Liquid Crystal Phases of Helical Particles: What is Special

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The helical shape is ubiquitous in Nature and can be found also in important synthetic materials, like polymers. Then, it is of utmost interest to acquire knowledge of the structures that can be obtained by assemblies of helices. We have investigated the phase behaviour of helices focussing on the liquid crystal phases, exhibited at high density by solutions of (bio)polymers, including polynucleotides and polypeptides, and suspensions of chiral colloidal particles, like bacteria and viruses. Using Onsager theory and Monte Carlo (MC) computer simulations, we have studied systems of helices modelled as chains of hard spheres. We have found a rich polymorphism, with strong departures from the spherocylinder phase diagram: there are various nematic and smectic phases of different symmetry, whose relative stability depends on the helix parameters, radius and pitch. Remarkable is the presence of a special chiral nematic phase with screw-like order, where helices are well aligned along the director and their C₂ symmetry axes spiral around this direction with periodicity equal to the particle pitch. Roto-translational coupling allows a more efficient packing and hence an increase of translational entropy.

Screw-like ordering was observed in colloidal helical flagella. We can fully characterise this phase and show that it is a general feature in the phase diagram of helical particles; this raises the question of whether it could be observed in other systems, such as DNA, at sufficiently high densities. The screw-like nematic phase has an analogy with the twist-bend nematic, recently discovered in achiral liquid crystal dimers, although there are also some differences.

Figure: Roto-translational coupling in the screw-like nematic phase.

References:

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