BIOMOLECULAR ENGINEERING

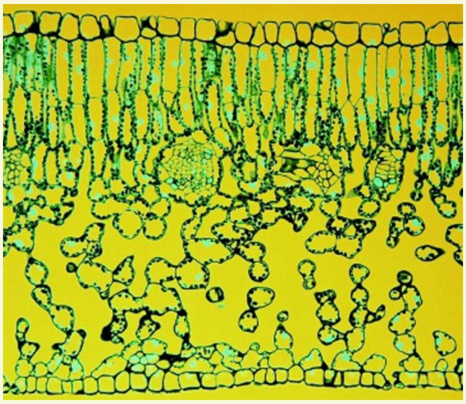
Negative success in tiny tree

When engineers were building beam engines in the early eighteenth century to pump out water-logged mines, they found that they couldn't pull water up more than about 9 metres (the height of water that can be supported by the drop in pressure between the atmosphere and a vacuum). Trees grow many times taller — more than 100 metres in the case of the tallest redwoods. Yet they supply their leaves with a constant flow of water. They achieve this feat by keeping the water high up in their trunks under pressures many atmospheres below that of a vacuum.

Elsewhere in this issue, Wheeler and Stroock report a duplication of this trick: they have created a tiny 'synthetic tree' through whose trunk water flows at pressures of around −10 atmospheres (T. D. Wheeler and A. D. Stroock *Nature* **455,** 208–212; 2008).

In trees, evaporation of water from leaf cells called spongy mesophyll pulls water up through hollow cells in the trunk (spongy mesophyll is the tissue in the lower half of this picture, a cross-section through a leaf). The strong, cohesive properties of water, responsible for its powerful surface tension, allow the water to exist at large negative pressures. But even the smallest bubble would explosively expand into the water, disrupting its flow in a process known as cavitation. The interface between the plant's water system and the air, formed by the spongy mesophyll, must allow water to pass, but not the gas molecules that would cause cavitation.

To create their tree, Wheeler and Stroock use a hydrogel, which mimics the mesophyll by holding water in molecular-scale pores, smaller than those of other porous solids. As their respective 'root' and 'leaf', the authors formed two networks of channels, 10 micrometres in diameter, in a sheet of poly(hydroxyethyl methacrylate), and connected them by a single channel, the 'trunk'. With the 'root' exposed to a source of water and the 'leaf' to a stream of damp air, water flows through the system powered solely by 'leaf' evaporation. The pressures developed in the trunk are some 15 times more negative than in any previously reported pumping system.


S. WALKER/GETTY

The device is shown in Figure 3a of the paper (page 210). It is just 5 centimetres long, and the flow is a little over 2 micrograms of water per second — but from such small acorns do mighty oaks grow. The synthetic tree can provide a test device for theories of tree physiology and, scaled-up, the technology could find uses in passive pumps or cooling devices — evaporation makes the 'leaf' a heat sink. Also, the large negative pressures developed might be used to drag water out of even quite dry soils, simultaneously filtering out impurities by passage through the 'root' hydrogel. This process, which the authors dub "reverse reverse osmosis", could form the basis of solar-powered mining of pure water in arid or contaminated environments.

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largest such entangled states contain eight ions[7] or six photons[8]. By contrast, experiments with entangled states that involve a large particle number (greater than 100) lack the possibility of controlling individual particles, which is necessary to exploit multipartite correlations. For example, nearest-neighbour interactions of atoms held in an optical lattice, produced by the interference of several laser beams, can create the entanglement of many thousands of atoms, but only as a result of global operations performed jointly on all atoms[9]. Manipulation and detection of single atoms within the lattice are not yet possible, because the lattice spacings are too narrow for any optical beam to interact with individual atoms.

Technological improvements, stimulated by the rapidly developing field of quantum information processing[10], will doubtless overcome these limitations in time. Brighter photon sources are being developed along with high-efficiency detectors with single-photon resolution. Continuous-variable approaches offer further possibilities beyond single-photon architectures. In addition, chip-based quantum circuits have been tested that contain silica-on-silicon waveguides[11]. Chip-based ion traps are also a promising route to engineering multipartite ion entanglement[7], and advances in single-atom manipulation within optical lattices[9] could provide controllable multipartite entanglement of thousands of particles.

The increased diversity of experimentally 'tamed' entangled particles brings theoretical challenges. The number of parameters needed to describe a state increases exponentially with the number of particles in the state, but this increased complexity also increases the potential utility of multipartite entangled states. For example, point-to-point quantum communication is more efficient when exploiting multipartite networks[12]. It is also possible that the computational power of multipartite states can be optimized or adapted to given architectures by making explicit use of specific entanglement properties such as intricate long-range correlations[13].

We are only beginning to understand and exploit the power of multipartite entanglement. Current developments may seem to be tiny steps, but they could soon add up to a (quantum) leap not only in information science but also in our fundamental understanding of macroscopic quantum systems. ■

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Correction

The News & Views article "Materials science: A desirable wind up" (*Nature* **454,** 591–592; 2008), by Neil Mathur, considered work by D. Lebeugle *et al.* describing investigation of the multiferroic and magnetoelectric properties of single crystals of $BiFeO_3$ (*Phys. Rev. Lett.* **100,** 227602; 2008). Coverage of closely related work by V. Kiryukhin and colleagues (S. Lee *et al. Appl. Phys. Lett.* **92,** 192906; 2008), published just before that by Lebeugle *et al.*, was inadvertently omitted from the article.