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Helical swimming in viscoelastic and porous media

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Many bacteria swim by rotating helical flagella. These cells often live in polymer suspensions, which are viscoelastic. Recently there have been several theoretical and experimental studies showing that viscoelasticity can either enhance or suppress propulsion, depending on the details of the microswimmer. To help clarify this situation, we study experimentally the motility of the flagellum using a scaled-up model system - a motorized helical coil that rotates along its axial direction. A free-swimming speed is obtained when the net force on the helix is zero. When the helix is immersed in a viscoelastic (Boger) fluid, we find an increase in the force-free swimming speed as compared with the Newtonian case. The enhancement is maximized at a Deborah number of approximately one, and the magnitude depends not only on the elasticity of the fluid but also on the geometry of the helix. In the second part of my talk, I will discuss how spatial confinements, such as a porous medium, affect the flagellated swimming. For clarity, the porous media are modeled as cylindrical cavities with solid walls. A modified boundary element method allows us to investigate a situation that the helical flagella are very close to the wall, with high spatial resolution and relatively low computational cost. To our surprise, at fixed power consumption, a highly coiled flagellum swims faster in narrower confinements, while an elongated flagellum swims faster in a cavity with a wider opening. We try understanding these effects with simple physical pictures.