discrete analogues of magnetic vortices and vortices in superconductors and superfluid helium. They are similar to discrete-vortex solitons recently observed in nonlinear photonic lattices[8,9].

In addition to structural and electric properties, what are the magnetic properties of these domain walls and vortices? In bulk manganese, spins order non-collinearly with 120° angles between neighbouring spins. The spin orientation is also determined (up to an overall sign) by the lattice trimerization. Thus, the rotation of the lattice distortion at a structural domain not only flips the polarization, but also rotates the spins. This explains the clamping of ferroelectric and antiferromagnetic domains found by Fiebig and colleagues[4]. Those 'loose' magnetic domain walls observed that are not locked to ferroelectric walls correspond to the 180° rotation of spins within one structural domain.

The 60° rotation of spins at domain boundaries implies that the cloverleaf defects are also magnetic vortices where lattice distortions and spins rotate together. It would be interesting to find out whether this amazingly complex interplay between structural, electric and magnetic properties of defects can lead to new magnetoelectric phenomena. ❐

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MATERIAL WITNESS

WEB DESIGNERS

PHILIP BALL

In a new book challenging neo-Darwinian adaptationist theory[1], cognitive scientists Jerry Fodor and Massimo Piattelli-Palmarini point out that "lacking observations of spiders, nothing (least of all the theory of natural selection) could have predicted that there are creatures that have the spider's kind of adaptation to their niches. What happened is that somebody who knew that spiders make a living by eating flies looked carefully at their natural history and was thus able to figure out that spinning webs is how they do it."

Whatever you make of Fodor and Piattelli-Palmarini's attack on the biological orthodoxy, they are right to point out that the theory of natural selection makes few if any specific predictions about how nature will turn out. Certainly, it cannot predict that spiders make webs (as opposed to, say, catching flies by growing wings or coating surfaces with adhesive). And indeed natural history shows that spiders did not evolve silk to spin fly-catching webs, but must have originally used it, around 380 million years ago, in sheets for some other purpose, such as wrapping eggs[2] (as they still do today).

And yet it is hard to imagine any process but natural selection that could have produced such a remarkably 'engineered' structure as the spider's web. The single silk thread is a masterpiece of materials processing, renowned for its combination of high tensile strength and elasticity. This is produced by control of the material's hierarchical structure during the spinning process, for which the spider has a sophisticated piece of apparatus called the spinneret. It involves careful control of liquid-crystalline ordering in the silk protein (fibroin) as the solution is progressively dehydrated, resulting in a composite of crystalline regions within a disordered matrix. The amino-acid sequence of the structural protein is varied depending on which function the strand serves. There has surely been some process of optimization to arrive at a biomaterial that we still struggle to mimic.

Physicists Yuko Aoyanagi and Ko Okumura of Ochanomizu University in Japan now show that the optimization doesn't stop there. They have developed a simple mechanical model of the canonical spider's web — the orb web, in which thin spiral threads bridge stronger radial threads — which shows that this hierarchical structure differs from common elastic materials in how it is affected by damage[3].

The researchers show that for typical values of the elastic moduli and cross-sectional area of radial and spiral threads, the force distribution in the threads is largely independent of the number and spacing of spiral threads, offering plenty of freedom in web design. And this distribution is virtually unchanged when spiral threads become damaged: it remains rather uniform throughout the web, with none of the stress concentration that develops near a crack and weakens other materials. So long as the radial threads are intact, the web is highly damage-tolerant.

As Aoyanagi and Okumura point out, these same principles are potentially valuable for human-built structures. And they reinforce the belief that whatever drives evolution, it is adept at finding 'good' solutions. ❐

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