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Structural response and remodeling of red blood cells - a multiscale modeling approach

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A red blood cell contains cytosol enclosed inside a composite membrane consisting of a fluidic lipid bilayer reinforced by a single layer of protein skeleton. It has been demonstrated that mechanical loads can trigger dissociation of inter-protein and protein-to-lipid linkages and cause structural remodeling and failure. To understand these effects, it is vital to quantitatively characterize the mechanical forces acting within the membrane. For this purpose we developed a multiscale model to study distributions of internal stress in response to external load. In this method, the cell is modeled at three length scales: in the complete-cell level it is depicted as two layers of continuum shells, one representing the lipid bilayer and the other the skeleton; a molecular-detailed model of the skeleton is developed to predict its constitutive properties; a nonlinear stain-stretch model of Sp (a major protein in the skeleton) is applied to study the mechanical properties of the cell in large deformations. With this model we investigated mechanical responses of the system under canonical experiments such as micropipette aspirations and optical tweezer stretching. Model validations were conducted through comparisons with benchmark experiments.

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