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Interplay between motor contractility and mechanical stability of active biopolymer networks

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The mechanical properties of cells are regulated in part by internal stresses generated actively by molecular motors in the cytoskeletal filamentous actin network. On a larger scale, collective motor activity allows the cell to contract the surrounding extracellular matrix, consisting also of biopolymer networks. Experiments show that such active contractility dramatically affects the networks' elasticity, both in reconstituted intracellular F-actin networks with myosin motors as well as in extracellular gels with contractile cells. We provide insight into this remarkable behavior with a model for the mechanics of contractile disordered networks consisting of simple straight fibers with linear bending and stretching elasticity. We find that these networks exhibit a low-connectivity rigidity threshold governed by fiber-bending elasticity and a high-connectivity threshold that controls a crossover between bending and stretching dominated network elasticity. Owing to their low connectivity, typical biopolymer networks fall below this upper threshold and their mechanical stability thus relies on the fibers' bending rigidity. The macroscopic elasticity of such networks is governed by soft fiber bending deformations. However, we find that motor-generated contractile forces can "pull out" these soft bending modes, thereby inducing a crossover to a mechanically more stable regime governed by stiff fiber stretching modes. Using scaling arguments and mean field theory, we show that this transition—induced by motor contractility—can be understood from the stress-dependence of the mechanical stability thresholds. These results suggest a physical principle by which active contractility can control biopolymer network mechanics, even when the fiber constituents are linear elastic elements.