nucleic acid nanotechnology. Invoking shape-complementarity principles and generic weak-contact interactions has also recently emerged as one strategy towards producing reconfigurable, higher-order DNA assemblies[5]. One clear goal in both fields is to produce large-scale 3D crystals by rational design. In DNA nanotechnology, this has been achieved in one singular case with DNA tensegrity triangles and variants of it[6]. In DNA-mediated nanoparticle assembly, many 3D crystallites have now been produced[4], but it appears to be difficult to prepare crystals that grow larger than ~5 μm. We speculate that further increasing the nanoparticle uniformity and decreasing the degree of chemical defects in the sticky DNA shell will help to grow larger crystals. In DNA nanotechnology, the self-assembly of shape-complementary objects surrounded by a dense, generically weakly attractive envelope (as realized, for example, by using short single-stranded DNA tails) may prove to be a promising route to producing complex 3D crystals from defined-size DNA objects such as 3D DNA origami[7] or 3D DNA-tile bricks[8]. ❐

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MATERIAL WITNESS

LIQUID-STATE PARTICLE PHYSICS

PHILIP BALL

The ability of condensed-matter physics to offer models for fundamental and particle physics has a distinguished history. Arguably it commenced with the liquid-droplet model of the atomic nucleus formulated in 1936 by Niels Bohr, which provided a simple approximation for thinking about nuclear stability and fission in terms of familiar concepts such as surface tension and heat of vaporization. Since then, real materials systems have offered all manner of laboratory analogues for exploring fundamental physical phenomena that lie outside the range of direct experimentation: for example, the use of liquid crystals to mimic the topological defects of cosmic strings and monopoles[1], the representation of graphene's electronic structure in terms of massless relativistic Dirac fermions[2], or the way topological insulators made from oxide materials might manifest the same properties as Majorana fermions, putative spin-1/2 particles that are their own antiparticles[3].

These cases and others supply an elegant demonstration that physics is unified not so much by reduction to a small set of underlying equations describing its most fundamental entities, but by universal principles operating at many scales, of which symmetry breaking, phase transitions and collective phenomena are the most obvious. It's perhaps curious, then, that particle physics has traditionally focused on individual rather than collective states — as Ollitraut has recently put it, "on rare events and the discovery of new elementary particles, rather than the 'bulk' of particles"[4]. One indication that bulk properties are as important for high-energy physics as for materials science, he suggests, is the new discovery by the CMS Collaboration at CERN in Geneva that the plasma of quarks and gluons created by a proton collision with a lead nucleus has emergent features characteristic of a liquid[5].

It was initially expected that the quark–gluon plasma (QGP) — a soup of the fundamental constituents of nucleons — produced in collisions of heavy nuclei would resemble a gas. In this case, as in an ideal gas, the 'bulk' properties of the plasma can be derived rather straightforwardly from those of its individual components. But instead the QGP turns out to be more like a liquid, in which many-body effects can't be neglected.

Shades of Bohr, indeed. But how many many-body terms are relevant? Earlier studies of the tiny blob of QGP formed in lead–proton collisions, containing just 1,000 or so fundamental particles, showed significant two-particle correlations[6]. But in an ordinary liquid, hydrodynamic flow produces coherent structures in which the motions of many molecules are correlated. The new CMS results show that the QGP also has small but measurable six- and eight-body correlations — suggestive of collective flow effects — that are evident in the variations in particle numbers with the azimuthal angle relative to the line of collision. The azimuthal variations indicate that this flow is anisotropic, and the CMS team proposes that the anisotropy comes from a hydrodynamic amplification of random quantum fluctuations of the colliding particles.

So exactly what kind of liquid is this? Since the strong force between quarks and gluons doesn't diminish with distance, the QGP seems likely to be quite unlike any we know so far. But might it be within the wit of colloid scientists to tune interparticle forces so as to create a simple laboratory analogue? ❐

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