15th International Symposium on Computer Methods in Biomechanics and Biomedical Engineering
and
3rd Conference on Imaging and Visualization
CMBBE 2018
P. R. Fernandes and J. M. Tavares (Editors)

Abstract ID-135

A STATISTICAL FRAMEWORK BASED ON THERMODYNAMICS AND BIOLOGICAL PRINCIPLES TO PREDICT CELLULAR MORPHOLOGY AND ORIENTATION ON SUBSTRATES WITH LINEAR PATTERNS

Tommaso Ristori[(1)], Gitta Buskermolen[(1)], Siamak Shishvan[(2)], Nicholas Kurniawan[(1)], Carlijn Bouten[(1)], Frank Baaijens[(1)], Sandra Loerakker[(1)], Vikram Deshpande[(3)]

[(1)]Eindhoven University of Technology, Netherlands
T.Ristori@tue.nl, A.B.C.Buskermolen@tue.nl, N.A.Kurniawan@tue.nl, C.V.C.Bouten@tue.nl, F.P.T.Baaijens@tue.nl, S.Loerakker@tue.nl

[(2)]University of Tabriz, Iran
ss2304@cam.ac.uk

[(3)]University of Cambridge, United Kingdom
vsd20@cam.ac.uk

Keywords: Statistical modelling, Contact guidance, Cell orientation, Cell morphology

Summary: It is well known that cells on substrates with alternating adhesive and non-adhesive lines manufactured with the microcontact printing technique tend to align in the direction of these linear patterns. Nevertheless, the underlying mechanisms determining such cellular response are currently unclear.

In this study, we propose a new computational approach to study cells on substrates with alternating adhesive and non-adhesive lines. This computational approach stems from a recent study by Shishvan et al. [1], who developed a new statistical mechanics theory to study the behavior of single cells. As in their study, the focus was on the system comprising the cell and the substrate to model. Each configuration of the system, identified by the contact points between the cell and the substrate, was associated with a magnitude of the Gibbs free-energy. The statistical distributions of the cellular orientation, aspect ratio, and number of adhesive lines touched by the cell were then calculated with the Monte Carlo method, by assuming that cells prefer configurations with low values of the Gibbs free-energy and that, during their life, they strive to maintain a constant homeostatic value of this free-energy. The Gibbs free-energy for every configuration was computed by accounting for the contributions of stress fibers, other passive cellular components (such as cytoplasm and nucleus) and, in addition to what was proposed in Shishvan et al. [1], the adhesions of the cell with the substrate. The comparison between the computational results and experiments performed in our lab confirmed that considering the cellular adhesion contribution to the Gibbs free-energy enables the qualitative prediction of the shape and orientation of cells on substrates having linear patterns with different widths. Therefore, the computational approach of this study has a high predictive potential and can provide valuable information about the behavior and mechanics of cells on substrates with linear patterns. For example, it can be used to investigate the relative importance that the width of non-adhesive lines has on cellular (re)orientation, compared with the width of adhesive lines.

References

[1] Shishvan, S.S., Vigliotti, A. & Deshpande, V.S. The homeostatic ensemble for cells. submitted (2017).