# MODELLING THE INTERACTION OF PHYSICAL AND REGULATORY MODULES IN CELLS THROUGH AN IMMERSOGEOMETRIC APPROACH

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## ABSTRACT

Cellular processes such as migration, division, and morphogenesis arise from the interplay between biochemical signaling and cellular mechanics [1,2]. Defects in these regulatory mechanisms contribute to pathological conditions including cancer and developmental disorders.

We developed a unified framework capable of describing the mechanochemical bulk--surface coupling between Rho GTPase signaling, through activation--deactivation and membrane attachment--detachment cycles, with the actomyosin cortex modelled as an active viscous surface coupled to incompressible Stokes flow.

To computationally resolve the deforming interface of the resulting bulk--surface problem, we implement an immersogeometric formulation [3] in which the cortex is represented by B-spline geometries immersed in a fixed background mesh describing the cytoplasm. The smooth geometric representation provided by isogeometric analysis accurately captures the evolving cortex, while the immersed formulation naturally accommodates large deformations without remeshing.

Our simulations demonstrate that cell geometry and deformation influence the emergence of polarized signaling patterns, while cortical contractility and intracellular flows redistribute signaling proteins, stabilizing and modifying polarization. The proposed methodology provides a flexible platform for investigating mechanochemical symmetry breaking and intracellular dynamics in deformable cells. More generally, it offers a computational strategy for mixed-dimensional bulk--surface multiphysics problems on evolving interfaces.

## REFERENCES

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