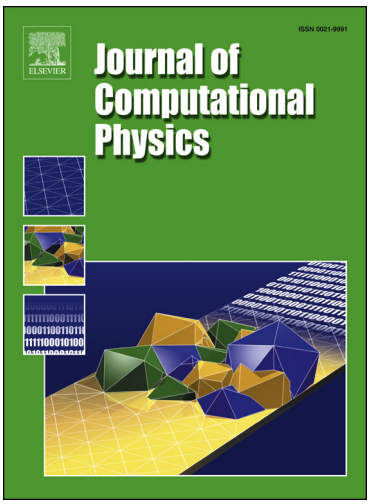
Accepted Manuscript



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PII: S0021-9991(17)30656-3
DOI: http://dx.doi.org/10.1016/j.jcp.2017.09.006
Reference: YJCPH 7577

To appear in: *Journal of Computational Physics*

Received date: 25 November 2016
Revised date: 16 August 2017
Accepted date: 4 September 2017

Please cite this article in press as: L. Yao, Y. Mori, A numerical method for osmotic water flow and solute diffusion with deformable membrane boundaries in two spatial dimension, *J. Comput. Phys.* (2017), http://dx.doi.org/10.1016/j.jcp.2017.09.006

A numerical method for osmotic water flow and solute diffusion with deformable membrane boundaries in two spatial dimension

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Abstract

Osmotic forces and solute diffusion are increasingly seen as playing a fundamental role in cell movement. Here, we present a numerical method that allows for studying the interplay between diffusive, osmotic and mechanical effects. An osmotically active solute obeys a advection-diffusion equation in a region demarcated by a deformable membrane. The interfacial membrane allows transmembrane water flow which is determined by osmotic and mechanical pressure differences across the membrane. The numerical method is based on an immersed boundary method for fluid-structure interaction and a Cartesian grid embedded boundary method for the solute. We demonstrate our numerical algorithm with the test case of an osmotic engine, a recently proposed mechanism for cell propulsion.

Keywords: Fluid structure interaction, Osmosis, Immersed boundary method, Cartesian grid embedded boundary method, Advection diffusion

1. Introduction

Differences in solute concentration across a semipermeable membrane or interface generates transmembrane osmotic water flow, which is of central importance in dialysis and desalination [1, 2], water absorption in epithelial systems [3, 4], and the swelling/deswelling of polyelectrolyte gels [5, 6]. The interaction of such flows with membrane and flow mechanics is a little explored area despite its potential significance in science and engineering [7, 8]. Here, we consider a model problem of such an interaction.

Our interest in this problem stems primarily from the problem of cell movement. Much recent evidence suggests that membrane ion channels and aquaporins (water channels), and thus, solute diffusion and osmosis, play an important role in cell movement [9, 10, 11]. To clarify the role of osmosis in cell movement, one needs to understand the interplay between solute diffusion, osmosis and mechanical forces. Our contribution in this paper is a step toward building a computational tool to study this interplay.

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