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Liquid Crystalline Polymers and Networks – orientation, molecular shape change, mechanics

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In a prescient paper of 1969, Pierre-Gilles de Gennes envisaged both liquid crystal polymers and elastomers. 10 years later, these systems were realised. After 25 years, monodomain elastomers were prepared and displayed phenomena he had predicted: rods incorporated into polymers induce liquid crystallinity in polymer melts and elastomers; orientational order causes shape changes in the back bones of such polymers; mechanical ramifications follow in networks, e.g. spontaneous elongations and contractions on changing order. The latter are proposed as the basis of micro-actuation and artificial muscles, both heat and light-driven. In 1969, de Gennes already described ideal networks heated through the nematic-isotropic transition losing all their order by mechanical relaxation. It is not obvious, but is true in theory and largely in experiment, even in highly non-ideal networks. He also envisaged that a cholesteric network, where there is a topological memory of chirality imprinted by crosslinking chains in a twisted state. Chirality cannot relax away on entering the isotropic phase, even in systems without molecular chirality (for instance those crosslinked in the presence of chiral solvent that is subsequently exchanged away). His chiral elastomers have found application as mechanically-tuneable, rubber lasers. De Gennes also constructed the first continuum elastic theories of nematic elastomers (1982), though distortions are generally very large. His elasticity has informed non-linear elasticity that works even at large amplitudes. I shall describe de Gennes' many contributions, and the current state of a field that has since yielded still more remarkable phenomena.