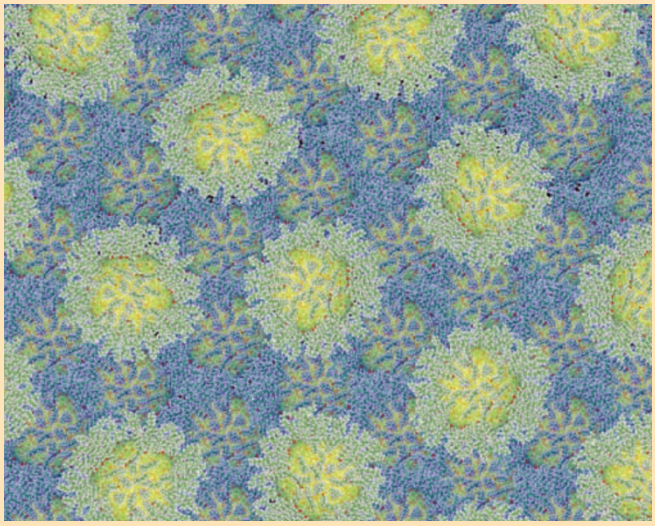
Condensed-matter physics

Supramolecular twelve-a-side

Quasicrystals are freaks of the crystal world. Strictly speaking, they are not crystalline: although the five-fold symmetry some of them exhibit in two dimensions might be acceptable for, say, a starfish, it is not permitted in a perfect crystal. For example, a floor can be tiled using only triangles, or squares or hexagons; tiles with five-fold, eight-fold or twelve-fold symmetry, however, will leave gaping holes if flat, or a puckered surface if forced to fit.

But in this issue, Xiangbing Zeng *et al.* report their discovery of a highly ordered molecular quasicrystal that has the 'forbidden' twelve-fold, or dodecagonal, symmetry (*Nature* **428,** 157–160; 2004). All but one of the quasicrystals known so far are metallic alloys (the notable exception is a liquid-crystal film with non-crystallographic helical symmetry). Instead of metallic atoms, the new quasicrystal is formed from organic dendritic (tree-like) structures that, Zeng *et al.* propose, have self-assembled into supramolecular spheres, or micelles.



This organic superstructure (shown here in simulation) was unexpected. Its stability may well have broader implications for cellular organization in tissues, for instance, or for a problem proposed by Lord Kelvin in 1887: in a foam, what shape of individual, equal-volume bubbles would yield the minimum surface area for the foam? Kelvin suggested a warped, 14-sided structure (a truncated octahedron) but was not able to prove it.

More than a hundred years later, Robert Phelan and Denis Weaire showed that a lower overall surface area would result if a foam contained two kinds of bubbles, one with 14 sides and the other with 12 (*Phil. Mag. Lett.* **69,** 107–110; 1994). With their dodecagonal quasicrystal in mind, Zeng and colleagues suggest that this classic packing problem might now have a solution based on quasicrystalline structure. **May Chiao**

possibly the errors are being underestimated by both groups. Whatever the explanation, for the moment the evidence for any variation in the fine-structure constant looks very weak indeed. ■

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1. Webb, J. K. *et al. Phys. Rev. Lett.* **87,** 091301 (2001).
2. Murphy, M. T., Webb, J. K. & Flambaum, V. V. *Mon. Not. R. Astron. Soc.* **345,** 609–638 (2003).
3. Chand, H., Srianand, R., Petitjean, P. & Aracil, B. *Astron. Astrophys.* (in the press); preprint at http://arxiv.org/abs/astro-ph/0402177 (2004).
4. Damour, T. & Dyson, F. *Nucl. Phys. B* **480,** 37–54 (1996).
5. White, R. L., Becker, R. H., Fan, X. & Strauss, M. A. *Astron. J.* **126,** 1–14 (2003).
6. Songaila, A. *Astron. J.* (in the press); preprint at http://arxiv.org/abs/astro-ph/0402347 (2004).
7. Cowie, L. L. & Songaila, A. *Astrophys. J.* **453,** 596–598 (1995).
8. Bahcall, J. N., Steinhardt, C. L. & Schlegel, D. *Astrophys. J.* **600,** 520–543 (2004).
9. Webb, J. K., Flambaum, V. V., Churchill, C. W., Drinkwater, M. J. & Barrow, J. D. *Phys. Rev. Lett.* **82,** 884–887 (1999).
10. Dzuba, V. A., Flambaum, V. V. & Webb, J. K. *Phys. Rev. Lett.* **82,** 888–891 (1999).
11. Spergel, D. N. *et al. Astrophys. J. Suppl. Ser.* **148,** 175–194 (2003).

Stem cells

More like a man

Allan C. Spradling

Most female mammals experience a reproductive decline with increased age, previously attributed to the instability of ageing oocytes. But could it be due to a previously unrecognized stem-cell well drying up?

Why can't a woman be more like a man? Male mammals generally can reproduce throughout most of their adult lives by continuously generating sperm precursors from germline stem cells maintained within the testis. In contrast, most mammalian females show a reproductive decline as they get older. Females of the few species that remain fertile throughout life, such as the well-studied fruitfly *Drosophila melanogaster*, contain germline stem cells like those of males, and use them in the constant replenishment of oocyte precursors[1].

Fifty years ago, mammalian ovaries were also thought by many to contain stem cells in an outer layer[2], but since then the stability of a fixed supply of follicles (growing oocytes encircled by support cells) produced during fetal life has been believed to determine the reproductive lifespan[3]. Women are fertile only when relatively young, and after the age of 30 years produce an increasing fraction of defective oocytes (Fig. 1, overleaf). Consequently, researchers have searched for factors that allow functional oocytes to be stored for 30 years but not for 40 years, with little success. An article by Johnson *et al.*[4] on page 145 of this issue now demonstrates that, contrary to long-held views, female mice contain a population of germline stem cells that are required to maintain overall follicle numbers during adult life. This important finding seems destined to greatly enhance our understanding of mammalian oogenesis and of its precipitous decline during adulthood.

Stem cells within the ovaries of mice might have been missed in earlier studies because, like other stem cells, they are expected to be rare and cannot be recognized definitively just on the basis of morphological criteria or by the use of known molecular markers. So Johnson *et al.*[4] instead carefully measured follicle numbers and their rate of loss after birth. As in previous studies, juvenile mice from several different mouse strains had 2,500–5,000 healthy follicles. But the number of dying follicles increased markedly, beginning about 30 days after birth, to as many as 1,200 per ovary and remained high until the mice were at least 4 months old. Dying follicles degenerate within a few days, which means that the follicular loss rate must be high. As the total number of healthy follicles decreased relatively little (if at all) despite this rapid follicle turnover, the authors concluded that new

follicles must be being made somewhere in young mouse ovaries. They proposed an active population of germline stem cells as the most likely source.

Four lines of evidence from the new study[4] strongly corroborate the existence of germline stem cells and the resultant ongoing follicle production in the ovaries of postnatal mice. First, Johnson *et al.* found a population of 63 ± 8 germ cells near the surface of the ovary that were outside follicles and that had the general characteristics of germline stem cells. They expressed a conserved germ-cell marker known as Vasa and were actively cycling — that is, they produced new cells.

Second, the authors found germ cells that had not yet developed into follicles in the ovary. This would be expected if the progeny of the germline stem cells were developing into new oocytes; indeed, Johnson *et al.*[4] identified germ cells that expressed several markers of this process. The overall levels of these marker proteins in the ovaries amounted to 6–25% of the levels that occur in adult testes, which contain large numbers of cycling germline stem cells and their maturing progeny (which express these same proteins).

Third, that the progeny of germ cells went on to produce follicles was shown by grafting a small part of a fluorescently labelled ovary into an unmarked host ovary. Follicles that comprised fluorescently labelled oocytes surrounded by unmarked follicle cells could subsequently be found. Germ cells had therefore moved out of the graft and formed a follicle within the host ovary, something that would be expected only if follicle formation was ongoing.

Last, treating mice with the toxic drug busulfan, which selectively kills male germline stem cells, rapidly depleted the pool of young follicles. The rapid time frame in which it did so suggested that female germline stem cells in mice contribute an average of 77 new follicles per ovary per day. The group's findings[4] all point to the existence of germline stem cells and a requirement for them in maintaining follicle numbers throughout the reproductive lifetime of female mice.

The finding raises many interesting and important questions. Determining the exact number and location of these functional germline stem cells will require tagging germ cells and showing that their descendants form follicles and, ultimately, mature oocytes. Such lineage-tracing experiments will also address whether the progeny of mouse germline stem cells differentiate directly into oocytes or whether they first increase their numbers by forming interconnected 'germ-cell cysts'. These structures are present during fetal stages[5] and form after germline stem-cell division in most organisms.

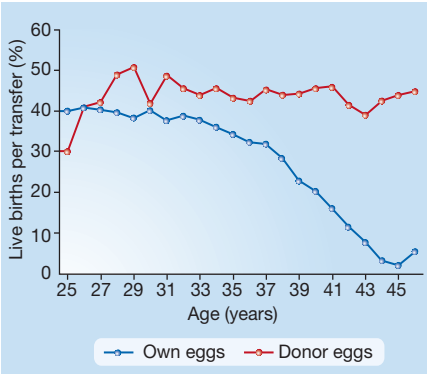

Figure 1 **Falling fertility. The graph shows the decreasing success rates (live births) with increasing age for *in vitro* fertilization using embryos derived from a woman's own eggs compared with using eggs from a young donor.**

Another issue will be to assess the relative use of follicles generated during fetal life compared with those produced by adult stem cells. Do the follicles produced before birth fail to survive to reproductive maturity, so that female fertility actually depends on the presence of young follicles produced recently from germline stem cells? And does the loss of these stem cells soon lead to follicle ageing, depletion and reproductive decline?

Now that germline stem cells in the mouse have been discovered, determining the cellular and molecular mechanisms that maintain them as such will be the mission of many a scientist. Previous work on *Drosophila* germline stem cells might usefully guide this quest. These stem cells reside in a niche where certain conditions are met to ensure that they continue to survive and function. Germline stem cells have several requirements: contact with a specific body (non-gamete) cell type; a particular signal, a member of the 'bone morphogenetic protein' family; and the expression of a small number of special regulatory genes[1,6]. Many of these mechanisms have probably been conserved between species. All these issues can now be addressed in mice by using existing technology.

Last, but far from least, the question on everyone's lips will be whether there are germline stem cells in the human ovary. Germline stem cells in humans might easily have been missed for the same reasons that they escaped detection in mice for so long. Indeed, the work of Johnson *et al.*[4] raises the strong possibility that the reproductive decline seen in female thirtysomethings is due to the depletion of germline stem cells coupled with a high follicular age-dependent incidence of defects occurring during reductive divisions when oocytes mature[7]. ■

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1. Spradling, A., Drummond-Barbosa, D. & Kai, T. *Nature* **414,** 12–18 (2001).
2. Raven, C. P. *Oogenesis: The Storage of Developmental Information* (Pergamon, New York, 1961).
3. Tilly, J. L. *Nature Rev. Mol. Cell Biol.* **2,** 838–848 (2001).
4. Johnson, J., Canning, J., Kaneko, T., Pru, J. K. & Tilly, J. L. *Nature* **428,** 145–150 (2004).
5. Pepling, M. E. & Spradling, A. C. *Development* **125,** 3323–3328 (1998).
6. Song, X., Zhu, C. H., Doan, C. & Xie, T. *Science* **296,** 1855–1857 (2002).
7. Pellestor, F., Andréo, B., Arnal, F., Humeau, C. & Demaille, J. *Hum. Genet.* **112,** 195–203 (2003).

Planetary science

Secrets of the deep

Jonathan Aurnou

The magnetic fields of Uranus and Neptune are markedly different from those of other planets in the Solar System. Can this be attributed to structural differences deep inside the planets?

Several planets in the Solar System — including Jupiter and its moon Ganymede, Saturn and possibly Mercury[1] — have a magnetic field that is similar to Earth's. The magnetic fields resemble that of a bar magnet, with the alignment of north and south poles oriented close to the rotation axis of the planet. But data from NASA's Voyager 2 probe have shown that the magnetic fields of Uranus and Neptune are different from those of other planets. Their fields are effectively tipped over: instead of aligning along the rotational axis, the north–south axis of the field lies midway or closer to the equatorial plane. These unusual magnetic fields have been difficult to model. But on page 151 of this issue, Stanley and Bloxham's simulations[2] show that, by altering the description of the internal structure of the planets, complex magnetic fields can be generated that are similar in structure to those of Uranus and Neptune.

All models of the generation of planetary magnetic fields include the same essential ingredients. There must be a region of electrically conducting fluid and an energy source to drive the motion of that fluid. A model of Earth's field, for instance, simulates its iron-rich molten outer core (the