MATERIALS SCIENCE

Flaky research

Urban legend has it that American engineers spent more than a million dollars inventing an 'astronaut pen' that could work in space, while the Russians simply used a pencil. True or not, the tale shows that the best solutions can sometimes be found in mundane objects. And, indeed, that they can be found in pencils.

Pencils contain graphite, a form of carbon in which atoms are ordered in thin sheets stacked regularly on top of each other. The interaction between these sheets is small, so layers of graphite rub off easily, for example when a pencil draws a line on paper.

Not satisfied with such an obvious, practical use, physicists have long been fascinated by the electronic properties of a single sheet of graphite, called graphene. Graphene is unlike any other material because electrons within it can behave as massless particles, which means they can mimic relativistic physics. Exotic effects that normally require huge particle accelerators might therefore be observed in a simple device — if only it were possible to rub off one, and only one, sheet of graphene.

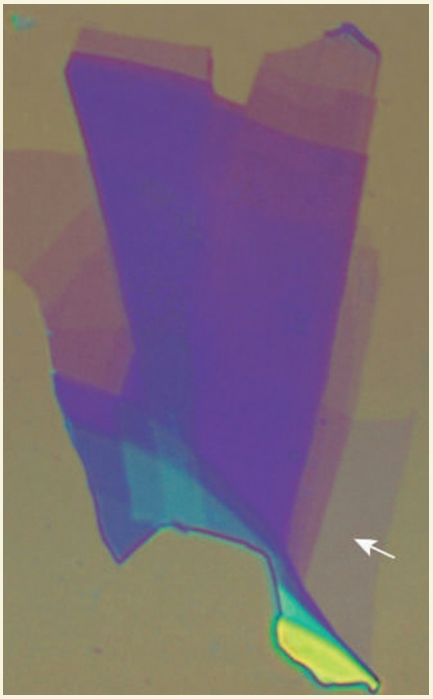
Despite concerted efforts, this proved problematic. In 2004, researchers at the University of Manchester, UK, finally isolated graphene when they peered through a conventional optical microscope at flakes of graphite that they had simply ripped off from a larger piece with sticky tape (K. S. Novoselov *et al. Science* **306,** 666–669; 2004). Graphene, being a layer just one atom thick, is transparent to light. But, as the picture here shows, there is just enough contrast from the thickness variation in a graphite shaving to locate the graphene layer under the microscope (here, the faint, semi-transparent region on the right, indicated by an arrow).

The image was obtained by Hubert Heersche and colleagues, who in this week's issue describe an experiment in which they attached a graphene sheet to two superconducting electrodes (H. B. Heersche *et al. Nature* **446,** 56–59; 2007). Previous experiments had thrown up the unexpected finding that graphene has a small electrical conductivity even in the absence of mobile charge carriers.

Heersche *et al.* add to the surprise by showing that the same holds true for a superconducting current. Moreover, it was not at all clear that a supercurrent could flow in graphene. As it turns out, not only does a conventional electron supercurrent flow, but so does one consisting of holes, which carry positive charge.

This experiment shows yet again that novel and surprising effects can be observed in simple materials — good news for those who don't have a million dollars to spend on discovering something new.

Liesbeth Venema



H. B. HEERSCHE *ET AL.*

mixture of proteins and other macromolecules. They do not readily dissolve to release soluble polyhedrin that could be recrystallized. Artificially exposing polyhedra to destabilizing conditions — such as very alkaline pH — leads to polyhedrin aggregation, and sometimes also to the breakdown of the protein[8].

The data needed to determine the structure therefore had to be obtained from microcrystals grown *in vivo*. Diffraction data were collected using a third-generation synchrotron — the Swiss Light Source — equipped with a micro-diffraction set-up[9]. This beamline, together with the ID13 beamline at the European Synchrotron Facility in Grenoble (which has the first dedicated single-crystal micro-diffraction facility to be installed at a synchrotron[10]), have had a major impact in structural biology by reducing the crystal size necessary for single-crystal diffraction experiments.

What does Coulibaly and colleagues' structure[4] tell us about the three-dimensional lattice of polyhedra? It shows that polyhedrin is a trimer, in the shape of a pyramid with a triangular base (Fig. 2). The vertices of the base are extended by amino-terminal, α-helical arms involved in creating a network of packing interactions among trimers in the crystal. The packing surfaces show striking complementarity, having a score for matching[11] higher than that of an antibody–antigen complex.

One remarkable feature is that the polyhedron solvent content is below 20% of the crystal volume, which is extremely low for a protein crystal: solvent content usually ranges between 40% and 70%, with rare cases reaching 27% or 85%[12]. This implies extremely close packing of the protein molecules, and the pyramidal shape of the polyhedrin trimer is clearly important in achieving such tight packing. For instance, the interstitial volume of the densest possible packing of rigid spheres is 26% of the crystal volume, and the solvent content in crystals of globular proteins rarely approaches this lower limit[12]. Also, in most protein crystals the solvent channels connect to the outside, allowing diffusion of small molecules within the crystals. By contrast, in the CPV polyhedra the solvent cavities are completely sealed off from the external environment.

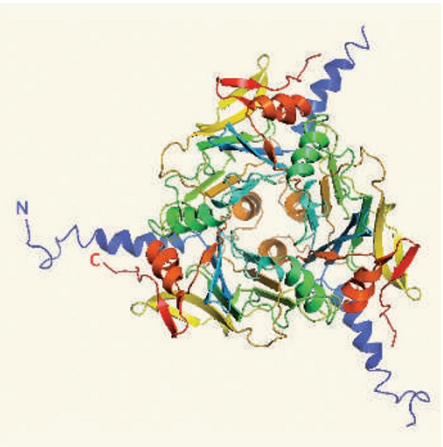


Figure 2 | Ribbon illustration of the polyhedrin trimer. Each subunit is rainbow-coloured from blue (amino terminus) to red (carboxy terminus). As Coulibaly *et al.*[4] show, the trimer has the shape of a pyramid (here viewed from the top) with a triangular base. An amino-terminal α-helical arm extends from each vertex of the base (one for each subunit of the trimer), and is involved in packing interactions in the crystal. (Data from ref. 4; illustration prepared with PyMOL software[15].)

If the packing between polyhedrin trimers is so tight, how do the virions get incorporated during crystal growth? This is not entirely clear, but we do know that they are included in polyhedra through the recognition of an 'inclusion signal' composed of a segment of the CPV outer virion protein VP3 (ref. 13). The interaction between polyhedrin and VP3 must be very strong so that crystal growth proceeds by surrounding the virion, instead of displacing it. The inclusion signal is contained within the amino-terminal 70 amino acids or so of CPV-VP3, and has biotechnological applications: fusion of this sequence to any protein leads to its incorporation into polyhedra[14], as illustrated in Figure 1c.

In principle, then, to take one example, it is possible to use these polyhedra to make ultra-stable protein chips, in which the protein of interest is protected from dehydration and other damage, as well as presented at the surface[14]. The next steps will be to carry out structure-based engineering of polyhedrin to derive mutants for various purposes, so that,