

FIG. 3 The ligand **6** used by Osborne and colleagues to make a molecular box, **7**.

spontaneous and correct assembly of altogether eleven particles. . .”.

These studies fit into a wider framework of studies involving the metal-directed construction of supramolecular architectures. Whereas Lehn's group has demonstrated the use of a single type of metal to assemble to different ligands, we have demonstrated the ability of one type of ligand to assemble two different metal ions into heteronuclear double-helical arrays⁵. The attractive triple-helical motif of the cylinder **5** has been the target of the group of Williams in Geneva⁶. It turns out that subtle factors control the assembly of double- or triple-helices in a particular metal-ligand system. This observation is borne out by the unexpected helical twisting of **5**.

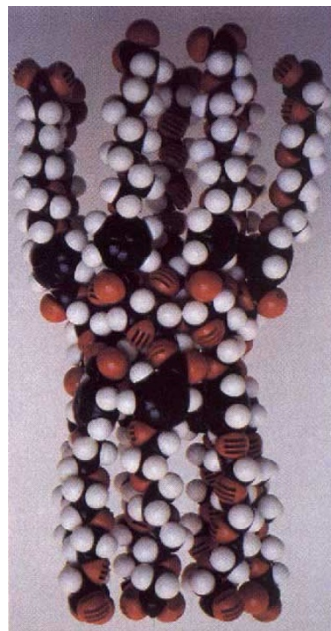
It is perhaps appropriate to mention a microstructure that has recently been described by the group of Osborn, also in Strasbourg⁷. Compound **6**, which bears an obvious similarity to **4**, reacts with copper(I) to self-assemble a molecular box containing four copper centres, compound **7** (Fig. 3). This compound may be seen as an electron reservoir, and each of the copper(I) centres may be sequentially oxidized to copper(II) without the disruption of the supramolecular architecture. Such compounds provide an entry to new types of microstructures which imitate electronic components. Compound **7** may be thought of as the seed of a molecular accumulator or capacitor which may store and then release up to four electrons to a molecular wire. □

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Ion-channel studies blossom

LEHN's homage to nature is even more obvious in a second paper, describing the synthesis of artificial ion channels that can be incorporated into a lipid membrane resembling a cell wall (M. J. Pregel, L. Jullen & J.-M. Lehn *Angew. Chem. Int. Ed. Engl.* **31**, 1637–1640; 1992). The transport of electrons across membranes constitutes the critical step in photosynthesis, and hence the key step in the production of food and of energy. Similarly,

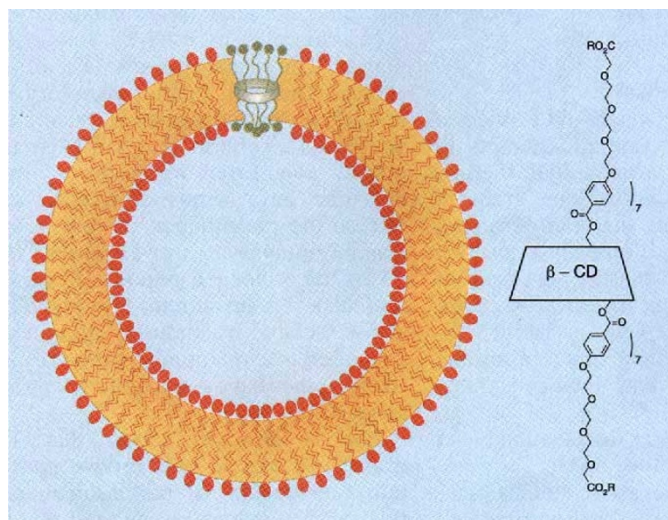


the transmembrane transport of ions is the critical step in metabolism for the controlled production of energy and for the firing of nerve signals. Ions are carried from one side of a membrane to another by one of two processes: by forming complexes with some other agent which can diffuse across the membrane, acting as a shuttle or diffusive carrier; or a large molecule which spans the breadth of the membrane produces a pore through which the ions can easily penetrate.

Lehn and colleagues have made a new class of artificial ion channels by grafting poly(oxyethylene) or polymethylene chains of various lengths onto macrocyclic rings. The authors call their compounds 'bouquet' molecules, as the long chains emanating from the central annulus (with a little imagination) resemble long-stemmed roses protruding from a vase. They have prepared two such molecules, one with a ring-like crown ether as the central ring, the second with a modified cyclodextrin core (resembling a truncated cone).

The authors prepared their lipid vesicles, resembling cells, in lithium chloride solution.

Once these had formed, sodium chloride was added to the solution, so that the composition inside and outside the cells was different. NMR spectroscopy showed that mixing between the two samples was much faster with the bouquet molecules in the vesicle walls. The simplest interpretation is that the metal cations become complexed at one end of the pore, carried through the channel and released at the opposite end.



Top: molecular model of the bouquet molecule based on cyclodextrin (β -CD). Left, structure of the same molecule, showing just two stems. Incorporated into a vesicle wall (far left), the molecule allows rapid interchange of alkali metal atoms between the 'cell' interior and exterior.

Many possibilities can be imagined for using such molecules in studying mechanisms of ion transport and for determining the effect of including other small and large molecules on the effectiveness of cross-membrane channelling. Because these artificial systems are amenable to synthetic manipulation, one could design different lengths of 'bouquets' and choose the best 'flowers' and 'stems' to control selective ion transport to include even non-alkali metals or larger organic cations.

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