance in mathematics, computation, fluid mechanics/transport phenomena/ reaction engineering