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Nonlinear Elasticity: From Single Chain to Networks and Gels[1]
ANDREY DOBRYNIN, University of Connecticut, JAN-MICHAEL CARRILLO, Oak Ridge National Laboratory, FRED MACKINTOSH, Vrije University — Biological and polymeric networks show highly nonlinear stress-strain behavior leading to material hardening with increasing deformation. Using a combination of theoretical analysis and molecular dynamics simulations we develop a model of network deformation that describes nonlinear mechanical properties of a broad variety of biological and polymeric networks and gels by relating their macroscopic strain-hardening behavior with molecular parameters of the network strands. The starting point of our approach is a nonlinear force/elongation relation for discrete chain model with varying bending rigidity. This theory provides a universal relationship between the strain-dependent network modulus and the network deformation as a function of the first invariant and chain elongation ratio that depends on a ratio of the unperturbed chain size to chain dimension in a fully extended conformation. The model predictions for the nonlinear shear modulus and differential shear modulus for uniaxial and shear deformations are in a very good agreement with both the results of molecular dynamics simulations of networks and with experimental data for biopolymer networks of actin, collagen, fibrin, vimentin, neurofilaments, and pectin.

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