Depolymerization Can Drive Nematode Spermatozoon Crawling

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Abstract

Cell migration promotes wound healing, yet allows cancer to spread. As a prototype, nematode spermatozoa exhibit steady amoeboid locomotion on prepared surfaces. Prior experiments, on isolated cell extracts, suggest that disassembly of networked cytoskeletal polymer provides the requisite driving force. For corroboration, I have implemented cytoskeletal depolymerization in a mathematical model for whole cells and successfully reproduced empirically measured relationships among size, shape and speed for crawling spermatozoa. Extension at the front of a cell involves polymerization, with monomers pulled from the cytosol, while retraction at the rear involves depolymerization, with monomers returning to solution. This suggests a model, like mine, which intermingles solid and fluid phases. My simulations have demonstrated previously unrecognized or unappreciated roles for cytoskeletal anisotropy, cytosolic pressure gradients and transmembrane flow.

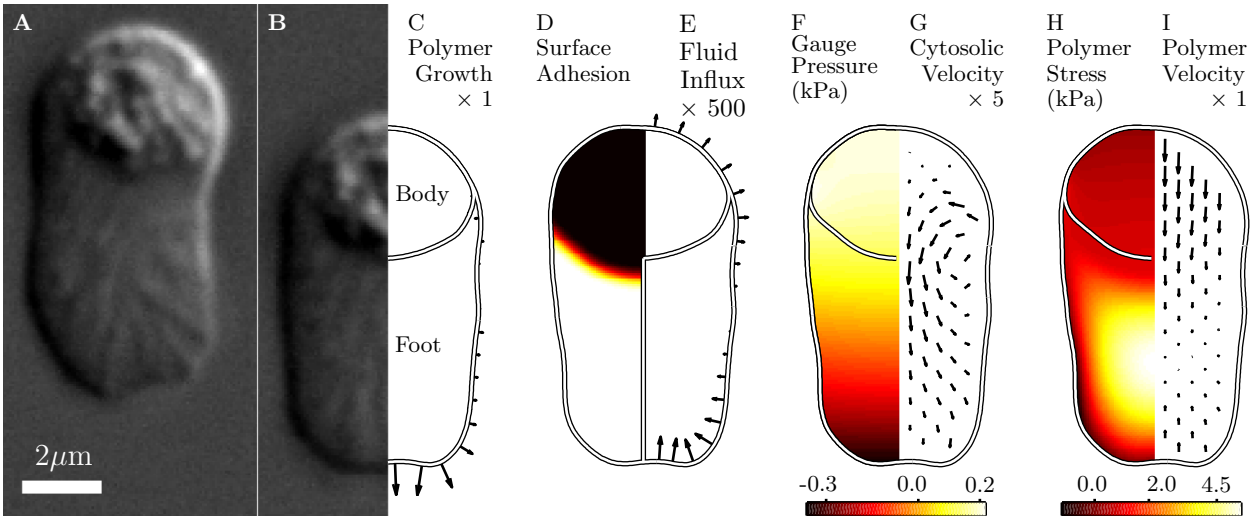

Figure 1: A typical *C. elegans* spermatozoon advances nearly 3 μm in 5 seconds (A, B), with little change in shape. The cell has a domed body at the rear (C) and a laminar foot, at the front. Given an empirically determined shape, simulations predict the peripheral cytoskeletal assembly rate (C) for a steadily crawling cell, with a maximum of 0.4 μm/s at the leading edge. Simulations represent transmembrane adhesion as external drag (D), with strong adhesion at the front and weak adhesion under the cell body. Relative to the assembly rate, arrows for fluid flux (E), cytosolic velocity (G) and cytoskeletal velocity (I) are scaled by factors of 500, 5 and 1 respectively. For ease of comparison with preexisting empirical data, transmembrane fluid flow and cytosolic velocity are plotted in a frame that moves with the cell while cytoskeletal velocity is plotted in a fixed laboratory reference frame. Simulations also yield cytosolic gauge pressure (F) and the magnitude of cytoskeletal stress (H), determined from anterior-posterior and transverse components.