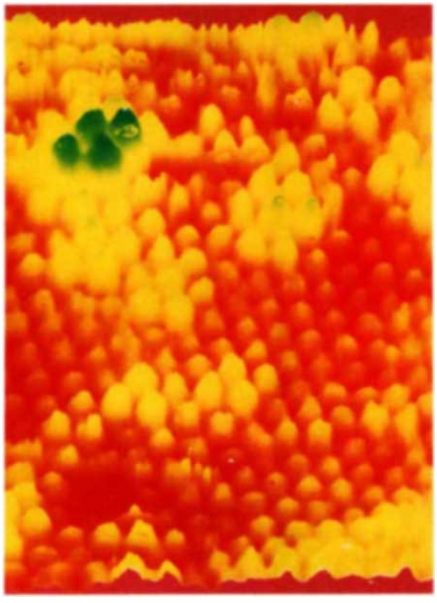
BUCKMINSTERFULLERENE

Chemistry comes round

Philip Ball

WHEN in 1987 physicists at a meeting of the American Physical Society held an all-night session to discuss the newly discovered high-temperature superconductors, they may have established a precedent. Certainly this comparison was on the tongues of some of the 500-plus participants of the post-midnight symposium staged by the Materials Research Society at its fall meeting*, who had gathered to hear the latest news on the sixty-carbon molecule dubbed buckminsterfullerene. But although it is tipped to provide new directions in organic, inclusion and polymer chemistry, lubrication and perhaps electrochemistry and semiconductor technology, the jury remains out on whether this promise will be fulfilled.



Buckminsterfullerene (C_{60}) molecules packed in a hexagonal monolayer on a gold surface. The image is obtained with a scanning tunnelling microscope (STM), each bump representing a single molecule. The reason for the variation in height is not clear, but possibly the taller species are the slightly elongated C_{70} molecules. Resolution of individual carbon atoms is not yet possible. These images, obtained by Donald Bethune *et al.*, and related results by J.L. Wragg *et al.* are discussed on pages 621 and 623.

The discovery, by a collaboration between laboratories at the University of Arizona and the Max-Planck-Institut at Heidelberg, of a means to isolate the football-shaped C_{60} molecule in solid form (W. Krätschmer *et al. Nature* **347**, 354–358; 1990) undoubtedly broadens the horizons of carbon chemistry: in the words of Harry Kroto (Sussex), one of the fathers of C_{60} research, "round carbon is in".

Two factors lend particular drama to the discovery. The first is that, although it is five years since the molecule was proposed as a possible component of interstellar dust after showing up in mass spectra of carbon soot (H. W. Kroto *et al. Nature* **318**, 162–163; 1985), the independent efforts of several groups to prepare a pure, solid form began to converge within a few months of each other earlier this year. Kroto's group had already obtained the red solvent-extracted C_{60} solutions when the *Nature* paper appeared, and a team from IBM Almaden had at that time several papers in press elsewhere reporting their own synthetic route.

The second factor is that the material turns out to be astonishingly easy to make. All one needs, according to Richard Smalley of Rice University, is a commercial arc welder, a standard vacuum line and some graphite rods. Such simplicity has allowed many laboratories rapidly to duplicate the initial results. But this kind of crude cookery runs against the grain for synthetic chemists, who, as Robert Whetten (University of California at Los Angeles) explained, had been searching in vain for elegant synthetic routes to the C_{60} cage.

Surprisingly little attention seems to have been devoted so far to exploring the "round organic chemistry" that Kroto predicts, although James Heath at the University of California at Berkely reported success in osmylating the unsaturated framework. Osmylation is a standard precursory step in the introduction of functionality to unsaturated hydrocarbons, and Heath suggests that it could lead to carbon–carbon bond cleavage, opening a hole in the cage through which one might insert guest atoms. □

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HAEMOGLOBIN

Molecular inventiveness

M. F. Perutz

THE haemoglobins of all bony vertebrates are tetramers made up of a pair of closely, but not covalently, linked αβ dimers. Judging by the sequence similarity of the residues in contact with the haems and with neighbouring subunits, all their tertiary structures are similar to that of sperm-whale myoglobin and they all share a common allosteric mechanism based on a transition between the same two quaternary structures.

Haemoglobins of invertebrates, plants, fungi and bacteria also share tertiary structures similar to that of myoglobin, but they include monomers, dimers, oligomers and polymers assembled in many different ways[1]. In the dimeric haemoglobin of the blood clam *Sapharca inaequivalvis*, the haems and the haem-linked helices E and F of neighbouring subunits are in contact rather than facing outwards as in vertebrate haemoglobins[2–4]. In the tetrameric haemoglobin of the 'fat innkeeper' worm *Urechis campo*, the helices B and D and the GH corner make contact around one twofold symmetry axis, and helix E and the AB corner make contact around the other, whereas in vertebrate haemoglobins all these segments face outwards[5]. In the polymeric haemoglobin of the earthworm *Lumbricus terrestris* three different globin chains are linked by disulphide bridges, one of them between cysteines in helix A and the other between cysteines in the neighbouring GH corner[6]; both of these segments face outwards in vertebrate haemoglobins. These haemoglobins are all made up of globin chains of a relative molecular mass of about 16,000 (M_r 16K), the same as vertebrate haemoglobins, but the subunit contacts are different from those in vertebrates and from each other.

The haemoglobin of the brine shrimp *Artemia* is a dimer made up of α and β chains of $M_r \sim 130$K (ref. 7). On page 653 of this issue[8], Manning *et al.* show that these chains consist of homologous, myoglobin-like domains linked in tandem.

Domain 4 of *Artemia* haemoglobin: residues at invariant non-polar internal sites.

A8	Ile	E15	Phe
A11	Ser	E18	Leu
A12	Trp	E19	Leu
A15	Ala	F4	Leu
B9	Leu	F5	Gly
B10	Phe	G5	Phe
B13	Met	G13	Ile
B14	Phe	G15	Ile
C4	Tyr	G16	Leu
CD1	Phe	H8	Trp
E4	Phe	H11	Phe
E8	Met	H12	Phe
E11	Val	H15	Ser
E12	Leu	H19	Ile

Trp A12	Important spacer between helices A and E.
Lys A14	Found in many globins.
Arg B12	Found in many globins.
Pro C2	Determines BC corner.
Phe CD1	Haem contact.
Phe CD4	This is Phe CD6 in *Artemia* owing to insertion of two residues in CD.
His E7	Distal histidine.
Val E11	Distal valine
Leu F4	Haem contact.
His F8	Haem contact.
Phe G5	Haem contact.
Lys H10	Found by Bashford *et al.*[11] in many globins.
Tyr H8	Internal spacer. This is Trp in *Artemia* as in human γ-globin.
Leu H19	Haem contact. Ile in *Artemia*.