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Elasticity on the edge of stability: what Maxwell can teach us about biology

FRED MACKINTOSH, Vrij University

Life makes use of filamentous proteins for many structures, both in cells and tissues. In the cell, the cytoskeleton consists of networks of protein biopolymers for mechanical stability, organization and transport within the cell. Extracellular proteins such as collagen and fibrin form similar networks. One hundred and fifty years ago, Maxwell taught us about the minimal conditions for stability of simple spring-based networks [J. C. Maxwell, Philos. Mag. 27, 27 (1864).]. Interestingly, as a function of connectivity, such networks exhibit second-order rigidity transitions. We discuss recent theoretical and experimental progress in understanding the mechanics of such networks. We focus particularly on implications of the marginal state of networks near, and below Maxwell's isostatic connectivity. We show how fields such as stress, molecular motor activity and thermal fluctuations can stabilize networks. In the process, this can help us to understand long-standing problems in collagenous tissue mechanics.