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Physical Aspects of Evolutionary Transitions to Multicellularity

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An important issue in evolutionary biology is the emergence of multicellular organisms from unicellular individuals. The accompanying differentiation from motile totipotent unicellular organisms to multicellular ones having cells specialized into reproductive (germ) and vegetative (soma) functions, such as motility, implies both costs and benefits, the analysis of which involves the physics of buoyancy, diffusion, and mixing. In this talk, I discuss recent results on this transition in a model lineage: the volvocine green algae. Particle Imaging Velocimetry of fluid flows generated by these organisms show that they exist in the regime of very large Peclet numbers, where the scaling of nutrient uptake rates with organism size is highly nontrivial. In concert with metabolic studies of deflagellated colonies, investigations of phenotypic plasticity under nutrient-deprived conditions, and theoretical studies of transport in the high-Peclet number regime, we find that flagella-generated fluid flows enhance the nutrient uptake rate per cell, and thereby provide a driving force for evolutionary transitions to multicellularity. Thus, there is a link between motility, mixing, and multicellularity.