EVOLUTION

Memories of mammoths

If elephants never forget, the memories of mammoths need a little prompting. Nevertheless, inventive approaches to the extraction and sequencing of DNA from mammoths preserved in Siberian permafrost are allowing direct access to the deeper memories of elephant evolution.

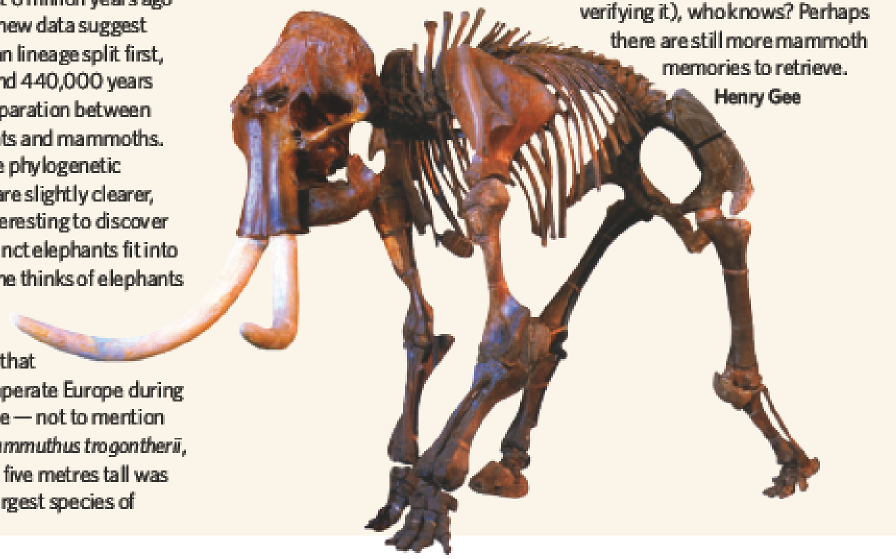
There has been much debate about whether the woolly mammoth (*Mammuthus primigenius*) — that archetype of everything icy and Palaeolithic — was more closely related to the extant African or Asian elephant (*Loxodonta africanus* and *Elephas maximus*, respectively). Analysis of the complete mitochondrial genome of a mammoth by Hofreiter and colleagues (*Nature* **439**, 724–727; 2006) provides the answer: mammoths are more closely related to Asian elephants, but only just.

Current wisdom has it that the lineages leading to mammoths and both extant elephant species diverged about 6 million years ago in Africa. The new data suggest that the African lineage split first, followed around 440,000 years later by the separation between Asian elephants and mammoths.

Now that the phylogenetic relationships are slightly clearer, it would be interesting to discover how other extinct elephants fit into the picture. One thinks of elephants such as *Anancus* and *Palaeoloxodon* that foraged in temperate Europe during the Pleistocene — not to mention the mighty *Mammuthus trogontherii*, which at up to five metres tall was possibly the largest species of elephant ever, making the woolly mammoth look, if not dwarfed, then at least somewhat petite.

These questions may not be answered using ancient DNA, however. The permafrost environment seems to favour the preservation of ancient DNA in quantity, from mammoths as well as other species, as shown by Poinar and colleagues (*Science* **311**, 392–394; 2006). But the likelihood of finding sufficiently informative DNA from species living outside the Arctic is almost certainly very much less. Yet, given the advances in sequencing ancient DNA (and, more importantly, verifying it), who knows? Perhaps there are still more mammoth memories to retrieve.

Henry Gee



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scanning tunnelling microscopy and modelling to show that this conventional analysis cannot fully explain electron transport in nanoscale silicon films. Using silicon-on-oxide membranes, already employed as the basis of low-capacitance, fast-switching devices, they demonstrate that transport is feasible even with very thin membranes, and for doping levels at which the Si–SiO_2 interface effectively depletes all carriers within the semiconductor. Electronic conduction is seemingly, in this case, not controlled by dopants in the bulk of the solid.

So what does control electron transport in silicon membranes? The authors provide compelling arguments to implicate surface states that come about when the single dangling bond of two neighbouring silicon surface atoms combine to form so-called 2×1 dimers. This process results in filled and empty surface states that are very close in energy to the valence band of the bulk silicon, and, in the authors' model, generate holes that dominate charge transport (Fig. 1).

This behaviour is probably not unique to the 2×1 surface configuration, or even to silicon. In fact, any surface 'termination' that provides energy levels that are low enough to accept electrons from the valence band should suffice. In the case of silicon, this would obviate the need to work with the notoriously reactive 2×1 surface, which is impractical for any real device application. That would open up new avenues to the manufacture of nanoscale devices.

The surface states associated with the 2×1 surface can be eliminated by chemical reaction: terminations such as hydrogen or halogens would suppress the surface states and prevent the generation of holes within the film. Such terminations could be patterned, providing a method of creating locally conducting and insulating regions of the substrate. But generating new surface states close to the energy gap is best achieved by tailoring the gap between the highest occupied and lowest unoccupied orbitals of molecular species attached to the surface[4]. This would in principle allow the generation of both hole- and electron-conducting regions in the film.

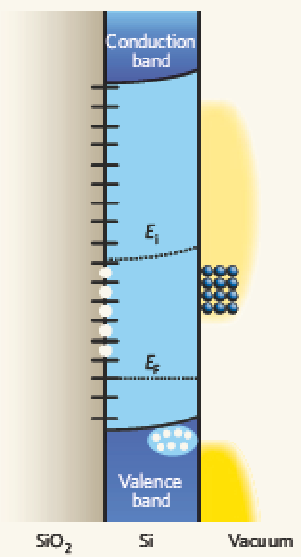

Figure 1 | The band structure of a silicon-on-insulator membrane. Trap states (short lines) at the silicon–silicon-dioxide interface in Zhang and colleagues' thin silicon membrane[1] depress the Fermi energy (E_F) of the membrane to below its intrinsic level (E_i), hindering conduction. But surface effects create allowed energy states (yellow) just above the valence band, into which electrons (blue circles) can be excited thermally, producing 'holes' (white circles) that can propagate through the valence band. This surface effect in silicon works equivalently to the doping effect in bulk silicon in enhancing the material's conduction properties. (Adapted from ref. 1.)

Although such surface-state models provide a potentially powerful route to control the electronic structure of nanoscale semiconductors, further studies will be needed to allow a detailed understanding of the transport mechanisms that result. Temperature-dependent conductivity measurements and high-resolution scanning tunnelling spectroscopy would be useful in this regard. Mechanism aside, Zhang and colleagues demonstrate[1] that, in the quest for ever-smaller electronic devices, surprises and opportunities abound. ■

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