and the adjoining layer of cells. The nucleus in these elongated radial glial cells moves up and down during the cell-division cycle, with mitosis occurring at the apical end, adjacent to the ventricle. After division, one cell remains a radial glial cell while the other differentiates into a neuron or a neuronal precursor that migrates away from the ventricular zone.

When Wang *et al.* labelled the centrioles in developing mouse brain with fluorescently tagged proteins, they found that the older mother centriole was preferentially inherited by the cell that retained the stem-cell fate. To test whether this pattern is important for stem-cell function, they used RNA interference to remove the protein ninein, a component of the centriolar appendages required for mother-centriole functions. Strikingly, when ninein was removed, centriole asymmetry was lost, and the pool of stem cells became depleted, suggesting that inheritance of the older mother centriole is crucial for maintaining stem-cell fate in radial glial cells.

How does the older mother centriole specify stem-cell fate after cell division? On the basis of the properties of centrioles, I consider three possibilities. First, the mother centriole initiates the formation of a primary cilium at the beginning of the cell cycle in most cells. A recent report[5] indicates that the cell that inherits the older mother centriole usually projects a cilium before its sister, and that the sister cell thus differs in its response to signals mediated by the cilium. Such a temporal difference in receptiveness to external differentiation signals might result in a cell-fate difference in recently divided cells.

A second possibility is that the older and newer mother centrioles differ in their complement of anchored microtubules during the cell cycle before division. As anchored microtubules can serve as tracks on which to move components towards the centrosome, the older mother centriole might accumulate proteins[6] or RNA[7] that influence cell fate after division.

Last, it has been proposed that stem cells are maintained by asymmetric segregation of a set of 'stem' chromosomes, all of a similar replicative age[8]. Such asymmetric chromosome segregation is at odds with the known mechanisms of mitosis, but has been observed in some types of mammalian stem-cell division[9]. Perhaps the older mother centriole maintains a connection to the chromosomes (the nuclear envelope notwithstanding) from one mitosis, through interphase to the next mitosis, allowing all similarly aged sister chromatids (the copies of a replicated chromosome) to segregate together.

Possibly the most exciting result from Wang and colleagues' work[1] is that their findings are remarkably similar to those of studies[10] of male germline stem cells in the fruitfly *Drosophila melanogaster*. In that system, the older centrosome also stays in the stem cell, and this asymmetric segregation is part of a stereotyped division choreographed by signals from the stem-cell niche. We can hope that a unifying mechanistic principle of differentiation will be revealed by future experiments investigating this remarkable organelle and its behaviour during division. ■

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MATERIALS SCIENCE

Quasicrystals from nanocrystals

Alfons van Blaaderen

Quasicrystals have a host of unusual physical properties. These intermediates between amorphous solids and regular crystalline materials can now be made to self-assemble from nanoparticles.

The discovery of quasicrystals about 25 years ago[1,2] brought about a paradigm shift in solid-state physics. The observation that the arrangement of atoms in these solids exhibited long-range order yet lacked the three-dimensional periodicity and translational symmetry that characterizes conventional crystals puzzled physicists[3–5] — not least because certain 'forbidden' rotational symmetries occur in these materials. Initially discovered in certain exotic metal alloys, quasicrystals were later found in more common mixtures of elements and even in soft matter[3]: liquid crystals, surfactants and polymers. Adding to this growing list, Talapin *et al.*[6] (page 964 of this issue) now report that binary colloidal nanoparticle

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50 & 100 YEARS AGO

50 YEARS AGO

In his presidential address to the British Association at York on September 2, Sir James Gray pleaded strongly for a wider outlook in the teaching of science and stressed the need for a considered judgment as to the proportion of our total educational effort which should be devoted to the training of scientists and technicians — upon whom we depend for maintaining or extending our standard of living — and the proportion which should be expended on raising the intellectual standards whereby the bulk of the population forms its judgments on matters which are susceptible to personal prejudice or political propaganda. Sir James recognized the implications of Dr. Trenaman's inquiry into the impact of the mass media and maintained that the key to the problem lies in the schools. The responsibility resting on secondary school teachers is not easily exaggerated, and Sir James pointed out that really inspired teachers, working with adequate but simple equipment, would achieve far more for general education than specialists in highly equipped laboratories.

From *Nature* 17 October 1959.

100 YEARS AGO

The British School of Archaeology at Athens has made further important discoveries on the site of the city of Sparta. The great temple of Artemis Orthia has been now completely cleared. The site known as the Menelaion, at Therapne, about two miles south-east of Sparta, has been partially examined. The sanctuary of Menelaus and Helen, mentioned by Herodotus, Livy, Pausanias, and Polybius, was a favourite resort of the Spartan ladies, where the goddess was believed to confer the gift of beauty on her worshippers. The discovery of Mycenaean remains on this site suggests that this was the famous palace of Menelaus.

From *Nature* 14 October 1909.

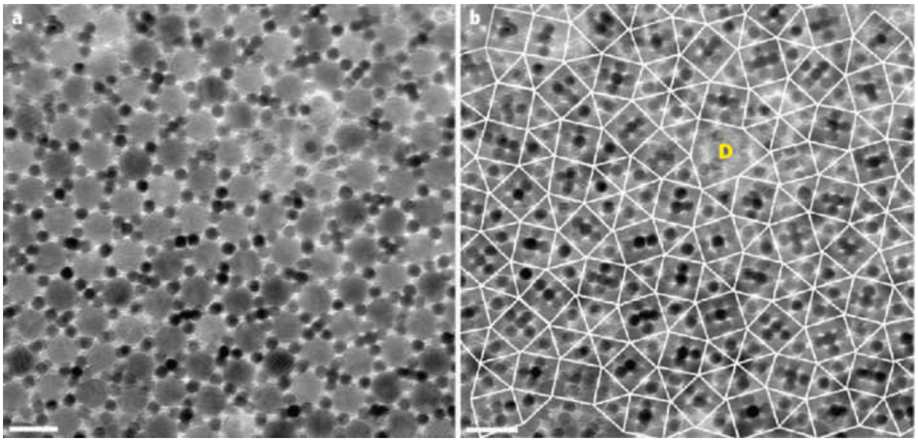
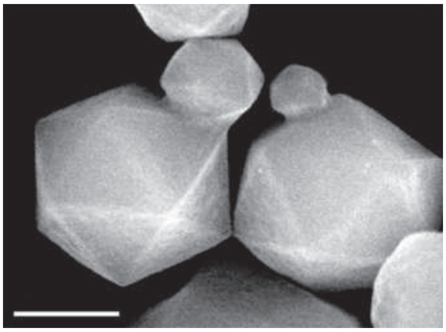


Figure 1 | Binary colloidal quasicrystal. Talapin and colleagues[6] demonstrate self-assembly of a binary quasicrystal that involves a mixture of two types of nanoparticle: 13.4-nm Fe_2O_3 and 5-nm gold colloidal spheres. **a**, Transmission electron microscopy (TEM) image of the quasicrystal. **b**, Square–triangular tiling overlaid onto the TEM image. A structural defect ('D') is visible. (Scale bars, 20 nm.)

systems, involving mixtures of two kinds of nanocrystal, self-assemble with quasicrystalline order.

Talapin and colleagues' colloidal quasicrystal self-assemblies are dodecagonal — that is, they display a 12-fold 'forbidden' rotational symmetry (a rotation about a particular axis by an angle 360°/12 does not change the material's scattering pattern). The assemblies are aperiodic in a certain plane but periodic in the direction perpendicular to this plane. Larger, micrometre-sized colloidal particles had already been reported to arrange in a decagonal (ten-fold) quasicrystalline pattern, but this was achieved by using laser beams and forcing them to form an interference pattern that conferred the desired symmetry on the system[7].

Many of the unique properties of quasicrystals — hardness, low thermal conductivity, low friction and remarkable electronic properties (such as strong anisotropy in electronic transport) — have to do with the interplay between short-range and long-range order in these materials. The short-range order mainly refers to recurrent structural building units, and the long-range order to how these units are arranged in patterns that never repeat themselves. This interplay makes it hard for conventional methods to reconstruct the three-dimensional structure of quasicrystals from their diffraction patterns, although the quality of some of the quasicrystalline diffraction data is as good as the best obtained for periodic crystals. The interplay is also responsible for the lack of positional atomic data of high quality. Finally, it is at the root of the debate about the mechanisms that underlie the growth and stabilization of quasicrystals. All this despite the fact that the number of research papers on quasicrystals is running towards 10,000.



ACS

Figure 2 | Icosahedral quasicrystals. Scanning electron microscopy image[10] of quasicrystal isocahedra (20-faced regular polyhedra displaying five-fold rotational symmetry) formed from composite silica spheres (not shown) about 30 nm across. (Scale bar, 2 μm.)

In their experiment, Talapin and colleagues[6] used nanoparticles that are large enough to show up clearly in transmission electron micrographs (Fig. 1) but sufficiently small to be considered 'designer atoms', or 'quantum dots'. In binary arrangements of quantum dots, the collective quantum behaviour of the interacting particles can give rise to novel 'metamaterial' properties. For example, a regular arrangement of two sets of different-sized semiconducting nanoparticles has been shown to create a new kind of semiconductor[8]. Combining the properties of such binary metamaterials with those of quasicrystals would no doubt lead to new opportunities in materials design.

Talapin *et al.* resorted to projection transmission electron microscopy, which led, for instance, to the clear identification of a structural defect (Fig. 1). However, the use of transmission electron microscopy tomography on several periodic binary-crystal structures made of similar nanoparticles has previously succeeded in determining the three-dimensional particle locations[9]. Application of this technique to the dodecagonal quasicrystal structures studied by Talapin and colleagues would allow a full, three-dimensional characterization of the materials, and could provide insight into how these quasicrystals grow.

The authors[6] observed that several different binary mixtures of nanoparticles (involving metals, magnetic materials and semiconductors), whose only common trait is a particle-size ratio of 0.43, self-assembled into the same type of quasicrystal. This observation is important both for unravelling some of the many mysteries associated with this type of aperiodic crystal and for our ability to design and fabricate novel materials. Most likely, it means that there is no strict requirement for a specific inter-particle interaction, allowing quasicrystal self-assemblies of many combinations of materials and, possibly, of (much) larger colloidal particles.

In fact, the formation of icosahedral quasicrystals (Fig. 2) made up of silica-coated surfactant spheres about 30 nanometres across, twice the size of Talapin and colleagues' largest nanoparticles, has already been reported[10] — although the authors do not actually identify them as quasicrystals. The central part of the underlying formation mechanism, if correct, is that the surfactant/silica composite spheres form before the quasicrystal self-assembles. The size of the beautiful quasicrystal icosahedra formed, roughly 2 micrometres across, is within the colloidal length-scale regime, leading one to daydream that these icosahedra themselves might be made to self-assemble on yet another level of order. The sequence of structural order at which matter could be arranged would then range from an amorphous glass to an aperiodic quasicrystalline solid made of nanoparticles, to finally a periodic structure made of micrometre-sized particles.

Lastly, quasicrystals could provide the means to the development of photonic quasicrystals by self-assembly. These materials differ from photonic crystals — materials specially engineered to trap and guide light — in the quasiperiodicity and forbidden symmetries of their crystal structures. These differences could make photonic quasicrystals outperform their conventional analogues. A photonic band gap — the forbidden energy range of photon propagation that characterizes photonic crystals — in the microwave regime has already been demonstrated for quasicrystalline structures made by lithography[11]. The development of photonic quasicrystals by self-assembly may well be within reach. ■

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