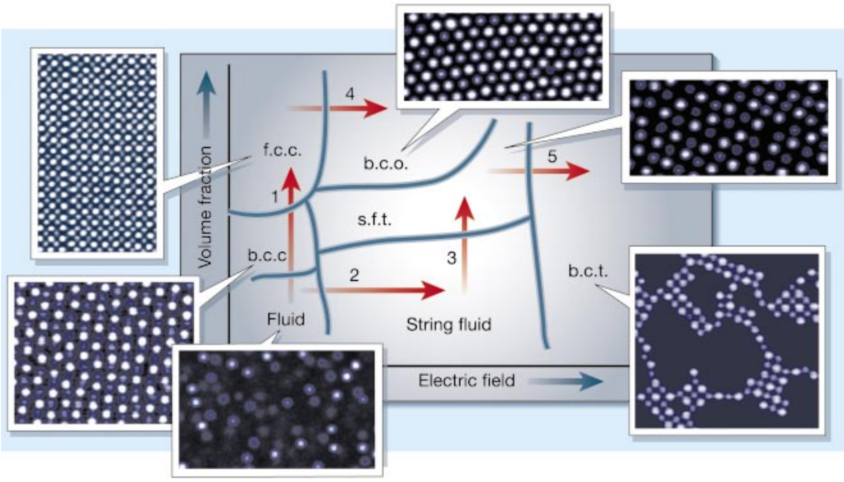

Figure 1 **How to tune your colloidal crystal. Yethiraj and van Blaaderen[1] have devised a model colloid whose structure can be effectively 'tuned' by varying the applied electric field and the volume fraction, or density, of colloidal particles. At low field values, increasing the volume fraction (**1**) causes the random, fluid arrangement of colloidal particles to take on body-centred cubic (b.c.c.), then face-centred cubic (f.c.c.) crystal structures (shown in the insets). Increasing the electric field at fixed volume fraction (**2**), however, transforms the colloid into a string fluid structure. If the volume fraction is then increased (**3**), a space-filling tetragonal (s.f.t.) structure results. Alternatively, starting from high volume fraction with f.c.c. structure and increasing the electric field (**4**) produces the body-centred orthorhombic (b.c.o.) state. From the s.f.t. state, if the electric field is pushed up still further (**5**), the colloidal crystal takes on another, more open structure, known as body-centred tetragonal (b.c.t.).**

actions, and the dye imparts charge and generates weak electrostatic repulsions that can be moderated by adding a soluble salt. So the interaction potential superposes a hard-sphere repulsion (considered to have infinite magnitude and zero range), an exponentially decaying repulsion (of finite magnitude, with its decay length dependent on salt concentration) and an orientation-dependent dipolar attraction/repulsion (with magnitude proportional to the electric field strength, and range comparable to the particle radius). The result is a three-dimensional phase diagram defined by the volume fraction, the range of the dipolar force and the strength of the electric field.

Yethiraj and van Blaaderen first sampled one plane of the phase diagram, looking at the effects of varying volume fraction and range of the electrostatic repulsion, in the absence of an electric field. They found fluid-to-b.c.c.-to-f.c.c. transitions for soft repulsions, fluid-to-f.c.c. transitions for harder electrostatic repulsions, and fluid-to-r.h.c.p. transition for nearly hard spheres, consistent with earlier results.

But then, looking at the variation with volume fraction and electric field, they found richer phase behaviour. At low values of electric-field strength, increasing the volume fraction induces a fluid-to-b.c.c.-to-f.c.c. sequence (Fig. 1). But maintaining a low volume fraction and increasing the field strength instead leads across a phase boundary from the isotropic fluid to a disordered phase in which the spheres condense into strings. Then, increasing the volume fraction at intermediate field strength drives a first-order transition, forming a space-filling tetragonal (s.f.t.) crystal. More interesting still are the solid–solid transitions Yethiraj and van Blaaderen observed by increasing the field strength from the f.c.c. crystal to a body-centred orthorhombic (b.c.o.) structure, and then from the s.f.t. crystal to a body-centred tetragonal (b.c.t.) structure, the phase that had been generally expected for hard spheres in a strong electric field. The tunability of the system through the electric field also means that the process can be reversed to observe complex melting phenomena, as one or more phase boundaries are traversed.

Yethiraj and van Blaaderen's model system, incorporating tunable dipolar attraction and soft repulsion, has revealed several new phase transitions for colloidal crystals. The newly identified crystalline phases, s.f.t. and b.c.o., as well as the b.c.t. phase expected in electric fields, represent anisotropic distortions of the b.c.c. lattice into more open structures with lower coordination numbers. Converting these fragile colloidal crystals into robust solids could have technological implications, and further tuning of the pair potential should reveal even more interesting crystal structures. ■

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Behavioural genetics

Family matters

David Haig

Differential activation of genes inherited from mothers and fathers will manifest itself as conflict in families. The effects are being explored experimentally with mice.

The evolution of maternal care involves a complex interplay between the genetic interests of mothers and those of offspring, with offspring predicted to favour higher levels of care than those favoured by mothers[1]. This interaction is further complicated by the possibility of conflict within offspring genomes through a phenomenon known as genetic imprinting[2], and of conflicts within maternal genomes between genes that are inherited by a particular offspring and genes that are not[3]. A study by Hager and Johnstone (page 533 of this issue[4]) reveals some of the genetic complexities behind how these conflicts are resolved.

Imprinting is an important concept in this context. Two copies — alleles — of a gene are inherited by offspring, one from the father and one from the mother. In imprinting, some modification of the DNA sequence, such as the addition of a methyl group to cytosine residues, means that one copy of the gene is inactivated and so only the paternally or maternally inherited version is expressed. Natural selection on genes expressed in offspring favours the solicitation of higher levels of maternal care when the gene is inherited from a father than from a mother because, in the former case, the allele has less 'interest' in the mother's future reproduction. This asymmetry sets up the possibility of a three-way conflict within offspring genomes — among unimprinted genes, maternally expressed imprinted genes (when the allele inherited by the offspring from its father is silent), and paternally expressed imprinted genes (when the allele inherited by the offspring from its mother is silent). For interpreting Hager and Johnstone's study, the important point is that the influence of imprinted genes will show up as an effect of either the mother's or the father's genotype.

Hager and Johnstone compared litter sizes from crosses within and between two inbred strains of mice (CBA and C57/B6). Surprisingly, the father's strain had a highly significant effect on litter size, whereas the effect of the mother's strain was nonsignificant — that is, CBA males produced larger litters than did C57/B6 males when mated to females of either strain. So either a father's strain influences the number of eggs a female produces, or it influences the proportion of eggs that produce a newborn mouse. The authors suggest that an offspring's paternal genotype affects the proportion of embryos that are implanted in the mother's uterus but are subsequently resorbed. These possibilities are testable. Paternal effects on the number of eggs produced could be assessed by counting corpora lutea, the glandular bodies that develop from an ovarian follicle after its egg has been released. And differential survival could be estimated by counting embryos at different stages of pregnancy.

The genetic nature of the paternal influence on litter size is unclear. Hager and Johnstone's analysis tests for effects of the mother's strain and the father's strain, not for the effects of offspring genotype. Thus, CBA (mother) × C57/B6 (father) and C57/B6 (mother) × CBA (father) litters are treated as maximally distinct, because they differ from each other for both the mother's and the father's strain. But these litters have identical genotypes if parental sex is ignored with regard to strain, and they would be grouped together as a single class in most analyses testing for effects of offspring genotype.

Whether or not this is appropriate depends on the relative importance of imprinted and unimprinted genes. If litter size had been analysed with respect to the unimprinted genes carried by the offspring, several alternative explanations for the size difference could have been considered. For example, one could have tested for additive effects — was litter size influenced by the proportion of CBA alleles in offspring? Alternatively, tests could have looked for dominance effects — was litter size influenced by either the presence or absence of CBA or C57/B6 alleles in offspring?

Clearly, the possible paths of causation remain to be disentangled. Nevertheless, the authors' analysis emphatically rejects what, at first sight, would have been the most intuitive reason — that litter size is determined solely by the mother's strain. The influence of maternal genotype, if present, is weak, whereas there is strong evidence of the effects of offspring genotype. Further analysis is required to decide whether those effects are due to paternally expressed imprinted genes or unimprinted genes. But maternally expressed imprinted genes clearly do not have a major influence.

In Hager and Johnstone's experiment, newborn litters were cross-fostered to mothers of both inbred strains; no litters were raised by their actual birth mother. Hager and Johnstone assessed a female's level of milk supply by removing a foster mother from her 6-day-old pups for 4 hours, and then recording her weight loss during the 2 hours after their reunion. Not surprisingly, the foster mother's strain had a significant effect on the level of milk provisioning. Of greater interest is the fact that there was a notable interaction between a foster mother's strain and the maternal strain of her adoptive pups. Specifically, foster mothers lost more weight if they were of the same strain as their pups' birth mother. The absence of an equivalent interaction between the foster mother's and the father's strain implies that foster mothers can distinguish offspring from reciprocal crosses between CBA and C57/B6 mice. The nature of this parent-of-origin effect is unresolved, but there are several possible explanations. These include the effects of extranuclear genetic material passed on by the mother through the egg's cytoplasm; persisting maternal effects from having spent gestation in the uteri of birth mothers of different genotype; or the influence of maternally expressed imprinted genes.

Why should a female supply more milk to pups that carry maternally derived genes matching her own? Hager and Johnstone suggest two possible explanations — that pups may have evolved behaviours for extracting resources from foster mothers that are of the same strain as their own mother, or that mothers may have evolved mechanisms for preferentially provisioning their own offspring in communal nests shared with other females.

Hager and Johnstone's elegant experiments have uncovered intriguing interactions between the genotypes of mothers and offspring. These crosses, however, involved only two inbred strains of mice, and one cannot tell how far the results will apply to other strains, or to outbred mice. A further consequence of using inbred parents is that all offspring within litters have the same genotype — except that brothers and sisters inherit different sex chromosomes from their father — and every gene in a parent has an exact match in each offspring. So the experiments reveal little about competition within litters, or about the effects of maternal alleles that are not passed on to offspring. But Hager and Johnston have opened a promising line of investigation, and future experiments should help to unravel these complexities. ■

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NATURE

100 YEARS AGO

The paper on electric automobiles read by Mr. H. F. Joel before the Institution of Civil Engineers on January 13 is one of great interest. The desirability of the automobile replacing horse traction from a sanitary point of view is probably admitted by everyone, and certainly the electric car would afford the best solution. Mr. Joel is of opinion that there is a great future before the electric automobile, which has already proved itself capable of running 100 miles on one charge and of performing much longer tours. This shows that even the storage battery of to-day is sufficiently good to give very satisfactory results; the author in his paper goes carefully into the results of the battery test made by the Automobile Club of France, and into the question of the ratio of weight of vehicle to weight of battery. Many valuable curves showing the relations between ton.mileage, total weight, useful load, &c., are given, and the paper is, on the whole, a valuable contribution to the subject.
From *Nature* 29 January 1903.

50 YEARS AGO

The granting of a Royal Charter to Queen Elizabeth College, University of London, marks the beginning of a new phase in the work of what has hitherto been known as King's College of Household and Social Science. Beginning as a department of King's College for Women in 1908, it gradually developed research and teaching in the scientific aspects of household and social work, until in 1920 there was introduced the first degree in these subjects — B.Sc. (Household and Social Science). By 1928, the department became an independent school in the University of London under the title of King's College of Household and Social Science. It played a prominent part in the development of dietetics as a specialized study, and began, in 1933, the first courses leading to a diploma in dietetics. Now, with its Royal Charter and its new name, Queen Elizabeth College (after Queen Elizabeth, the Queen Mother) [it] is breaking new ground. From October 1953 it will be training men and women undergraduates in the science of nutrition, leading to the new degree of B.Sc. (Nutrition). So far as we know, there is no other university in Britain which gives an undergraduate course for a first degree in this subject.
From *Nature* 31 January 1953.