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Control of semi-flexible polymer networks by architecture and dynamic cross-linking

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The rigidity of elastic networks depends sensitively on their internal connectivity and the nature of interactions between constituents. Particles interacting via central forces become rigid above the isostatic connectivity threshold first identified by Maxwell. Stiff or semi-flexible polymers, such as those that form the cellular cytoskeleton, develop a finite network shear modulus G at a lower threshold, although the degree to which the mechanics of such networks are governed by filament bending resistance remains a subject of considerable debate. Such networks also exhibit rich viscoelastic properties. For cytoskeletal networks, there is increasing evidence that the network response is governed by the compliance and dynamics of the cross-links, many of which are transient in nature. Here we study the effects of both local network architecture and dynamic cross-linking in disordered fibrous networks. Surprisingly, the network mechanics in both 2D and 3D are still governed by the central-force isostatic point, which acts as a zero-temperature critical point. Near this point, we find divergent strain fluctuations and an associated diverging length-scale, as well as an anomalous elastic regime that exhibits fractional power-law dependence of G on both fiber bending stiffness and stretch modulus. Furthermore, dynamic cross-linking gives rise to a broad, power-law viscoelastic regime at low frequency ω in which $G \sim\omega^{1/2}$.