the real world. Previous work using a similar process of surface modification to produce thin films of graphite did not have this advantage[4]. Thin films, and other kinds of graphite sheet, could be used for specialized applications, in electronic devices or for certain high-performance nanocomposites[5].

Stankovich and colleagues' efforts[3] resulted in composites with intriguing properties. Only 0.1% by volume of graphene in the composite is required for electrical conduction — this is the lowest threshold observed for conductive polymer composite materials, except for those using carbon nanotubes. The conductivity rapidly increases by incorporating more graphene, reaching 1 siemen per metre at a loading of 2.5% by volume; conductivities in the range of $0.1\ \mathrm{S\ m^{-1}}$ are sufficient for many applications.

The graphene composites could be very useful: for example, in the manufacture of fuselages for aircraft, which must combine low weight, high strength and electrical conductivity. This last property is necessary for protection against lightning strikes while in flight. Nevertheless, the conductivities of these composites[3] are still several orders of magnitude lower than those of the best examples of nanotube mats (which are made entirely of nanotubes). They are also lower than the conductivity of graphite itself, or that of other nanotube composites[6–8]. The positive trade-offs for graphene-sheet composites are low cost and the plentiful supply of graphite.

The small amount of graphene required in the composite[3] for conductivity results from a high probability of sheet-to-sheet contact even at relatively low graphene loading, and from the conductive highway formed by the overlapping electron clouds of adjacent carbon atoms. However, high conductivities, rivalling those of individual nanotubes or thin nanotube films, will not be achieved with these composites. This is because of the limited degree to which the phenyl-isocyanate-modified sheets mix in the polymer solution; the large number of defects in the carbon layers; and the slow rate of electron tunnelling through gaps between the sheets.

The technology described by Stankovich and colleagues has two main advantages. The first is its ease of use for large-scale industrial applications where the conductivity of carbon fibres is insufficient, but where carbon nanotubes would be too expensive. The second is its applicability to a variety of polymers. The modification of graphite oxide by phenyl isocyanate should be considered as a proof-of-concept demonstration. The phenyl group could be replaced by other groups compatible with different polymers. This opens up a wide area of research that could lead to a large family of composites with differing properties. Clearly, the next step is to determine the mechanical properties of the graphene composites, and to see whether they can compete with nanotube-based materials. ■

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STRUCTURAL BIOLOGY

Proteins downhill all the way

Jeffery W. Kelly

The hundreds of hydrogen atoms in a protein can be used as reporters to describe how the protein folds into and out of shape. The results challenge the dogma that this is always an all-or-nothing process.

The three-dimensional structures of proteins govern their activity, yet we know far less than we would like to about how these molecules fold into shape. Proteins use an intricate network of weak, non-covalent interactions to acquire the folded state[1]. Conventional wisdom states that protein folding is a highly cooperative process — proteins are either completely folded or completely unfolded. This all-or-nothing model is convenient because it enables spectroscopic data to be converted into thermodynamic data, simply by measuring the distribution of folded and unfolded molecules at equilibrium. But is this model always correct? Muñoz and colleagues (page 317 of this issue)[2] use nuclear magnetic resonance (NMR) spectroscopy to follow the unfolding of an all-helical protein known as BBL.

BBL folds in a 'downhill' fashion — that is, the process is characterized by very low energy barriers between the folded and unfolded

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50 & 100 YEARS AGO

50 YEARS AGO

International conferences can be very stimulating affairs for those who attend, and the discussions, in particular, open up entirely new lines of thought. Publication of the proceedings can extend the stimulus to a much wider circle of workers, but only if the publication follows close on the heels of the conference itself… The proceedings of the symposium on nutritive aspects of preserved food…have been published approximately eighteen months after the conference took place; despite this delay, many of the papers are still badly in need of editing, the English sometimes being so poor that a sentence must be read several times over before its meaning can be grasped.

From *Nature* 21 July 1956.

100 YEARS AGO

"The day of the week for any date" — We assign a number for each month in accordance with the *old* style, beginning with March, so that the last four months are numbered according to their Latin names, as follows: January, 0; February or March, 1; April, 2; May, 3; June, 4; July, 5; August, 6; September, 7; October, 8; November, 9; December, 10; next January 11; next February, 12. For a Leap Year, January and February must count as 11 and 12 respectively in the *preceding* year. It is only in dealing with the month-number that anything not straightforward and obvious is involved. The rule then runs as follows:

A. For the *century*: divide by 4 and calculate *5 times the remainder*.
B. For the *year*: *add to the number the quotient obtained from divisor 4*.
C. For the *month*: multiply by 4, and *negate the units digit* (*i.e.* subtract instead of adding it).
D. For the *day* retain the number unchanged.
Then add together the results A, B, C, D (casting out *sevens*, of course, as you proceed), and the result gives the required day of the week…

Examples—1815, June 18 (Battle of Waterloo).

A. For *century*: $2\times5=10 \quad \equiv 3$
B. For *year*: $15+3=18 \quad \equiv 4$
C. For *month*: 4×4 gives $10-6=4\equiv4$
D. For *day*: $18 \quad \equiv 4$
$A+B+C+D=15\equiv1$, *i.e. Sunday*

From *Nature* 19 July 1906.