Mechano-chemical waves in viscoelastic models of cell cytoplasm: Applications to cell locomotion

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The cytoskeleton of the single living cells is a prominent example of a complex active viscoelastic material wherein stresses induce flows along the organism as a result of the action of molecular motors. Experiments with different types of cells have revealed a rich variety of mechano-chemical patterns including standing, traveling and rotating waves that arise from instabilities of spatially homogeneous states. We investigate simple models where an active stress induced by molecular motors is coupled to a model describing the passive viscoelastic properties of the cellular material [1].

Our focus is on the analysis of the conditions that cause destabilization of spatially homogeneous states and the related onset of mechano-chemical waves and patterns. We carry out linear stability analyses and numerical simulations in one spatial dimension for different models [2]. In general, sufficiently strong activity leads to waves and patterns. Specifically, two models for viscoelastic fluids (Maxwell and Jeffrey model) and two models for viscoelastic solids (Kelvin-Voigt and Standard model) are investigated, see differences among both responses in Fig. 1. The primary instability is stationary for all active fluids considered, whereas all active solids have an oscillatory primary instability. All instabilities found are of long-wavelength nature reflecting the conservations of some biochemical concentrations in the models studied [2].

A even more realistic approximation is to assume the cytoplasm as a porous media where a viscoelastic solid formed by the actin network is immersed in the viscous cytosol, formed by water and small molecules [3]. We have applied the concept of active poroviscoelastic cytoplasm [1] to the study of the thickness and chemical oscillations in micro-droplets of *Physarum polycephalum* [4]. The oscillations of such micro-droplets is related with the polarization of the cell and produces the self-organization of the resulting cell and the final motion [5].

The self-organization process inside of the cell is also observed in amoebae motion of neutrophils and other cells like *Dictyostelium discoideum*. We couple the internal polarization processes responsible for the locomotion of such cells and the viscoelastic properties of their cytoplasm for the evaluation of the modifications in the motion properties of the cells. We integrate numerically the resulting equations to characterize the dependence of the velocity on the viscoelastic parameters.

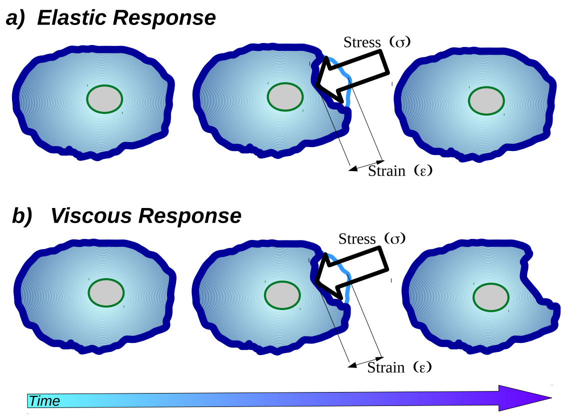

Fig. 1. Scheme of the characteristic responses of an elastic (a) and a viscous (b) cell to an externally applied stress in the limit of solid (cell recovers initial configuration), and fluid (cell interior flows and remains deformed) cytoplasm, respectively.

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