Coordination of contractility, adhesion and flow in migrating *Physarum* amoebae: experiments and modeling

Robert D. Guy *
Department of Mathematics
University of California Davis
guy@math.ucdavis.edu

Owen L. Lewis
Department of Mathematics
University of Utah
olewis@math.utah.edu

Shun Zhang
Mechanical and Aerospace
Engineering Department
UC San Diego
shz019@ucsd.edu

Juan Carlos del Álamo
Mechanical and Aerospace
Engineering Department
UC San Diego
jalamo@ucsd.edu

Categories and Subject Descriptors
J.3 [**Life and Medical Sciences**]: Biology and genentic

Keywords
cell locomotion, cytoplasmic streaming

Physarum plasmodia exhibit a periodic back-and-forth flow of cytoplasm (known as shuttle streaming) through a network of tubular structures reaching velocities up to 1 mm/s. Small-scale *Physarum* amoeabe ($\approx$100 μm in length) exhibit a similar behavior with a rhythmic flow of cytoplasm along the centerline of a roughly tadpole shaped cell. The onset of this behavior has been observed to coincide with a drastic increase in the locomotion speed of growing *Physarum*. The periodic waves of cytoplasmic streaming in tadpole shaped cells have been well characterized by PIV, and it has been argued that the traveling-wave nature of the intracellular flow is responsible for generating directed motility [2]. However, a purely hydrodynamic explanation of *Physarum* amoeboid motility does not address the transmission of traction stress to the underlying substrate, which is ultimately necessary for cellular migration to take place.

This work examines the relationship between spatiotemporal coordination of intracellular flow and traction stress and the speed of amoeboid locomotion of microplasmodia of *Physarum polycephalum* presented in [1]. We simultaneously perform particle image velocimetry and traction stress microscopy to measure the velocity of cytoplasmic flow and the stresses applied to the substrate by migrating *physarum* microamoebae. In parallel, we develop a mathematical model of a motile cell which includes forces from the viscous cytosol, a poro-elastic, contractile cytoskeleton and adhesive interactions with the substrate. See Figure 1.

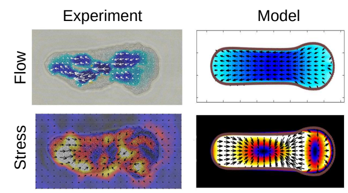

Figure 1: Instantaneous intracellular flow (top row) and traction stresses (bottom row) observed in our experiments (left column) and produced with our model (right column).

Our experiments show that flow and traction stress exhibit back-to-front directed waves with a distinct phase difference. The model demonstrates that the direction and speed of locomotion is determined by this coordination between contraction, flow, and adhesion. Using the model, we identify forms of coordination that generate model predictions consistent with experiments. We demonstrate that this coordination produces near optimal migration speed and is insensitive to heterogeneity in substrate adhesiveness. While it is generally thought that amoeboid motility is robust to changes in extracellular geometry and the nature of extracellular adhesion, our results demonstrate that coordination of adhesive forces is essential to producing robust migration.

This extended abstract summarizes a contributed presentation delivered at PhysNet 2015.

*Presenting author.

1. REFERENCES

[1] O. L. Lewis, S. Zhang, R. D. Guy, and J. C. del Álamo. Coordination of contractility, adhesion and flow in migrating physarum amoebae. *Journal of The Royal Society Interface*, 12, 2015.

[2] K. Matsumoto, S. Takagi, and T. Nakagaki. Locomotive Mechanism of Physarum Plasmodia Based on Spatiotemporal Analysis of Protoplasmic Streaming. *Biophysical Journal*, 94:2492–2504, 2008.

BICT 2015, December 03-05, New York City, United States

DOI 10.4108/eai.3-12-2015.2262456