MAFIA - the seminar you can't refuse

Implications of tissue heterogeneity in cartilage modelling

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12 February 2019
13:15–14:15
in T112

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Trojanova 13, 12000 Praha

Abstract: Current models targeting mechanobiology of cartilage are becoming increasingly refined and complex by the inclusion of ever more details such as heterogeneous distribution of solid matrix within cartilage, fixed charged density, heterogeneous Darcy's law with preferential directions of flow determined by deformation, fibres, compaction effects (the closing of pores), and complex 3D geometries. Despite the undoubted benefit of having a finer description of the cartilage tissue and hence the prospect of capturing its behaviour in a wider context there is at the same time the issue of model verification as the amount of data necessary for parameter estimation and subsequent independent model validation rapidly increases.

In this talk we follow a different path to minimise the problem of overestimation by revisiting the 1D experimentally relevant (confined compression with rotational symmetry) biphasic model which allows for qualitative insight and more reliable parameter estimation. Particularly we shall see that the inclusion of heterogeneity

in the initial solid volume fraction corresponding to the presence of proteoglycans in cartilage matrix has profound implications on both bulk equations, and initial and boundary conditions. This influence is mediated by swelling pressure being a consequence of achieving electroneutrality in the system.

We shall rederive the 1D biphasic model carefully, as the linear bihpasic model previously used that allows for an analytical solution has some limitations in its presentation and derivation and is a special case of the model formulated here with the swelling pressure contribution. Then we continue with exploring the fundamental consequences of heterogeneous distribution of initial volume fraction via the swelling pressure term noting that compactification (pores closing) is naturally reflected in the swelling pressure term.

If time permits, we shall discuss possible replacement of the classically used Donnan theory for swelling pressure by a model reflecting some of the microscopic natures of the cartilage tissue: a macroscale model for swelling pressure that is an upscaled version of Poisson-Nernst-Planck microscopic description. To this end we use the method of multiple scales which is suitable even for systems with slowly varying periodicity.