IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Cluster and conquer: structure and dynamics of self-organized colonization of soft materials by populations of active, self-propelled particles	
Project Number	**IMURA0961**	
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Research Clusters:

Research Themes:

Highlight which of the Academy's CLUSTERS this project will address? *(Please nominate JUST **one**. For more information, see www.iitbmonash.org)*		**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	*Material Science/Engineering (including Nano, Metallurgy)*	***1***	*Advanced computational engineering, simulation and manufacture*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*	2	*Infrastructure Engineering*
3	*Math, CFD, Modelling, Manufacturing*	3	*Clean Energy*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*	4	*Water*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*	5	*Nanotechnology*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*	6	*Biotechnology and Stem Cell Research*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*	7	*Humanities and social sciences*
8	*HSS, Design, Management*	8	Design

The research problem

In biology, we see many situations where an invading species consisting of large numbers of mobile individuals colonizes a soft material or substrate. Disease-causing bacteria often consist of mobile cells that quickly spread through soft tissue layers to start an infection. Cancer cells break out of tumours in a process called metastasis into the surrounding tissue before spreading to other parts of the body. Even the formation of root systems can is due to plant cells pushing through the granular material of the soil environment.

What determines the speed at which such invasions take place? At first glance, it may appear that the answer to this question will vary from system to system. In prior work, we have used computer simulations to show that invasions of soft materials by mobile particles share generic features. We have observed that, depending on how stiff the material is and how quickly an individual particle moves, particles can cluster together to spread more rapidly. There are many fascinating features of this behaviour that we do not yet fully understand, such as the complex fractal structures of the path networks created by the particles.

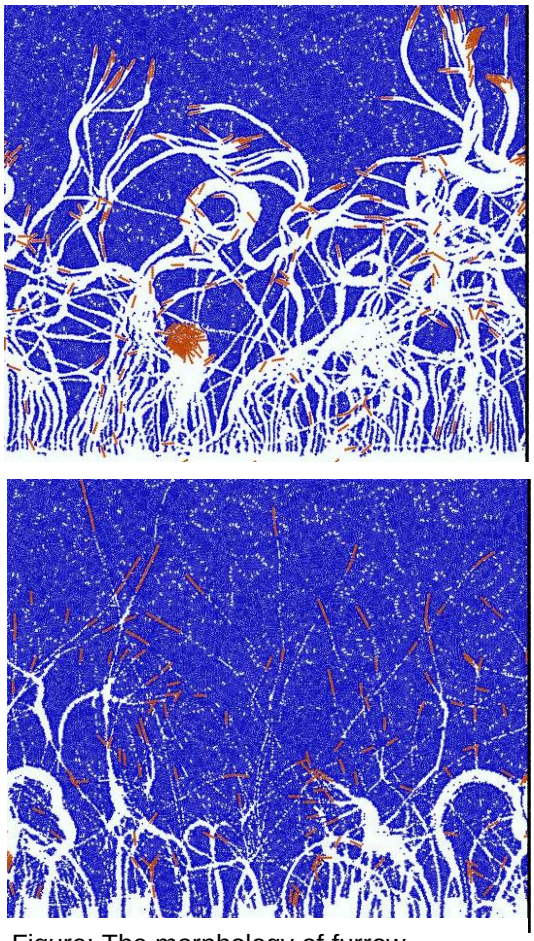

Figure: The morphology of furrow networks formed by invading rod-shaped particles (red) in soft substrates (blue) depends sensitively on substrate stiffness.

Project aims

Our goal in this project is to develop the ability to clearly predict the rate at which colonization will occur, given the properties of the substrate and the invading particles. On the one hand, this would firstly enable the development of therapeutic strategies to slow down or even stop nasty infections, particularly by antibiotic-resistant “superbug” bacteria in hospitals. It may also contribute valuable insight into metastases in cancer. On the other hand, it would enable the novel design of processes that mimic biology, wherein artificial self-propelled particles driven by chemical reactions could be used to create minimally-invasive fractal networks through soft materials. Such network structures could enhance thermal and electrical conductivity of the soft materials.

Expected outcomes

We expect to publish papers in high-impact journals elucidating the regulation of the mechanics of pattern-formation in tissues. The PhD project will provide training in several areas: advanced modelling of systems of “active” self-propelled particles; novel simulation tools and open-source packages for large-scale parallel simulations of particles; analytical techniques for quantifying complex morphologies; techniques for understanding and explaining pattern-formation. As such, the project can be a springboard for an exciting research career in microsale and macroscale modelling and simulations of complex materials with applications in biophysics, biomedical engineering, microfluidics or in conventional solid or fluid mechanics.

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

The project aims to explain the origins of phenomena observed in biological processes using modelling and large scale computer simulations. It therefore addresses Themes1 & 6.

Capabilities and Degrees Required

Strong academic background in Chemical/Mechanical Engineering or Physics.
Strong interest in a long-term career in modelling and computation

Potential Collaborators

A collaboration between Profs. Raghu Chelakkot and Mandar Inamdar at IITB and Dr. Prabhakar Ranganathan at Monash is already in progress.