YCCSA Seminar Series
Autumn 2015

Mathematical tales of a sperm tail

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30 October 2015

Abstract:
A detailed look at the biological world generates endless untracked problems in fluid and solid mechanics. Cells and microorganisms endure in a variety of environments, while nodal cilia generate flows that are responsible for determining the normal asymmetry of the internal organs of the mammalian body. A crucial task is, however, to propel fluid or swim on small, cellular, scales. This requires intricate microfluidic actuation in order to overcome the excessive hydrodynamic friction from the surrounding environment. In particular, sperm cells and flagellated microorganisms ingeniously solved this problem by periodically deforming whip-like, flexible appendages, such as cilia and flagella. Here we will develop mathematical models to explore the dynamics of the sperm flagellum, from the hydrodynamics exterior to the cell to its intricate internal mechanics. This will be achieved by combining constructively concepts from solid and fluid mechanics to formulate simple elastohydrodynamic models. We will further demonstrate how the latter can be utilised to interpret observations of flagellar dynamics, swimming trajectories, beating patterns, as well as unexpected phenomena associated with their complex material response. Finally, we highlight that this is a fertile and challenging area of inter-disciplinary research and demonstrate the importance of future observational and theoretical studies on the underlying mechanics of these motile cell appendages.