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Strain induced critical behavior in athermal biopolymer networks

ABHINAV SHARMA, Georg August University, Gottingen, ALBERT LICUP, ROBBIE RENS, MICHAEL SHEINMAN, Vrije Universiteit Amsterdam, KARIN JANSEN, GIJSE KOENDERINK, AMOLF, Amsterdam, FRED MACKINTOSH, Vrije Universiteit Amsterdam — Biopolymer networks exhibit highly interesting mechanical behavior. An instructive model system is that of a network composed of rope-like filaments—zero resistance to compression but finite resistance to stretching. For networks with connectivity below Maxwell point, there is no elastic modulus for small deformations. However, when networks are subjected to an external strain, stiffness emerges spontaneously beyond a critical strain. We demonstrate that the spontaneous emergence of elasticity is analogous to a continuous phase transition. The critical point is not fixed but depends on the geometry of the underlying network. The elastic behavior near the critical point can be described analogous to that of Magnetization in ferromagnetic material near the Curie temperature. Surprisingly, the critical exponents are independent of the dimensionality and depend only on the average connectivity in the network. By including bending interactions in the rope network, we can capture the mechanical behavior of biologically relevant networks. Bending rigidity acts as a coupling constant analogous to the external magnetic field in a ferromagnetic system. We show that nonlinear mechanics of collagen are successfully captured by our framework of regarding nonlinear mechanics as a critical phenomenon

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