IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Multiphase mathematical modelling of tumour spheroid growth under drug treatment**
Project Number	**IMURA0470**

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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

Ovarian cancer is considered the leading cause of gynecological cancer deaths worldwide. A critical step in the spread of ovarian cancer is the formation of multicellular spheroids from cells shed from the primary tumour. In vitro and in vivo experiments have shown that mechanical stress from the surrounding microenvironment play a critical role in cancer spheroid growth over time and responsiveness to anti-cancer chemotherapy.

Since in vivo tumour investigations cannot be performed non-invasively and in vitro models are costly and time-consuming, biologically motivated mathematical models provide a useful investigative framework. Mathematical models that describe tumour spheroid growth can provide the means to identify elements of the process that can be manipulated for improved clinical management. The models can generate predictions that could not have been anticipated otherwise, thereby stimulating further biomedical research and reducing the need for costly experiments.

In this project, a multiphase mathematical model will be developed in spherical coordinates to simulate avascular tumour spheroid growth under conditions of different microenvironment stiffness and anti-cancer treatment. Conservation of mass partial differential equations (PDEs) will be derived for the evolution in time and space of the volume fractions of cellular species and the extracellular fluid, where cell growth and death terms will be dependent on the local nutrient concentration. This will be coupled with equations of momentum conservation. Constitutive assumptions will be made; for example, the extracellular fluid will be treated as an inviscid fluid and the cellular species as a viscous fluid. Reaction-diffusion equations for the nutrients (e.g. oxygen) will also be derived. Decision-making based on the resulting model requires reliable and detailed quantitative information on its solution. Advanced numerical methods will be used to approximate the solution of the system of PDEs describing the growth of tumour spheroids.

Project aims

This project aims to:

(a) Develop a multiphase mathematical model in 3D spherical coordinates for tumour spheroid growth

(b) Numerically approximate the model developed in (a) in 3D spherical coordinates

(c) Provide biological insight into tumour spheroid growth in 3D.

Expected outcomes

(a) Novel mathematical models of tumour spheroid growth in 3D spherical coordinates under conditions of different microenvironment stiffness and anti-cancer treatment

(b) For the first time, numerical simulation of multiphase models of tumour growth in 3D

(c) Quality international research publications;

(d) Joint supervision of a Ph.D. student from India which will help to boost the research in Numerical Analysis and Mathematical Biology in the country;

(e) Initiating collaborative research work between Monash University and IIT Bombay in the broad area of numerical analysis and mathematical biology

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

We would be addressing the **Advanced computational engineering, simulation and manufacture** theme, by developing abstract mathematical and computational models to describe the process (tumour spheroid growth). The results of this work will contribute to the **Biotechnology and Stem Cell Research** theme by furthering multidisciplinary research in biology-related areas.

Capabilities and Degrees Required

Candidates should

1. have a strong mathematical background;
2. have done courses in Partial Differential Equations and Numerical Analysis at the Masters level;
3. knowledge and aptitude in computer languages – like Matlab, Fortran90, C or C++ – is essential.

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

Mathematical Biology, Multiphase Modelling, Numerical Methods