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A coupled stress-fiber focal-adhesion model for cell contractility

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Cells can sense and respond to a variety of external mechanical cues. Cells attach themselves to the extra cellular matrix (ECM) through mechano-sensitive proteins, forming focal adhesions. The fluid material within the cell, cytoplasm, contain fibres which extend from one end of the cell membrane to the other, termed stress fibres [1]. They are essential for the distribution of stresses within the cell, and maintain equilibrium at focal adhesion. The growth of focal adhesion, based on the cues from the ECM, affects stress fibres through bio-chemical reactions and results in changes to the equilibrium of the cell [2]. Recent cyclic loading experiments have shown that cells tend to reorient away from the direction of loading and that contractility is higher when cells are placed on a stiffer substrate, exhibiting the presence of a continuous interaction between stress fibers and focal adhesions.

We present a phenomenological continuum model which can simulate the behaviour of cells under different loading and environmental conditions, emulating the in-vivo behaviour [3]. The model is coupling stress fibers and focal adhesions resulting in a non-linear bio-chemo-mechanical problem. We present the positive influence of the growth of focal adhesions along with a mechanosensitive feedback loop on the stress fiber growth and further reveal the characteristics of the re-orientation process due to cyclic loading. We use a non-linear Hill-type model to capture the growth of the active stress involved in the evolution law for the stress fibers and a thermo-dynamical approach to model the focal adhesions. Finally, we present performance properties in terms of robustness and solution quality by a comparison of a staggered and monolithic solution scheme.

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