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Microhydrodynamics of Linear Poroelastic Materials

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Abstract: Studies over the past two decades suggest that the cell cytoskeleton mechanics is best described as a poroelastic (PE) material composed of a biopolymer network permeated by the cytoplasmic fluid. Biot theory is the standard model used to describe PE materials. Yet, this theory does not account for the fluid shear stresses, which can lead to inaccurate predictions of the mechanics in the dilute filamentous network of the cytoskeleton. We adopt a two-phase model that extends Biot theory by including the fluid shear stresses in the momentum equation. We use generalized linear viscoelastic (VE) constitutive equations to describe the permeating fluid and the network stresses and assume a constant permeability that couples the fluid and network displacements. The linearity of the dynamic equations allows developing special-purpose mathematical and numerical method for modeling the dynamics of inclusions within a PE material, analogous to those developed in Stokes flow microhydrodynamics. Here, we present a few of these formulations namely (a) closed-form general solutions of the fluid and network displacement fields in spherical coordinates, (b) reciprocal theorem of equations of linear poroelasticity, and (c) the resulting boundary integral formulations of the fluid and the network displacement and traction fields. Using these formulations, we study the dynamics of spherical particles moving within bounded and unbounded domains and discuss their applications to different problems in cell mechanics.