Art and Science I: Drawing Buckyballs

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INTRODUCTION

As a scientist whose primary passion is art and graphics I have, for as long as I can remember, sought to find a satisfactory example in which Art and Science are totally interwoven. I have invariably found those attempts, that I have come across, at best unsatisfactory and at worst specious. Books purporting to find "Art" in some "Scientific" advance often consist of collections of photographs which reveal some previously hidden worlds (often taken by electron microscopes) – or elegant images which are some sort of visual representation of some theoretical/mathematical results. Modern computer-graphics packages have resulted in a plethora of elegant images / but does this result in art? – May be, maybe not - perhaps it is just semantics anyway. I do have the board from a computer and other elegant flotsam dropped overboard from our technologically underpinned World which produces so much obsolete and un-recyclable technology. To me such objects are as elegant as a Jackson Pollock or a Bridget Riley Op Art creation – but is it art and anyway does it matter? As far as I am concerned a deeper understanding of the question is more interesting and probably also more important than the answer – if indeed there is one.

The artist Allen Jones contacted me early in 2004 about an imaginative idea for that year's 2004 Royal Academy Summer Exhibition at Burlington House in London. The idea that he and David Hockney had come up with was to organise an exhibition of drawings that people, who were not practicing artists – such as for instance scientists - produced and used during their work. This was to me a most welcome request from artists, especially in the light of the virulent animosity towards science of some in the Arts such as William Blake and Henry Miller. The display was not to be an exhibition of art by people who paint or draw as a sideline or hobby, but an exhibition of working drawings that had played some key role in their professional work. In the case of scientists, drawings made by hand rather than by computer which had formed part of the research process. In response to this initiative I collected together some drawings made between 1985 to 1987 the period during which the field of Fullerene Science was born (Ref 1).

THE ART AND SCIENCE OF THE CARBON NANOWORLD

Diamond and graphite are the two forms of the element carbon that have been known since time immemorial. Amazingly in 1985 a third form was discovered (Ref 1) - a 60 atom cage molecule with the pattern of a modern football which has 12 pentagonal and 20 hexagonal patches, Fig 1.

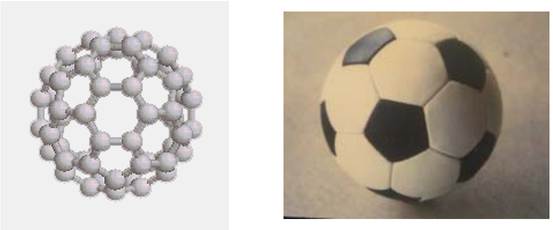


Fig1 a) Schematic diagram of a ball and stick model of the C_{60} Fullerene carbon cage molecule; b) Photograph of a soccer ball.

Basically one can consider the carbon atoms as residing at the 60 trigonal intersections of the seams of a soccer ball. After the discovery of this molecule (formula C_{60}), which I named Buckminsterfullerene after the designer of the geodesic domes, and its slightly larger and elongated cousin C_{70}, the possibility of other smaller and larger carbon cages began to interest me and I decided to play around and construct some possible models – initially just for fun.

Just as the Platonic and Archimedean semi-regular solids had fascinated Leonardo da Vinci and Piero della Francesca who had drawn them, so as I created models of these newly conceived molecules I was similarly moved to represent them in two dimensions. At the time I had no, readily available, molecular modelling computer programmes so I improvised a sort of modern (in 1985) analogue of the Camera Obscura approach that has been used by artists for centuries:
a) First of all various possible model Fullerenes were constructed out of simple molecular modelling components. The nuclei of the atoms are represented by small black 120° plastic bracket units, and these are linked together in a trigonal network by white plastic straws which represent the electrons that form the chemical bonds (Fig 2). This model-building exercise was carried out on the basis of some rather arbitrary aesthetic symmetry as well as chemical considerations to see what sort of structures might arise in accordance with the recipe that 12 pentagons and any number of hexagons (except one) can close into a cage structure. b) The models were then photographed using a Polaroid camera. The original photograph of the original model for C_{28} is shown in Fig 2.

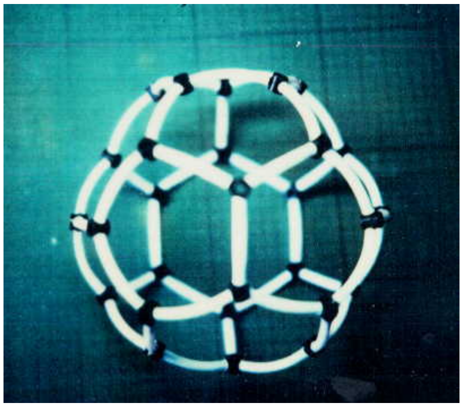


Fig 2 SX70 Polaroid photograph of a model of the small Fullerene C_{28} *constructed out of simple molecular modelling components. The nuclei of the atoms are represented by small black 120° plastic bracket units, and these are linked together in a trigonal network by white plastic straws which represent the electrons that form the chemical bonds.*

c) The photographs were then enlarged using a photocopier; d) On the photocopies the atoms were connected by straight lines and then; e) The resulting network was traced to produce a series of 2D images in perspective. The result was a set of drawings of a new family of pure carbon molecules that had never previously been considered – the Fullerene Family (Ref 2). Four: a) C_{70}, C_{50}, C_{32}, and C_{28} are depicted in Fig 3. The family is huge, in fact infinite – as an example there are some 14000 different possible cages for the case of 120 atoms. It turns out that for 60 atoms there is an especially symmetric structure – the one-and-only soccer ball structure.

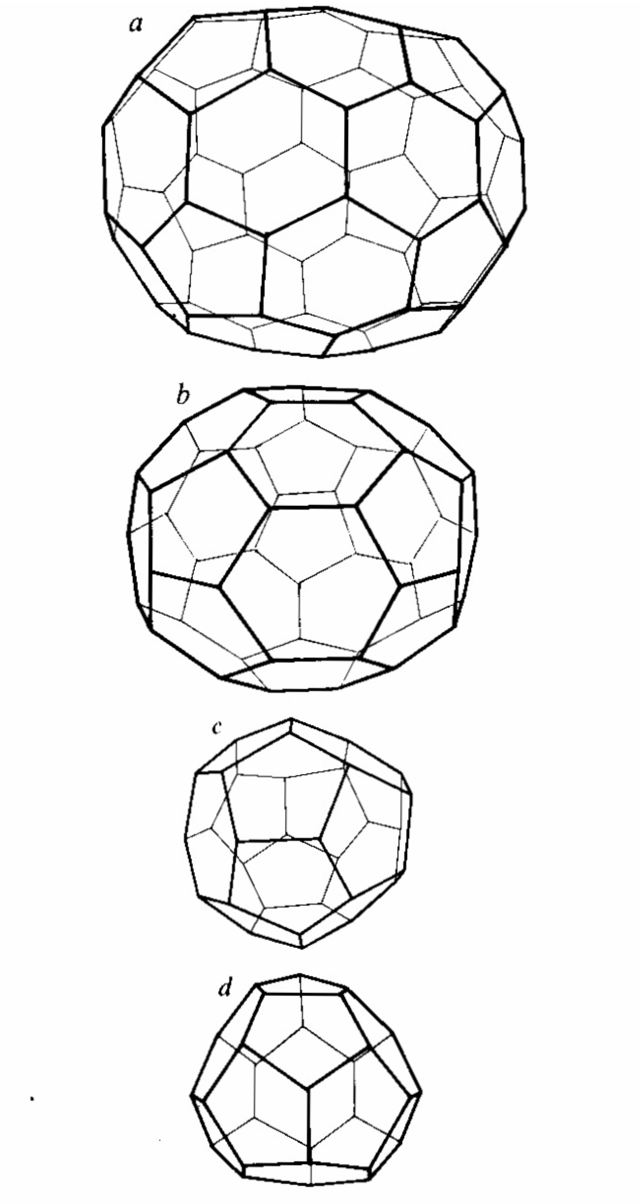


Fig 3 Schematic drawings of the Fullerenes: a) C_{70}, b) C_{50}, c) C_{32}, and d) C_{28}

THE DIAGRAMATIC REPRESENTATION OF MOLECULES AND CHEMICAL PROCESSES

Mercator's name is associated with one solution of the problem of how to represent the surface of the World on a flat sheet (eg how to make a map). In Chemistry a related problem arises and the name of Schlegel is associated with the problem of representing the surface of a polyhedron in 2 dimensions. In the case of the C_{60} molecule, which has a same pattern of 12 pentagons and 20 hexagons as a football, the same problem that Mercator had to solve arises - how to represent a Fullerene network on 2D sheet. One Schlegel solution for C_{60} is shown in Fig 4.

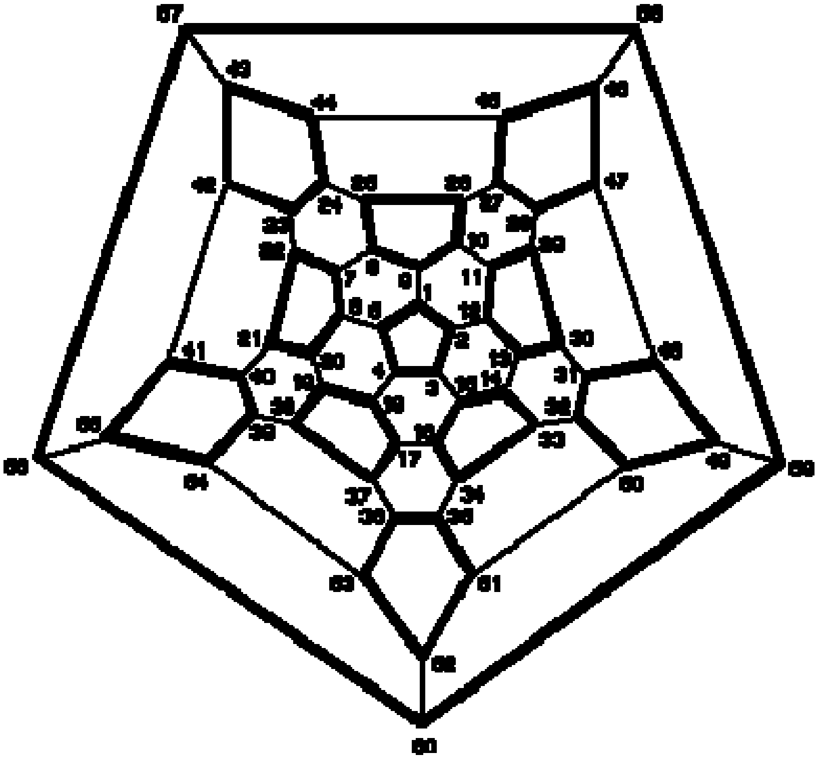
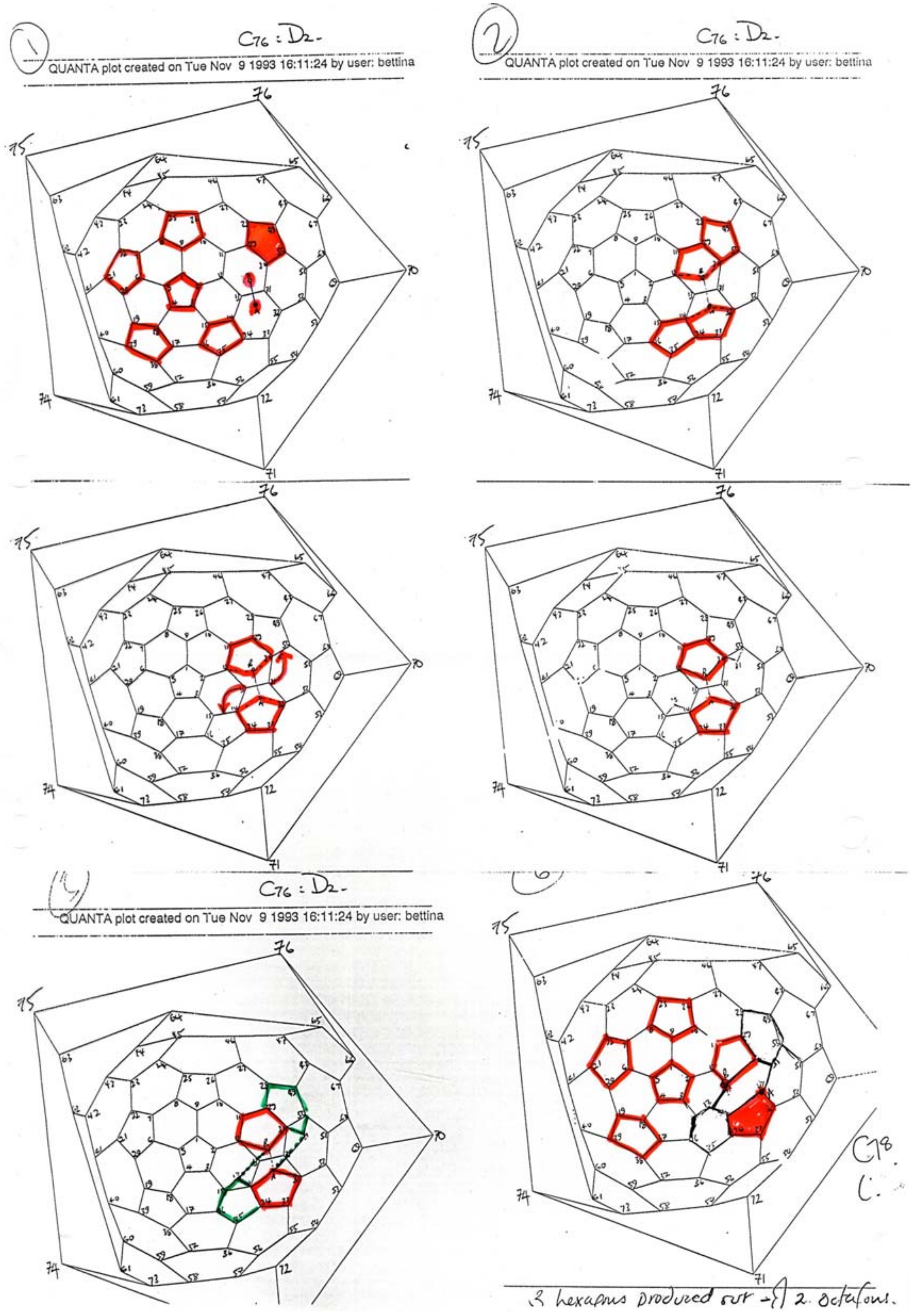


Fig 4 Schlegel diagram of the C_{60} molecule. Note that one pentagon lies at the centre of the pattern whereas the diagonally opposing pentagon is represented by the pentagonal outer perimeter surrounding the whole pattern

Just as in the case of Mercator's projection, in which the countries of the World are distorted to varying relative degrees, so the various polygonal shapes also are also distorted to varying relative degrees. What we have is a 2D network which is very useful for atom identification and chemistry book-keeping purposes. In a way it is rather analogous to Beck's famous London Underground Map, which is very useful for deciding quickly how to get from one location to another but rather less useful for the representation of the real geographical logistics involved.

THE "ART" PERSPECTIVE

In a way the problems that were confronted here were the same ones that Braque and Picasso confronted when they developed Cubism. Duchamp went somewhat further in his "Nude Descending a Staircase" where he attempted to portray – not that successfully in my opinion - motion as well. He attempted to represent the 4 dimensions (3 spatial dimensions as well as time) on an intrinsically 2D surface. In a somewhat analogous way, the set of chemistry images depicted in Fig 5 presents an attempt to represent a dynamic time-dependent chemical process.



3 hexagons produced out → 2 octagons.

Fig 5 The original series of hand-annotated diagrams depicting the sequential stages in a hypothetical carbon atom insertion reaction in which a carbon nanotube network might grow.

In Fig 5 a hypothetical chemical reaction is represented in which 2 carbon atoms are "ingested" into a Fullerene cage network, effectively inflating the cage. Two atoms, shown in red in Fig 5, on the surface assimilate into the network. A facile series of bond (localised electron) shifts, indicated by the red arrows, results in a new slightly larger cage. The interesting thing is that this process can continue sequentially and C atoms may add by the same mechanism two-at-a-time *ad infinitum*, resulting in a chiral (helical) tubular structure. Such a helical tubular structure is depicted in a somewhat more readily appreciated perspective representation in Fig 6.

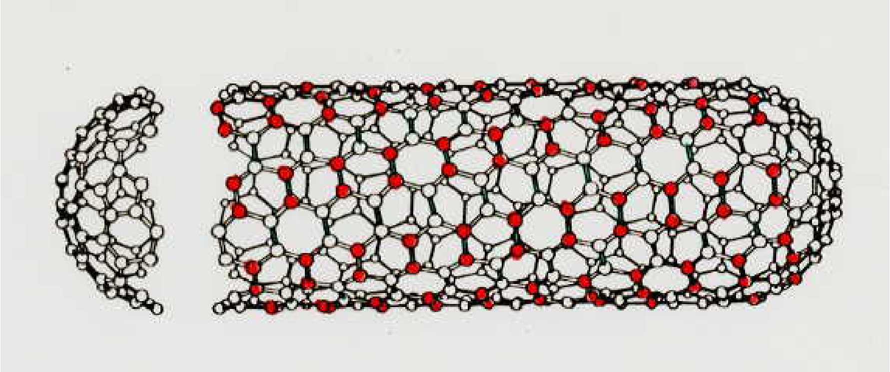


Fig 6 Diagrammatic representation of a ball-and-stick molecular model of a helical carbon nanotube.

The fascinating and elegant aspect here is that the end-cap pattern (which is the same pattern as half a soccer ball with one pentagon displaced – Fig 6) has not actually changed – but appears to have rotated one notch at a time. This is what we call a pseudo-rotation.

CONCLUSION

Examples have been described in which a model building exercise which started out as purely personal intellectual "artistic" exercises resulted in some elegant scientific advances. Furthermore the process of transcribing the results for publication required the use of diagram construction devices, which find parallels in the approaches that artists from Leonardo to Picasso have used for centuries. The drawings which resulted formed part of a display at the 2004 Royal Academy (London) Summer Exhibition.

ACKNOWLEDGEMENTS

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