

An Indian-Australian research partnership

Project Title:	Manufacturing 'Fish-Gill' Biomimetic Structures by Microstereolithography	
Project Number	IMURA0228	
Monash Supervisor(s)	Dr. Mainak Majumder	Full names and titles
Monash Primary Contact:	mainak.majumder@monash.edu +61 3 9905 6255	Email, phone
IITB Supervisor(s)	Dr. Prasanna Gandhi	Full names and titles
IITB Primary Contact:	gandhi@me.iitb.ac.in	Email, phone

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

Biomimicry (from *bios*, meaning life, and *mimesis*, meaning to imitate) is a new discipline that finds solutions to everyday problems by understanding and mimicking nature's time-tested approaches and strategies. Of interest here is the highly evolved organization of 'fish-gills' which can form the design basis of advanced gas-exchange systems. We are interested in mimicking the hierarchical features of the fish-gill structure to engineer advanced membranes for fluidic applications and to use this membrane scaffold as a model to understand mass transport processes in these biological structures.

The essential features of the fish-gill super-structure which enable the highly efficient gas-exchange are: (i) the **macroscopic lamella** which comprises (ii) the **branched capillaries** encapsulated under a very thin (iii) **epithelial tissue**. The macroscopic lamella allows incoming water (see functional diagram of secondary lamella) to form a cross-current flow circuit with the blood flow. The exchange of dissolved oxygen and essential nutrients takes place through the thin epithelium and the capillaries inside the lamella (see figure 1).

Microstereolithography (MSL) is a recent technology becoming increasingly popular for fabrication of true 3 dimensional structure using mainly polymers. The method uses a CAD model of component to be fabricated and processes it in software and subsequently prints a 3 dimensional microcomponent layer by layer. Figure 2 shows a picture of a novel (Patent pending) MSL system developed at Suman Mashruwala Advanced Microengineering Laboratory IIT Bombay along with 3D scaffolds fabricated using the system. MSL processes coupled with nanofabrication processes would be an ideal way to realise large size components having nanoscale features. This process is, therefore, an ideal platform for fabrication of the proposed fish-gill structure.

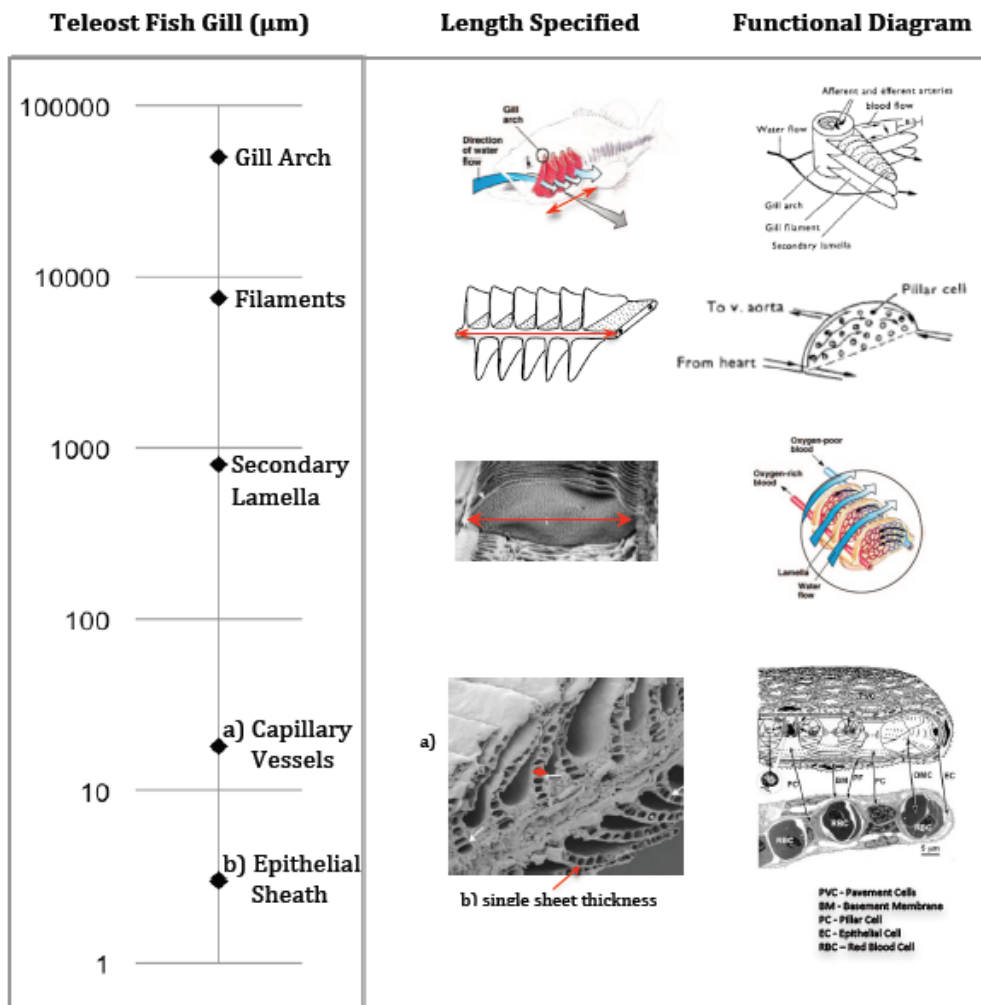


Figure 1: Hierarchical organisation of a typical fish-gill structure.

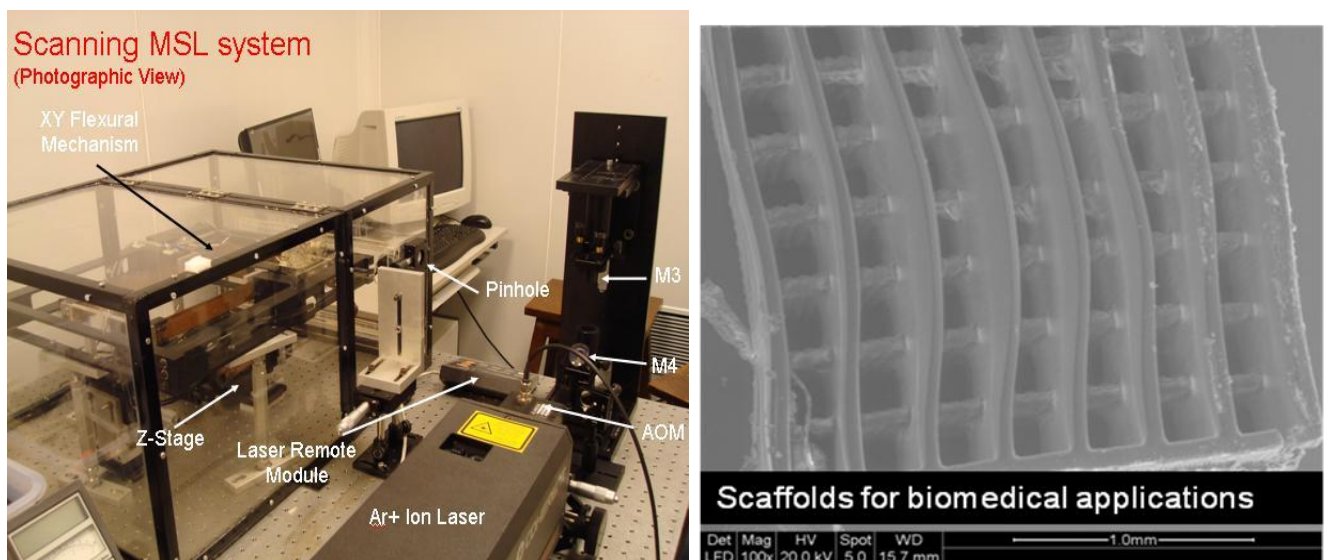


Figure 2: MSL system at IIT Bombay along with scaffolds fabricated using the system.

Project aims

- (i) Development of processes for synthesis of photodefinable nanostructured polymers using acrylates, photoinitiators and structure directing polymers such as poly-acrylonitrile using electrospinning technique
- (ii) Controlling the dimensions of nanofibers and developing protocols for dispersing nanofibers into solutions
- (iii) Development of 3-D patterning technologies for solution dispersed nanofibers
- (iv) Development of hierarchical microfluidic fish-gill like structures from consolidated structures
- (v) Measurement and modelling of transport processes in the hierarchy of macro- and micro-spaces

Expected outcomes

The generic platform of the fish-gill membrane can be engineered for several applications and can spawn a wide variety of separation processes depending upon the choice of the construction material. For example, the nature of the 'selective' epithelial tissue, engineered here through the i-CVD process several potential applications in CO₂ sequestration (if the selective layer is polyamines), and desalination by membrane distillation (if the selective layer is Teflon) can be envisioned. While it is very obvious that the enhanced surface area of the targeted structure will increase the efficiency of mass transport, it is also likely that the inherent hydrodynamics of the micro-macro-structure can lead to better understanding of **transport processes in biological systems**. Given the novelty of the research theme several high quality articles in reputed journals such as NanoLetters, ACS Nano can be expected.

In addition, the project can advance the technology of fabrication of large scale structures with nanoscale features not only for the above mentioned but other applications as well.

Capabilities and Degrees Required

List the ideal set (up to 8) of background and capabilities required in a student for this project noting that the more specific you make it, the less likely that you will get a candidate that matches the requirements exactly.

The students involved in this projects should possess backgrounds in:

- (i) Polymer Science and Engineering/Materials
- (ii) Chemistry
- (iii) Microfabrication Technologies
- (iv) Chemical Engineering