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FLAGELLA DYNAMICS AND THE EVOLUTION OF MULTICELLULARITY

*** Raymond E. Goldstein**

Department of Applied Mathematics and Theoretical Physics,
University of Cambridge, Wilberforce Road, Cambridge CB3 0WA, UK
R.E.Goldstein@damtp.cam.ac.uk   www.damtp.cam.ac.uk/user/gold

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ABSTRACT

Some of the most challenging questions in biology concern the emergence of multicellular organisms from unicellular individuals and the accompanying differentiation of cells: why and how did this happen? Not surprisingly for microscopic life in water, many of the issues surrounding these transitions involve the physics of diffusion and mixing, for the efficient exchange of nutrients and wastes with the environment is among the most crucial factors affecting the fitness of organisms. Motile algae serve as model organisms for the study of these evolutionary transitions to multicellularity [1-3], with species ranging from unicellular *Chlamydomonas* to *Volvox*, with thousands of biflagellated somatic cells and exhibiting germ-soma differentiation. This lineage also spans several orders of magnitude in size and the spherical body plan makes it particularly amenable to theoretical and experimental study. In this talk I will describe recent work done in collaboration with K. Drescher, T. Locsei, S. Ganguly, C.A. Solari, I. Tuval T. Ishikawa, J.O. Kessler, and T.J. Pedley on the interrelationship between fluid flows driven by beating flagella and the functioning of these organisms.

Locomotion and phototaxis of the multicellular species depends on the degree of coordination among the flagella, but little quantitative information has been available on the nature and degree of synchronization. Taking advantage of the spherical organism geometry, novel micromanipulation techniques, and high-speed imaging, we quantify in *V. carteri* the complex temporal dynamics of the flagella of individual somatic cells and the correlations of beat phase between nearby cells.

Phototaxis of the multicellular algae is achieved by the regulation of flagellar beating in response to light falling on photoreceptors, one per flagella pair. Despite the lack of any cytoplasmic connections between somatic cells, colonies achieve high-fidelity phototactic steering. In order to elucidate the interplay between phototactic response and locomotion, we studied the adaptive flagella dynamics and resultant swimming trajectories of *Volvox carteri* subjected to sudden changes in illumination. A mathematical model of the Stokesian dynamics of this swimming is developed.

As colonies of *Volvox* swim through their fluid environment they also exhibit persistent rotation about the colonial axis. Remarkably, when two colonies swim nearby in a thin chamber they can form a “bound state,” orbiting each other for very many periods. Micromanipulation methods and high-speed

imaging, along with studies of simplified mathematical models illustrate a possible mechanism for this behavior.

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REFERENCES

[1] M. B. Short, C. A. Solari, S. Ganguly, T. R. Powers, J. O. Kessler, and R. E. Goldstein "Flows driven by flagella of multicellular organisms enhance long-range molecular transport". *Proc. Natl. Acad. Sci. USA*, Vol. **103**, 8315–8319, 2006.

[2] C. A. Solari, J. O. Kessler, and R. E. Michod. "A hydrodynamics approach to the evolution of multicellularity: flagellar motility and the evolution of germ-soma differentiation in volvocalean green algae". *Am. Nat.*, Vol. **167**, 537–554, 2006.

[3] C. A. Solari, S. Ganguly, J. O. Kessler, R. E. Michod, and R. E. Goldstein. "Multicellularity and the functional interdependence of motility and molecular transport". *Proc. Natl. Acad. Sci. USA*, Vol. **103**, 1353–1358, 2006.