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Theory of swimming filaments in viscoelastic media

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Microorganisms often encounter and must move through complex media. What aspects of propulsion are altered when swimming in viscoelastic gels and fluids? Motivated by the swimming of sperm through the mucus of the female mammalian reproductive tract, we examine the swimming of filaments in nonlinearly viscoelastic fluids. We obtain the swimming velocity and hydrodynamic force exerted on an infinitely long cylinder with prescribed beating pattern. We apply these results to study the swimming of a simplified sliding-filament model for a sperm flagellum. Viscoelasticity tends to decrease swimming speed. The viscoelastic response of the fluid can change the shapes of beating patterns, and changes in the beating patterns can even lead to reversal of the swimming direction.