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Choanoflagellates are unicellular aquatic organisms with a single flagellum that drives a feeding current through a funnel-shaped collar filter on which bacteria-sized prey are caught. Using computational fluid dynamics (CFD) we model the beating flagellum and the complex filter flow of the choanoflagellate Diaphanoeca grandis. Our CFD simulations based on the current understanding of the morphology underestimate the experimentally observed clearance rate by more than an order of magnitude: The beating flagellum is simply unable to draw enough water through the fine filter. Our observations motivate us to suggest a radically different filtration mechanism that requires a flagellar vane (sheet), and addition of a wide vane in our CFD model allows us to correctly predict the observed clearance rate.

Morphology of Choanoflagellate Diaphanoeca grandis

The computational domain is discretized with 4.8 million computational cells. (A) The mesh is chosen very fine around the flagellum and in between the microvilli to resolve the flow structures, whereas a coarse mesh is sufficient to resolve the flow in the far field. (B and C) Details of the mesh between the microvilli seen from the side and in the z direction. (We apply the commercial CFD program STAR-CCM+ version 12.02.010-R8).

Governing equations and numerical method

Governing equations are the continuity and Navier-Stokes equations: \[ \nabla \cdot u = 0 \] \[ \text{Re} \left( \frac{1}{\text{Str}} \right) \frac{\partial u}{\partial t} + \left( u \cdot \nabla \right) u = -\nabla p + \nabla \cdot \mu \nabla u \] where \( u \) and \( p \) are dimensionless velocity and pressure, respectively, and \( \text{Re} = \frac{UL}{\nu} \) is the Reynolds number, and \( \text{Str} = \frac{f}{U} \approx 0.77 \) is Strouhal number, where \( U, L \) and \( f \) are the characteristic velocity, length and frequency.

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References


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