IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Deep in the Lung: Nano-particle transport and deposition in alveolar flows	
Project Number	**IMURA0474**	
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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**

The research problem

The transfer of aerosols into the body - whether desirable (inhalants, drugs) or undesirable (pollutants, pathogens) – occurs in small sacs in the lung known as alveoli. Under normal breathing conditions, alveolar air flow and particle transport properties control whether such nano-particles attach to the lung, a problem of widespread interest ranging from environmental health and safety to pharmaceutical drug delivery. The alveolar airflow is a periodic cavity flow and is typically Stokesian, where transport is typically considered to be reversible. , These periodic cavity flows can exhibit chaotic mixing, leading to complex flow topologies and significantly altered transport dynamics that are not easily predicted based on the Eulerian flow field. Several outstanding questions arise regarding the nature of these complex 3D chaotic flows and associated transport dynamics; however it is well established that the impact of chaotic mixing upon particle transport and subsequent attachment is significant. As such, understanding how the alveolar flow interacts with nano-particle transport (e.g. diffusion, inertia, sedimentation) will provide valuable insights into nano-particle deposition, with direct application to aerosol safety and drug delivery.

Project aims

This project will be jointly supervised by Dr. Guy METCALFE from CSIRO

Our aim in this project is to use a combination of computational methods and dynamical systems theory to elucidate the factors which control transport and deposition of nano-particles in alveolar flows, and to use this knowledge to develop criteria for the deposition of aerosol particles for OHS and drug delivery. The project will also deliver fundamental understanding of chaotic transport and 3D lobe dynamics, and the interaction of active particles with such flows. These fundamental research areas are still very poorly understood.

Expected outcomes

The expected outcome of this project will be new understanding of the transport mechanisms relevant to alveolar flows, specifically the impact of 3D lobe dynamics in cavity flows under periodic forcing, a problem at the forefront of dynamical systems research. This knowledge will assist in classifying coherent structures in alveolar flows and the impact upon the transport of passive particles. These insights between the flow field and the mixing template will be extended to the physics of nano-particles, including the impacts of particle diffusion, inertia, and gravity, as well as perturbations of the flow field. One of these latter scenarios will be chosen in the third year of the Ph.D. in order to directly investigate a real world mixing application.

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

The direct outcomes of this project, respectively fundamental insights into the biomechanics of alveolar transport, and development of criteria for the deposition of nano-particles in the lung, directly align with the goals of both the Biotechnology and Stem Cell Research Theme and the Nanotechnology Theme. In particular, basic research into the mechanisms which control flow, mixing and deposition in alveoli over a range of breathing conditions and nano-particle properties has direct relevance to biotechnology and biomechanics, and is expected to deliver rules for the optimal design of aerosol particles for inhalants and drug delivery.

With respect to the nanotechnology Theme, a burgeoning research area is that of the health impacts of nano-particles, where the question of particle deposition in the lung is of direct concern. A range of environmental (smoke, dust, fumes, bacteria, pollen) and engineered aerosol nano-particles present a potential health risk, and the deposition of such particles is strongly dependent upon the alveolar transport properties. The insights and research outcomes delivered by this project shall directly inform safety guidelines for a range of such nano-particles.

The computational fluid dynamics tools and dynamical systems theory required by this project are of direct relevance to the goals of the Advanced computational engineering, simulation and manufacture Theme. Specifically, elucidation of the mechanisms which govern flow, transport and deposition will require the development and extension of existing computational tools for understanding and simulating particle transport, and the dynamical systems theory shall provide novel approaches to simulating and analyzing this phenomena.

This project will be ideally suited to a multi-disciplinary approach, with expertise in Mathematics, Engineering and one or more of the basic Sciences being important to its success. Whilst the basic research undertaken in this Ph.D. project involves advanced computation, the outcomes are of direct relevance to biotechnological and nanotechnology applications.

Capabilities and Degrees Required

The student for this project must have the following skills

- Good mathematical background, with a very good understanding of numerical methods
- Demonstrated experience with computer programming, either with a high level language (such as C, C++, FORTRAN) or expertise in developing complex applications with MATHEMATICA or MATLAB.
- Good communication skills and an ability to interact with people from different scientific backgrounds.
- Desirable is some background in Fluid Mechanics related to one of: Mechanical Engineering, Chemical Engineering, Geoscience, Atmospheric Science, Biology, Chemistry, Physics.
- Experience with dynamical systems is desirable although not essential

Please provide a few key words relating to this project to make it easier for the students to apply.

Key Words: Biomechanics, Fluid mechanics, computational modelling, dynamical systems