11th. World Congress on Computational Mechanics (WCCM2014)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Fractional hereditariness of Lipid Membranes

K Dayal[2], L. Deseri[1,2,3], P. Pollaci[1,2,] M. Zingales[4,5]
[1]DICAM-University of Trento/IT, [2] CIT-CEE-Carnegie Mellon/USA ,
[3]THMR-Houston Methodist/USA, [4] DICAM-University of Palermo/IT,
[5] LBNMS-Mediterranean Center of Human Health and Advanced Biotechnologies, Palermo/IT

Abstract
In this contribution the authors will introduce some initial results in the analysis of lipid membranes including fractional-order hereditariness. A specific free energy function accounting for elastic and hereditary properties of the bilayer will be reported.
The evaluation of the mechanical stress across the membrane bilayer is a very challenging features since large strain/displacements of the bilayer are involved and configurational changes of the membranes may sensibly affect the stress distribution (see e.g. [1]). The impressive amount of research in terms of elastic free energy as well as of the membrane stress must be supplemented by the hereditariness of lipid membranes that affects the membrane configurations as well as the lipid phase change. Fractional-order calculus will be used to introduce hereditariness of lipid bilayers by means of an small-on-large approach investigating the possibilities arising for non-homogenous equilibria. Such portfolio of configurations essentially depends on the value of the underlying (constant) large strain upon which the lipid bilayer is perturbed.
Previously, some of authors of the present work showed how the elastic behavior of lipid membranes can be obtained in terms of a new Helmoltz free energy that accounts for the quasi-incompressibility as well as for the mean and gaussian curvatures of the membrane during congurational changes. The free energy function contains both local and non-local terms of the control variables. This is a result coming from the dimension reduction of the governing energy, which in turn allows for reduced kinematic fields to describe geometrical changes of such membranes.
In this paper it is shown that the onset of the loss of homogeneous configuration is possible even in the purely elastic case thanks to the interplay between the local and the nonlocal part of the response. An evaluation of the line tension at the very onset of the various situations is given and a frequency analysis of the lipid membrane behavior is discussed. This is pursued by considering lipid bilayers hereditariness in terms of the Staverman Schwartzl free energy that is the energy associated to power-law relaxation.

References

[1] Deseri L., Zurlo G., (2013) The stretching elasticity of biomembranes determines their line tension and bending rigidity. BIOMECH. MODELING IN MECHANOBIOLOGY, DOI: 10.1007/S10237-013-0478-Z

[2] Deseri L., Di Paola M, Zingales M., (2014). Free Energy and States of Fractional-Order Hereditariness, DOI: 10.1016/j.ijsolstr.2014.05.008, INT. J. OF SOLIDS AND STRUCTURES