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Modelling of a Single Cardiomyocyte Interaction with a Microcantilever Using COMSOL Multiphysics

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Introduction

- Cardiac muscle consists of interlacing bundles of cardiomyocytes (muscle cells) Cardiomyocytes are narrower and much shorter than skeletal muscle cells, being about 0.02 mm wide and 0.1 mm long.
- With the discovery of iPS cells, currently efforts are underway to generate cardiomyocytes in vitro.
- Use of iPS cell derived cardiomyocytes will require careful characterization of their properties.
- If it is possible to measure contractile properties of a single cardiomyocyte cell, then it can lay the foundation for quantitatively understanding the mechanism of heart failure and molecular alterations in diseased heart cells.

Background and governing equations

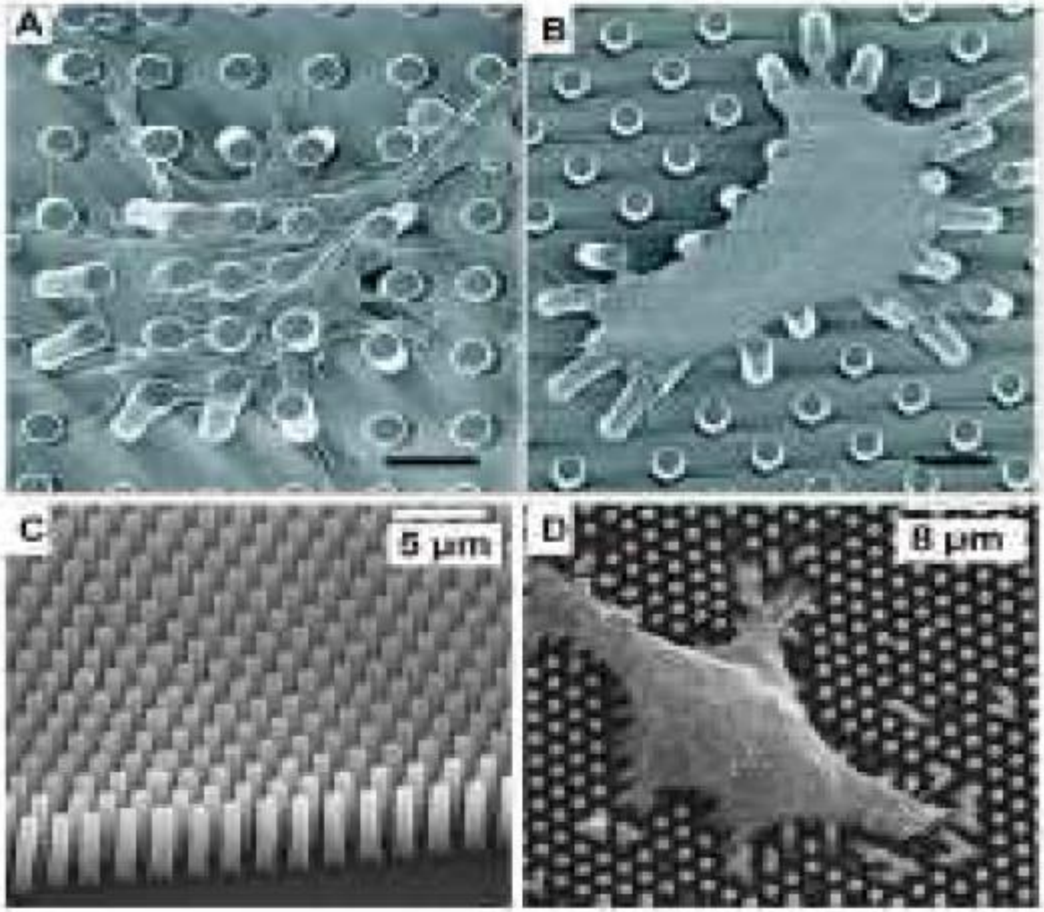
- Navier stoke's equation for describing the flow of incompressible fluids where u is the velocity field p is the pressure .

$$\rho\frac{\partial \mathbf{u}}{\partial t} - \nabla \cdot [-p\mathbf{I} + \eta(\nabla \mathbf{u} + (\nabla \mathbf{u})^T)] + \rho((\mathbf{u} - \mathbf{u}_m) \cdot \nabla)\mathbf{u} = \mathbf{F}$$

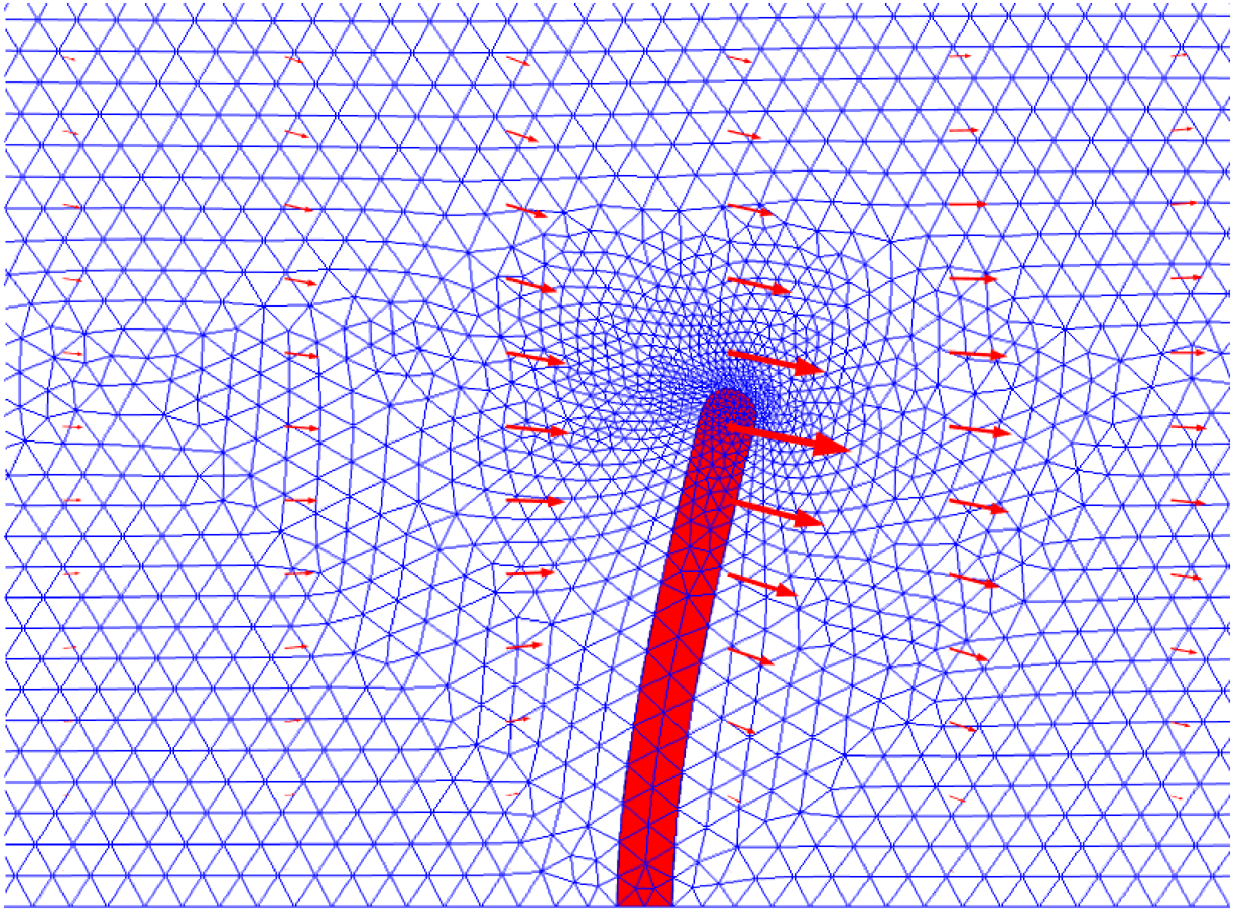
$$-\nabla \cdot \mathbf{u} = 0$$

- Cellular substrate is considered as an incompressible fluid over a bed of vertical microcantilevers.

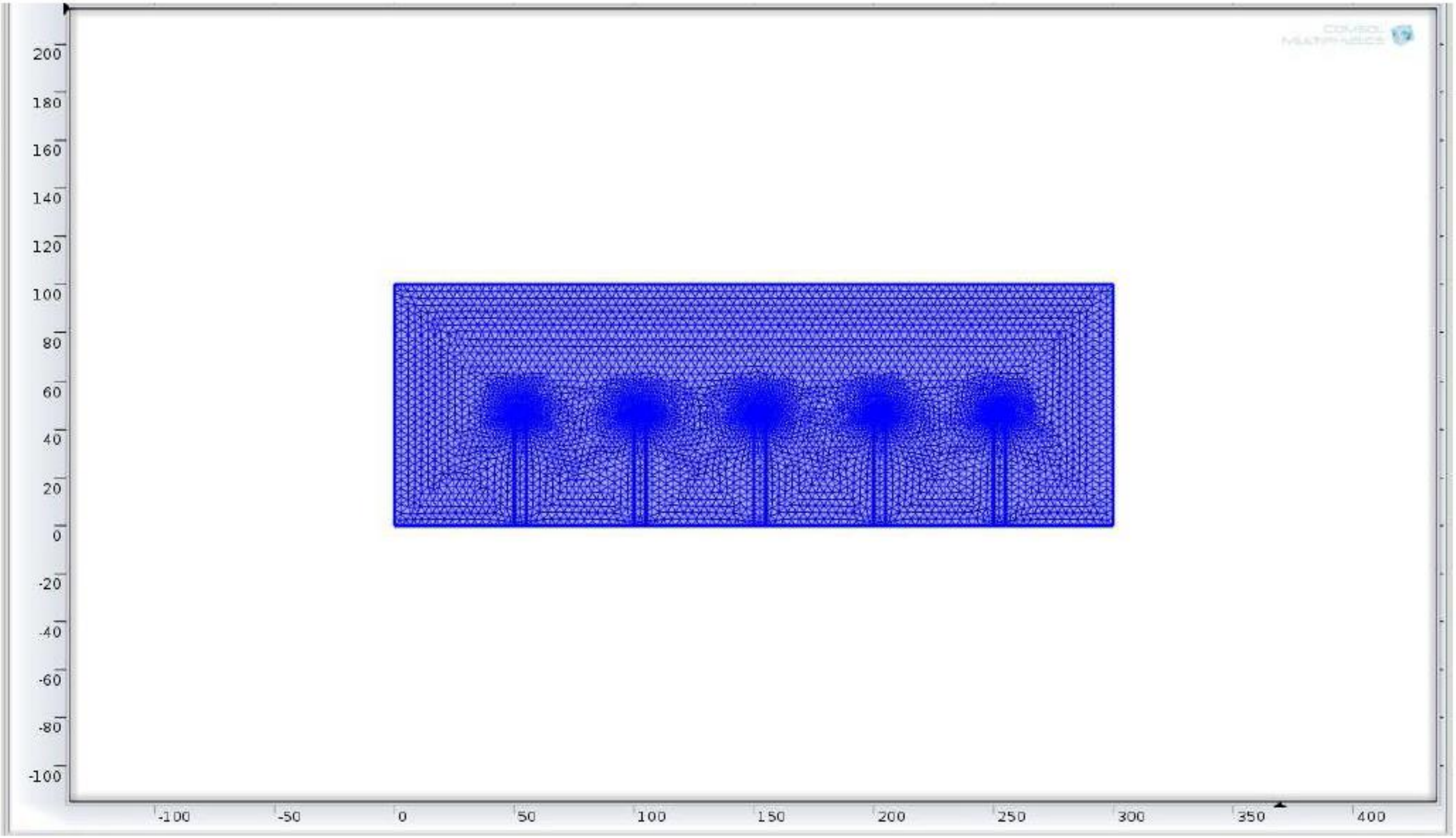
Array of Vertical Microcantilevers



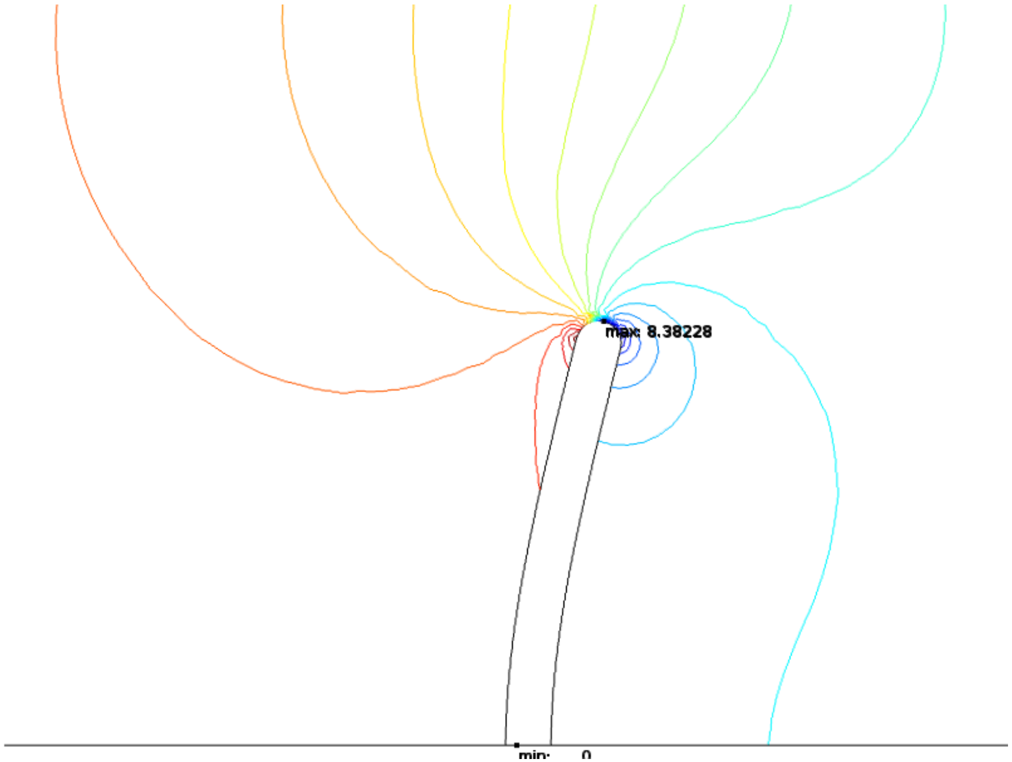
Simulations – Single cantilever deflection



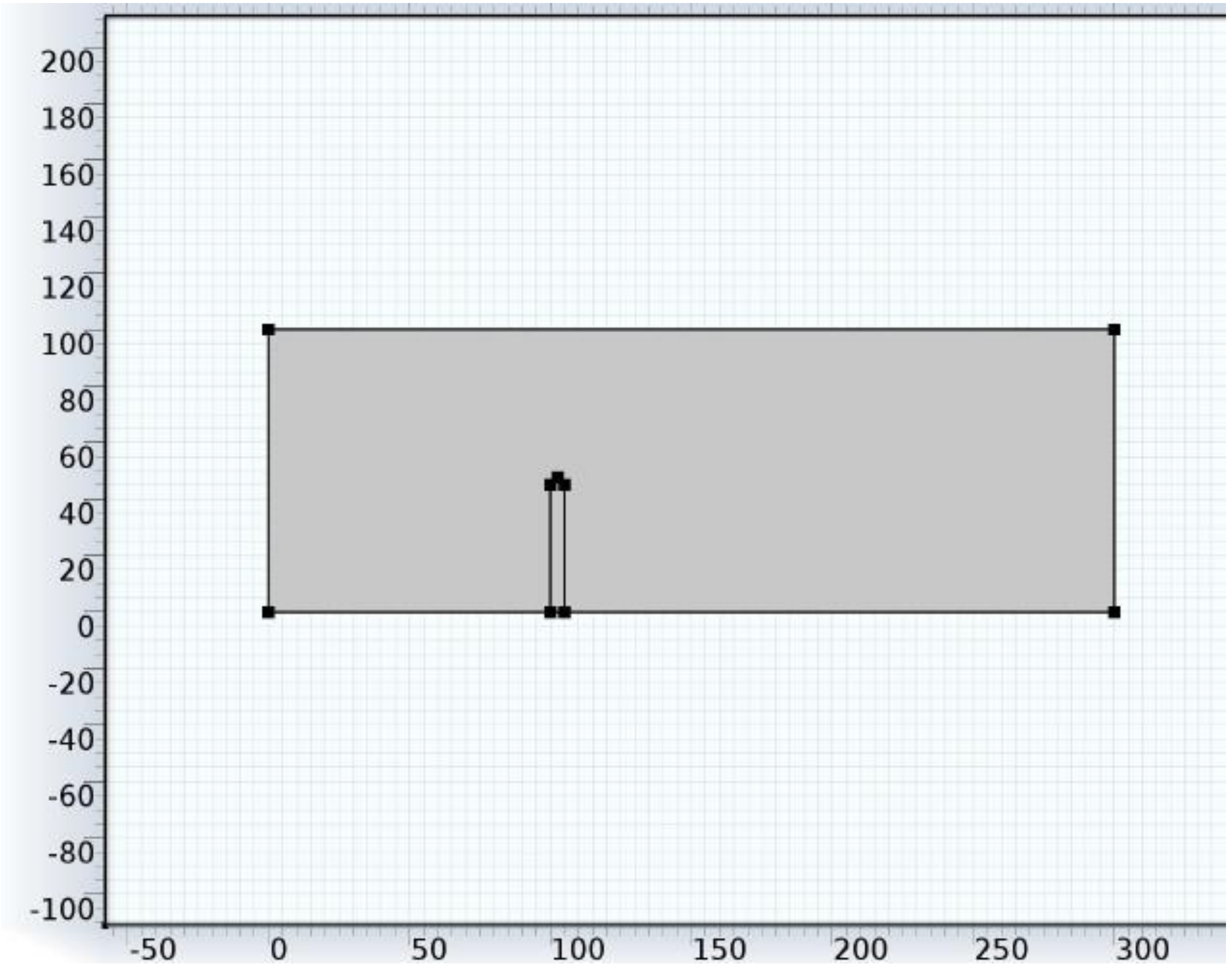
Simulations – multiple cantilever deflection



Simulation – Pressure and Displacement



Geometry should look like:



Simulation conditions

- Density – 950 kg/m3
- Viscosity – 0.78 x 10-3 kg/m3
- Stiffness constant – 0.002 N/m
- Maximum Deflection produced :8.3 um.
- Microcantílever dimensions – 500 um in length, 100 um in width, 0.9 um in thickness
- Estimated forces in the range of nanonewtons in sync with actual measured values.

References

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