Simulation of basal body deformation in *Tetrahymena thermophila*

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INTRODUCTION: Cilia are hair-like appendages that cells use to propel themselves through fluid. Each cilium is anchored to the cell by a cylindrical structure known as the basal body. Because these are nanoscale structures, detailed images are obtained by electron cryotomography, but much is still unknown about the physical properties of basal bodies and how cilia beat. We used computational modeling of the cilium, basal body, and accessory structures to better understand the mechanical properties and loading in basal bodies and associated structures.

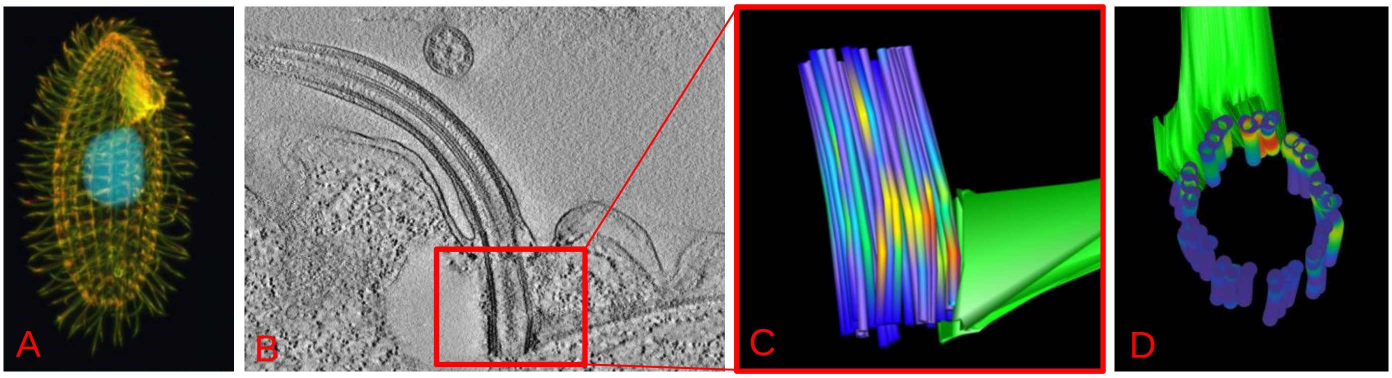

Figure 1. (A) *Tetrahymena thermophila*, (B) CryoET of basal body and partial cilium, (C,D) Basal Body with striated fiber. Colormap indicates curvature.

COMPUTATIONAL METHODS: Microtubule-based structures in the cilium, basal body, and accessory structures were modeled as Euler-Bernoulli beams. Elastic couplings between parallel beam structures were modeled either as transversely oriented beams or using linear extrusion couplings for greater modeling flexibility. Internal beating forces in the cilium were represented by follower loads and moments. This large deformation model is solved using stepped-loading continuation in the stationary solver or using ramped loads in the time dependent solver (BDF).

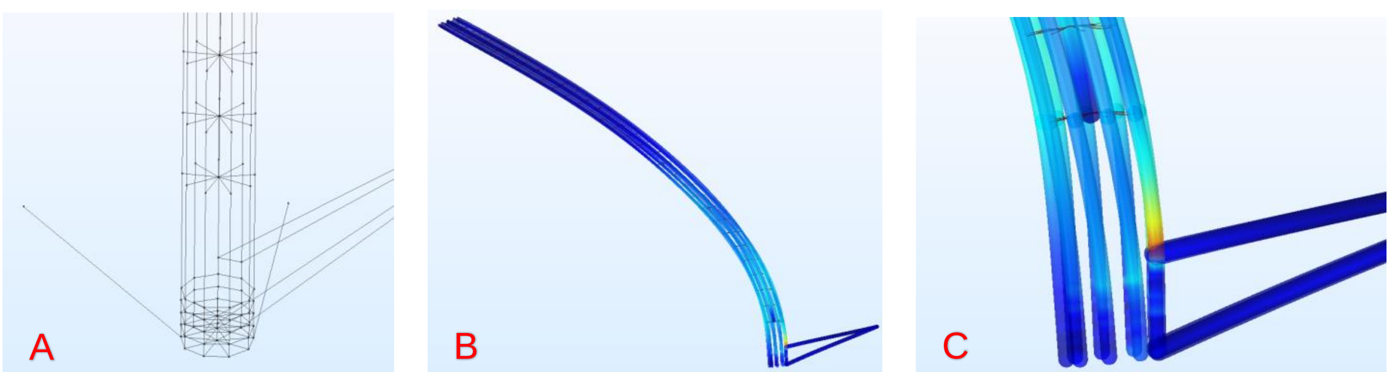

Figure 2. (A) Stick figure of basal body, cilium, and accessory structures, (B) Deformed shape of cilium and basal body, (C) Basal body deformation. Colormap indicates curvature.

RESULTS: Deformations like those observed in wild-type basal bodies were created by iteration and selection of plausible physical parameters, internal loading, and boundary conditions. A simplified 2D model allowed for rapid iteration, while a more complex 3D model allowed for direct comparison to observations. Curvature values and basal body translocations could be brought inline with observations by adjusting estimated parameters.

CONCLUSIONS: Inverse modeling of basal body deformations due to ciliary beating provides a valuable tool for estimating physical properties which elude experimental measurement and for determining the plausibility of hypotheses about the role observed accessory structures play in the overall system of ciliary beating.

REFERENCES:

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2. Adam W.J. Soh, Teunis J.P. van Dam, Alexander J. Stemm-Wolf, Andrew T. Pham, Garry P. Morgan, Eileen T. O'Toole, Chad G. Pearson; Ciliary force-responsive striated fibers promote basal body connections and cortical interactions. J Cell Biol, (2019)