MULTI-COMPONENT RED BLOOD CELL COMPUTATIONAL MODELING: A NEW MATHEMATICAL FORMULATION

With gratitude to the Institute of Mathematics and Computer Sciences of the University of São Paulo in São Carlos (SP), Brazil

LUCAS MEACCI
Instituto de Ciências Matemáticas e de Computação
Universidade de São Paulo, São Carlos (SP), Brazil
(E-mail: luca.meacci@usp.br)

ROBERTO FEDERICO AUSAS
Instituto de Ciências Matemáticas e de Computação
Universidade de São Paulo, São Carlos (SP), Brazil
(E-mail: rfausas@icmc.usp.br)

FERNANDO MUT
Bioengineering Department
George Mason University, Fairfax (VA), USA
(E-mail: fmut@gmu.edu)

and

GUSTAVO CARLOS BUSCAGLIA
Instituto de Ciências Matemáticas e de Computação
Universidade de São Paulo, São Carlos (SP), Brazil
(E-mail: gustavo.buscaglia@icmc.usp.br)

Communicated by Mario Primicerio; Received September 30, 2021.

This work is supported by INCT-MACC (Instituto Nacional de Ciência e Tecnologia - Medicina Assistida por Computação Científica), approved from CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) of Brazil and financed by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) of Brazil (Grant 2014/50889-7). This research was developed making use of the computational resources (Euler cluster) of the CeMEAI (Center for Mathematical Sciences Applied to Industry) financed by FAPESP of Brazil (Grant 2013/07375-0).

AMS Subject Classification: 76Zxx, 74F10, 74L15, 92Cxx.
Keywords: Red blood cell, Mathematical modelling, Biological fluid mechanics, Lipid membrane, cytoskeleton, Fluid-solid interactions.
Abstract.

In this article, we present a new mathematical/computational formulation for a multicomponent model to study the normal and pathological behaviour of red blood cells in slow transient processes. We take into account (i) the lipid bilayer behaviour, (ii) the cytoskeleton dynamics, (iii) the interaction activity between them, and (iv) the internal cytoplasm flow. The formulation considers the cytoskeleton as a discrete non-linear elastic structure. The first novelty is to couple it with continuum models of the lipid membrane and of the cytoplasm, instead of the usual discrete/particle models. The second novelty is that the interaction of the cytoskeleton with the membrane is through adhesion forces adapted from efficient solid-solid adhesion algorithms. The model is tested with virtual experiments such as relaxation towards equilibrium and stretching by optical tweezers.