degree of dendritic branching: dorsal root ganglion neurons, which have minimal dendritic branching, never displayed after-depolarization at any spiking frequency when grown on the same carbon nanotube surfaces.

Modelling the membrane voltage input–output relationship between the soma and dendrites, the European team found that the nanotubes may be effectively short-circuiting the dendrites and soma — that is, diverting the electrical activity through the nanotubes — and this may be sufficient to account for the enhanced after-depolarization of neurons grown on nanotubes. Furthermore, in a coupled-network version of the single-neuron model, the enhanced after-depolarization effect could significantly prolong the spontaneously recurring action-potential burst events in the network. In effect, the nanotubes were able to modulate the physiology of the neurons. Transmission electron micrographs of neurons grown on nanotubes showed tight contacts between the nanotubes and the cell

membrane, suggesting that specific changes in the electrical behaviour of the cell may be due to these intimate interactions.

This new work represents the ‘tip of the iceberg’ in that it hints at the potential of carbon nanotubes for interfacing with neurons, and eventually the nervous system. Although the observations and the electrotonic hypothesis are interesting, it remains unclear how this phenomena may contribute to a putative nano-engineered neural device: for example, calcium currents induced by backpropagation in dendrites of adult hippocampal neurons rarely result in calcium action-potentials, because the currents are too small⁹. It will take the degree of experimentation and modelling illustrated in this paper to answer these questions and engineer meaningful nanotube–neural devices.

Understanding the mechanisms that underlie the effect of carbon nanotubes on neural cells will be critical for designing

functional neural devices based on empirical data and engineering principles, rather than qualitative trial-and-error approaches. The engineering challenges involved demand this, but the potential impacts of successfully interfacing carbon nanotube devices with neural cells will be well worth it. □

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References

1. Massobrio, G., Massobrio, P. & Martinola, S. *Nano Lett.* **8**, 4433–4440 (2008).
2. Malarkey, E. B. *et al.* *Nano Lett.* **8**, 3538–3542 (2008).
3. Keefer, E. W. *et al.* *Nature Nanotech.* **3**, 434–439 (2008).
4. Li, J. & Andrews, R. J. *Acta Neurochir. Suppl.* **97**, 537–545 (2007).
5. Mazzatenta, A. *et al.* *J. Neurosci.* **27**, 6931–6936 (2007).
6. Nguyen-Vu, T. D. *et al.* *Small* **2**, 89–94 (2006).
7. Cellot, G. *et al.* *Nature Nanotech.* **4**, 126–133 (2009).
8. Kepecs, A. & Lisman, J. H. *Net. Comp. Neural. Sys.* **14**, 103–118 (2003).
9. Chen, S. & Yaari, Y. *J. Physiol.* **586**, 1351–1363 (2008).

IMAGING

Highs from lows

Diffraction imaging with X-rays or electrons could potentially probe the three-dimensional structure of single nanoparticles on the atomic scale, but its resolution is limited because weak coherent scattering cannot be detected by conventional diffraction imaging procedures. Now, Jian Zuo and colleagues at the University of Illinois at Urbana-Champaign report diffraction imaging of cadmium sulphide quantum dots with sub-ångström resolution by integrating information from a low-resolution ‘image’ with the diffraction pattern generated by the passage of electrons through the sample inside a transmission electron microscope (*Nature Phys.* **5**, 129–133; 2009).

Zuo and co-workers achieved a four-fold improvement in the resolution of the electron diffraction pattern for a cadmium sulphide quantum dot with a diameter of 7 nm (main image), which enabled them to resolve the 0.84 Å separation between the columns of cadmium and sulphur atoms (inset). As low-resolution images can be obtained from various sources, this technique provides a general method for the high-resolution, three-dimensional imaging of individual nanoparticles.

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