Mathematical modeling of apoptosis in cell collective dynamics: microscopic and macroscopic points of view

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In this work, we are interested in the mathematical modeling of the impact of apoptosis on the dynamics of cellular tissues, and in particular on cell tissue fluidity. Indeed, cell apoptosis corresponds to the programmed cell death : when they leave the tissue, they induce local contractions but also enable cells rearrangements.

We first propose an individual-based model that provides the dynamics of the positions, velocities and polarities of the cells, idealized as hard spheres. Cells interact with each other through contact forces, smooth attraction, and polarity alignment. The model also involves a microscopic description of apoptotic and proliferation events. The present work is an extension of the model proposed in [3] and validated by experiments on cellular rings. Numerical simulations are performed and several indicators of fluidity are analyzed.

Next, we derive a macroscopic description, following the methodology proposed in [2, 1]. We start from a mean-field dynamics of the kinetic distribution function in phase-space (position, polarity, radius), where contact forces have been replaced with repulsion forces. We then introduce a specific time and space rescaling and identify the equilibria distribution functions, which are parameterized by two macroscopic quantities : the density and the mean polarity. Based on the Generalized collision Invariant (GCI) method [2], we are then able to identify their dynamics : the resulting description can be seen as a modified Self-Organized Hydrodynamics (SOH) model. We finally discuss the obtained model and highlight the effect of the apopotic events on the dynamics.

This is a joint work with Laurent Navoret (Université de Strasbourg) and Marcela Szopos (Université Paris Cité). It has also been carried out in collaboration with Romain Levayer (Institut Pasteur) and Daniel Riveline (IGBMC, Université de Strasbourg) in the context of the ANR project MAPEFLU.

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