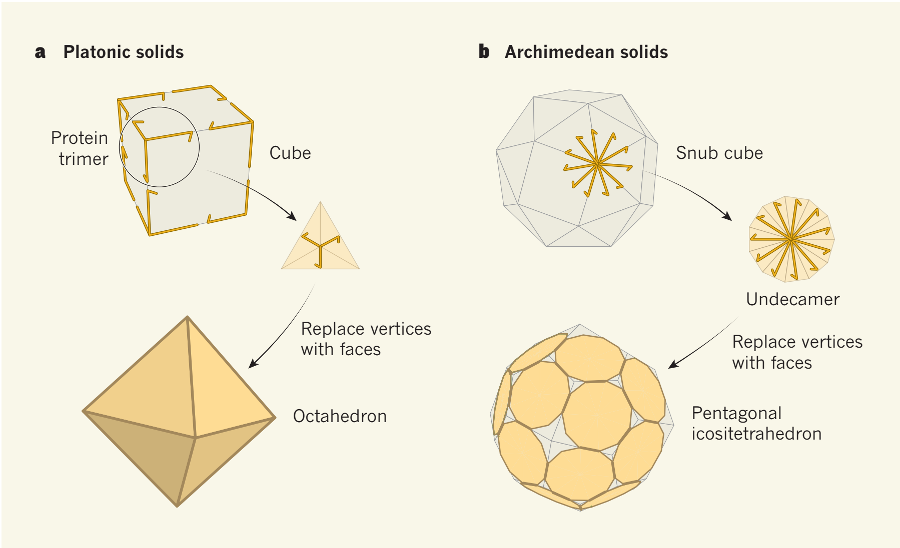

Figure 1 | The assembly of proteins into Platonic and Archimedean geometries. **a**, Platonic solids are a family of symmetrical 3D shapes that includes the cube. To assemble proteins into these shapes, protein multimers (such as trimers, for a cube) can be placed at the vertices. Interactions between multimers along a shape's edges hold the assembly together. Dual shapes form if the vertices are replaced by faces, and vice versa; the dual of a cube is an octahedron. **b**, A snub cube is an Archimedean solid — a polyhedron that has identical vertices but different types of edge and face. Malay *et al.*[3] found that an undecameric protein complex (an assembly formed of 11 identical protein subunits) can be engineered to assemble at the 24 vertices of a snub cube. The connections between subunits are mediated by metal ions along the edges. The resulting protein assembly has the shape of a pentagonal icositetrahedron, which is the dual of the snub cube.

contacts with the other undecamers, thus forming 60 edges.

Only 10 of the 11 thiol groups in any given undecamer participate in metal-mediated connections. This feature arises as a result of using metal ions for assembly: the strategy tolerates the presence of potential sites of attachment that do not actually form interactions through metal ions. This contrasts with design approaches that are based only on direct interactions between protein subunits[6] — the 'sticky' hydrophobic surfaces on proteins that mediate such interactions can lead to random aggregation if they do not interact successfully with other protein subunits.

In the reported snub cube, the 11 subunits in a given undecamer ring occupy different spatial environments and connect differently to neighbouring rings, breaking the symmetry of the system. Symmetry-breaking is also a feature of the architectures of many viral capsids (protein shells). A diverse array of viral capsids can be understood as systems in which a simple icosahedron is elaborated into something more complex, for example by subdividing its triangular faces into smaller triangles[12]. In such systems, large numbers of protein subunits can be tiled onto capsid faces so that there are only modest differences in the angles between them and in the environments they occupy. This 'quasi-equivalence'[12] allows unbroken interactions between subunits to be maintained throughout the capsid, so that an essentially solid shell can be formed.

Malay and colleagues' structure shows that molecular Archimedean architectures break symmetry differently: by not using a subset of potential lateral interactions. The resulting architectures therefore contain sizeable holes (Fig. 1b), which renders them more cage-like than shell-like. Interestingly, holes have previously been observed in other large, artificial protein shells that deviate from quasi-equivalence[13].

The authors' findings suggest an explanation for why (as far as we know) Archimedean protein architectures haven't evolved in nature, for use in cells, for example. The apparently unavoidable openings in such structures might have made them less suitable as enclosures, compared with their quasi-equivalent icosahedral (Platonic) counterparts, which evolved many times in viruses.

The current result was a serendipitous finding, but further studies should address whether similar outcomes can be obtained predictably using other protein building blocks. With this in mind, Malay *et al.* have produced computer models of architectures based on other Archimedean solids (such as the cuboctahedron), which might be constructed using other ring sizes, including 7-, 10- and 16-sided polygons. Success in building those architectures would be another exciting development in the field of designed protein assemblies. ■

Todd O. Yeates *is in the Department of Chemistry and Biochemistry, and at the DOE Institute for Genomics and Proteomics, University of California, Los Angeles, Los Angeles, California 90095 USA.*
e-mail: yeates@mbi.ucla.edu

NATURE

50 Years Ago

As pollution of crops and foodstuffs with pesticides increases, the continued use of persistent chemicals such as the chlorinated hydrocarbons, DDT and dieldrin, is being challenged. In the United States, Michigan and Arizona have already banned the use of DDT ... while an organization known as the Environmental Defense Fund is fighting the continued use of the pesticides in a test case against the State of Wisconsin. From the beginning of 1970, DDT will also be banned in Sweden for domestic purposes ... In Britain, the use of dieldrin and aldrin on spring sown seed has been banned since 1967, and a working party of the Advisory Committee on Pesticides and Other Toxic Chemicals is now reviewing the use of these pesticides in a wider context.
From *Nature* 17 May 1969

100 Years Ago

A memoir on Mars from the pen of Mr Harold Thomson, president of the British Astronomical Association, appears in *Scientia* for May. Mr Thomson narrates ... the facts known about the planet from observation, and takes the very proper view that it is not specially the function of the astronomer to indulge in speculations as to the possibility of inhabitants of other worlds based on such facts, but only to collect them. Nevertheless, he makes the point that the changes in the form of the dark markings and in their positions may represent changes on the surface of the planet which have analogies on our Earth in the destruction of large forest areas, the ploughing up of vast tracts of land, or the changes caused by the operations of husbandry, and this may supply arguments to those who assert the existence of intelligent beings on Mars of as great weight as those furnished by the canals.
From *Nature* 15 May 1919