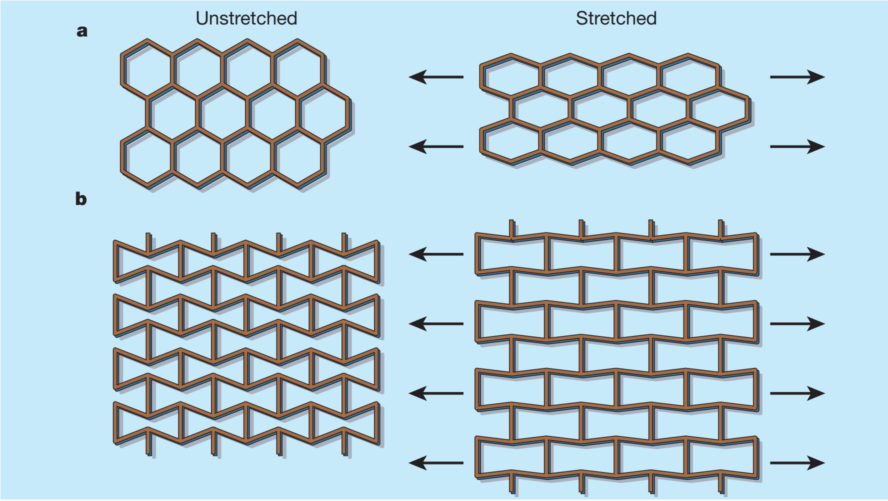

Figure 1 **Positive and negative Poisson's ratios. Stretching these two-dimensional hexagonal structures horizontally reveals the physical origin of Poisson's ratio.** a, **The cells of regular honeycomb or hexagonal crystals elongate and narrow when stretched, causing lateral contraction and so a positive Poisson's ratio.** b, **In artificial honeycomb with inverted cells, the structural elements unfold, causing lateral expansion and a negative Poisson's ratio.**

so the overall Poisson's ratio is almost always positive.

The elastic behaviour of the membranes studied by Bowick *et al.*[1] is said to be 'universal' because the authors require only a sparse set of assumptions to predict the Poisson's ratio. They start with a simple network of nodes, resembling a fishing net with fixed connections, which they model using a Monte Carlo simulation. Bowick *et al.* show that a negative Poisson's ratio is a universal property of such systems, whether the membrane is dominated by rigid bonds that resist bending or by 'self-avoiding' interatomic forces that prevent portions of the structure overlapping.

This unusual form of elasticity may also arise in biological processes because the membranes considered by Bowick *et al.* are similar to the protein skeletons[8] of biological membranes. The overall elasticity of a cell membrane results from both the protein skeleton and the high lipid content, but the relative contributions are not yet known. Even so, Bowick and colleagues' results are provocative. If our usual expectations about how things deform do not apply to biological membranes then we may need to reconsider the influence of membrane mechanics[7] on the shape of cells, the formation of vesicles, and the deformation of cells during life processes. For example, red blood cells are routinely deformed when they pass through fine blood capillaries. As they deform, the membrane skeleton can unfold, which might help to transport large molecules or expose reactive chemical groups. Similar concepts may be used in the design of industrial membranes for responsive filtration or catalysis. Materials with specific Poisson's ratios are always useful — cork, for example, has a ratio of almost zero, making it ideal for sealing wine bottles. For membranes with a negative Poisson's ratio, the applications are sure to keep expanding. ■

Roderic Lakes is in the Department of Engineering Physics, Engineering Mechanics Program at the University of Wisconsin-Madison, 1500 Engineering Drive, Madison, Wisconsin 53706-1687, USA.
e-mail: lakes@engr.wisc.edu

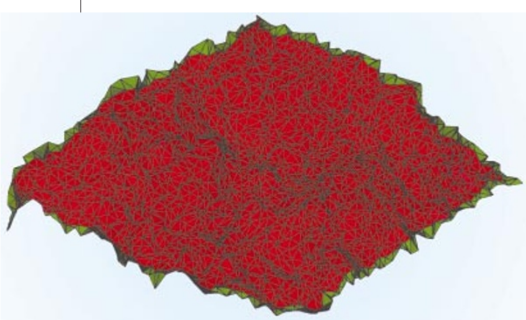

Figure 2 **An artificial membrane with a negative Poisson's ratio. The local roughness of a 'flat' fixed-connectivity membrane is due to thermal fluctuations. Stretching the membrane flattens the roughness, causing lateral expansion in the plane of the membrane. In their simulation, Bowick *et al.*[1] find that all fixed-connectivity membranes, possibly including some biological ones, share this property. (After M. Bowick, with permission.)**

1. Bowick, M., Cacciuto, A., Thorleifsson, G. & Travesset, A. *Phys. Rev. Lett.* **87,** 148103 (2001).
2. http://silver.neep.wisc.edu/~lakes/Poisson.html
3. Kolpakov, A. G. *Prikl. Mat. Mekh.* **59,** 969–977 (1985).
4. Gibson, L. J., Ashby, M. F., Schajer, G. S. & Robertson, C. I. *Proc. R. Soc. Lond. A* **382,** 25–42 (1982).
5. Lakes, R. S. *Science* **235,** 1038–1040 (1987).
6. Lakes, R. S. *J. Mat. Sci.* **26,** 2287–2292 (1991).
7. Lipowsky, R. *Nature* **349,** 475–481 (1991).
8. Schmidt, C. F. *et al. Science* **259,** 952–955 (1993).
9. Wen, X. *et al. Nature* **355,** 426–428 (1992).
10. Kantor, Y., Kardar, M. & Nelson, D. R. *Phys. Rev. Lett.* **57,** 791–794 (1986).
11. Aronovitz, J. A. & Lubensky, T. C. *Phys. Rev. Lett.* **60,** 2634–2637 (1988).
12. Baughman, R. H., Shacklette, J. M., Zakhidov, A. A. & Stafström, S. *Nature* **392,** 362–365 (1998).

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David Jones