Modeling and simulation of the dynamics of epithelial/endothelial monolayers

Ismael González-Valverde*, Jose Manuel García-Aznar*

*Multiscale in Mechanical and Biological Engineering (M2BE),
Mechanical Engineering Department,
University of Zaragoza (UZ),
Campus Rio Ebro, 50018 Zaragoza, Spain
e-mail: jmgaraz@unizar.es, web page: http://m2be.unizar.es/

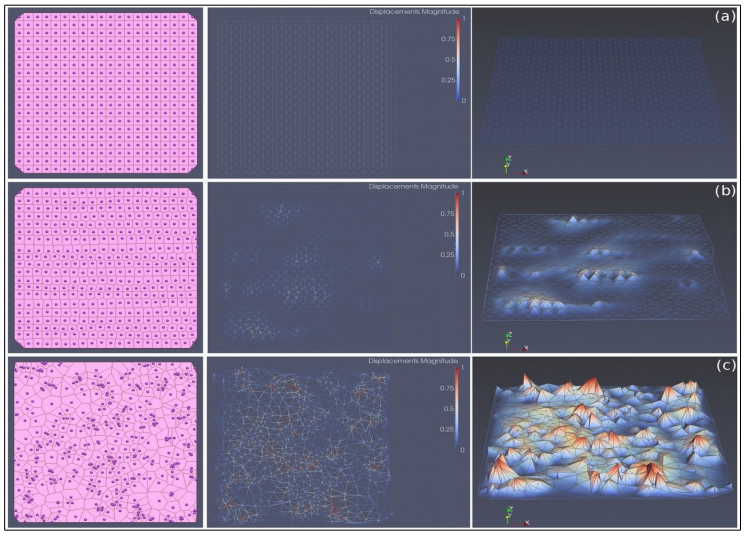

Figure 1. Cell monolayer multiscale model showing cell displacements due to interaction forces generated in different cell distributions: (a) perfect lattice distribution (b) disturbed lattice distribution (c) random distribution.

ABSTRACT

The work presented here is a multi-physic framework that is focused on the simulation of a cell monolayer by the combination of different discrete and continuum models. It is considered mechanical cell to cell interaction, cell signaling and diffusion phenomena.

On the one hand, by the usage of discrete models, we are able to store and manipulate important information about cells in the simulation treating them as individuals. This approach gives us the possibility to develop several ways of interaction between them as a communication network, attraction/repulsion forces derived from potentials or a proliferation subsystem.

On the other hand, it is included in our dynamic framework continuum media numerical techniques as the finite element method. Continuum models are useful to easily describe and simulate different physics of the biological system as the molecular diffusion or cell displacements due to different forces exerted on them.

Therefore, combination of both discrete and continuum models allow us to obtain a flexible tool to represent complex biological systems where there are many different physical and chemical phenomena acting together. For example, in Figure 1 is shown how initial cell distribution affect to the forces generation in order to reorganize the cell monolayer and reach a mechanical equilibrium.

One of the intended applications of this framework is to represent initial stage of new blood vessels generation [1] and try to predict the location of the sprouting due to the mechanical and chemical conditions in the layer. Nevertheless, it can also be applied to other biological systems and processes that typically form cell monolayers.

Acknowledgements: This study is supported by the European Research Council (ERC) through project (ERC-2012-StG 306751) and the Spanish Ministry of Economy andCompetitiveness (DPI2012-38090-C03-01).

REFERENCES

[1] Carmeliet P, Jain RK. Molecular mechanisms and clinical applications of angiogenesis. Nature. 2011 May 19