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Liquid-Crystallization of Ultrashort DNA and RNA Oligomers: a Phase Behavior Rich in Challenges for Soft-Matter Science

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Ultrashort complementary DNA and RNA oligomers, down to 6 base pairs in length, are found to exhibit nematic and columnar liquid crystal (LC) phases, even though such fragments of double helices lack the shape anisotropy required for liquid crystal orientational ordering. These phases are produced by the end-to-end adhesion and consequent living polymerization of the duplexes into polydisperse anisotropic rod-shaped aggregates, which can order.

The phase behavior of concentrated solutions of ultrashort DNA and RNA oligomers appears to be very rich and rooted in various basic mechanisms of self-organization of soft matter

Mixtures of single- and double-stranded oligomers phase separate. LC droplets rich in duplexes nucleate and coexist with an isotropic solution rich in unpaired single strands. This phase separation, that we find also in mixtures of DNA duplexes and PEG, can be understood as resulting from the combination of duplex adhesion and depletion-type forces favoring the segregation of rigid duplexes from flexible chains.

Quite surprisingly, this new form of spontaneous partitioning of complementary DNA extends to solutions of oligonucleotides with various degrees of randomness in their sequences. As an extreme example, we have found LC-isotropic phase separation in solutions of 20meric DNA with totally random sequence. These behavior results in an intriguing randomness-length phase diagram yet to be understood.

Another interesting topic emerges from studying the handedness of the chiral nematic N* phase, easily accessible since it often lays within the visible range. Quite remarkably, the handedness of the N* helix is not always the same, but rather it depends on the terminals of the oligomeric duplexes.