Biological Flows (L16)

Eric Lauga

Biology is rich with transport phenomena governed by fluid flows, from the circulation of blood and the movement of nutrients to the locomotion of microorganisms and the flows around plants and animals. These flows span an extraordinary range of time and length scales, encompassing the full spectrum of Reynolds numbers: from the turbulent wakes behind flapping birds to the viscous, steady flows within individual cells. This course explores the **mathematical foundations of biological fluid dynamics**, focusing on how fluid flows shape and enable life at both the cellular and organismal levels. These biological systems will serve as compelling case studies in **mathematical modelling in fluid mechanics**.

The first part of the course focuses on **internal flows** within cells and tissues, examining flow generation by biological pumps, transport driven by cilia and peristalsis and mechanisms of mixing by active flows. The second part turns to **external flows**, covering topics such as thin-film crawling, microorganism swimming and the collective behaviour of active fluids. Through these diverse examples, students will gain a deeper understanding of how fluid mechanics underpins biological function, with an emphasis on **mathematical modelling as a tool for uncovering the physical principles** behind life's dynamic processes.

Prerequisites

Undergraduate fluid dynamics, vector calculus and mathematical methods.

Literature

The link will be made with research in each of the topics discussed in the course and lectures will be accompanied by reading list of recent papers. Relevant books and articles include:

1. S. Vogel (1994) *Life in Moving Fluids*, Princeton University Press, USA.
2. E. Lauga (2020) *The Fluid Dynamics of Cell Motility*, Cambridge University Press, UK.
3. T. W. Secomb (2017) *Annu. Rev. Fluid Mech.* **49**, 443.
4. G. I. Taylor (1953) *Proc. Roy. Soc. A* **219**, 186–203.
5. M. Y. Jaffrin & A. H. Shapiro (1971) *Annu. Rev. Fluid Mech.* **3**, 13.
6. R. E. Goldstein & J.-W. van de Meent (2015) *Interface Focus* **5**, 20150030.
7. D. Saintillan & M. J. Shelley (2013) *C. R. Physique* **14**, 497.

Additional support

Three examples sheets will be provided and three associated examples classes will be given. There will be a one-hour revision class in the Easter Term.