Rheological Model for Cell Fluidisation Process

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ABSTRACT

Soft active tissues exhibit poroelastic behaviour [1], softening, hardening, and reversible fluidization [2]. Current understanding of these non-linear behaviours is based on several diverse processes taking part at different scales: active protein motors that actuate at the polymeric structure of the cell, (de)polymerization, remodelling of the cytoskeleton, changes in the cytoplasm volume and cell-cell connectivity changes that take place at the tissue level. The aim of this study is to offer a model that can explain these features.

In order to reconstruct tissue dynamics from the multicellular system and represent the reorganisation (remodelling) of the cytoskeleton, we use a cell-centre model, in which each cell is treated as a discrete entity and adjacent cell centres are connected by the poroelastic active element. Neighbouring cells are determined by a modified Delaunay triangulation while cell shapes are determined by a modified Voronoi tessellation (Figure 1, left).

Cell-cell interactions are modelled through specific non-linear elastic laws, and coupled active deformations [3]. In this model, a reversible (elastic) deformation and a non-reversible remodelling and lengthening are considered as two combined effects for a deformation of cross-linked actin filaments under a stretch process. By controlling different rates of cell porosity, we are able to model reversible softening that has been experimentally observed in biomechanical tests performed on epithelial lung cell monolayers (Figure 1, right). [4].

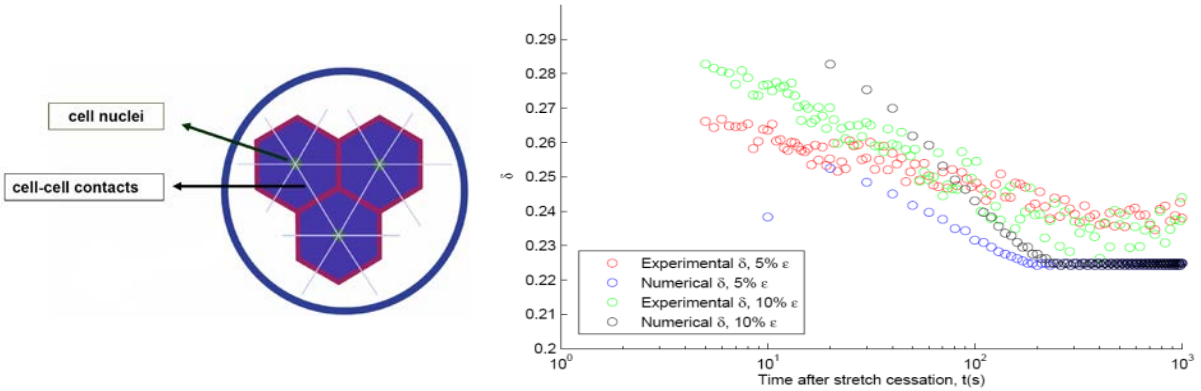

Figure 1: Left: Scheme of the cell-centered model: spheres represent cell nuclei, and red lines the cell boundaries. Right: A single transient stretch drives the phase angle δ up, indicating fluidization of the cytoskeleton.

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