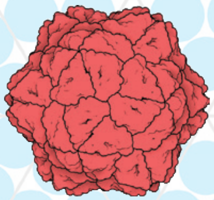
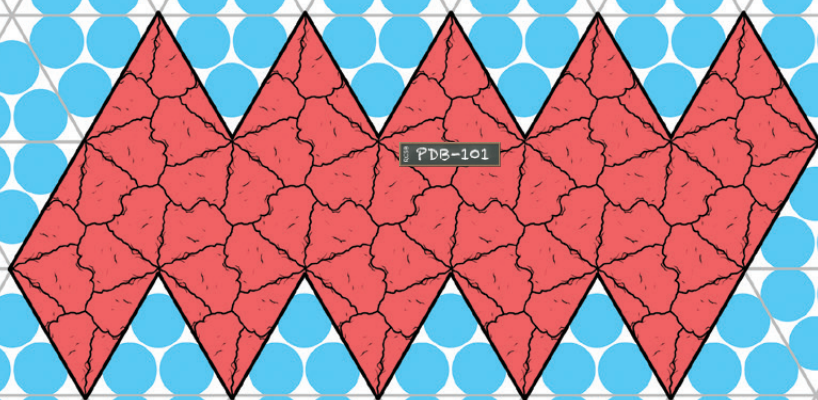
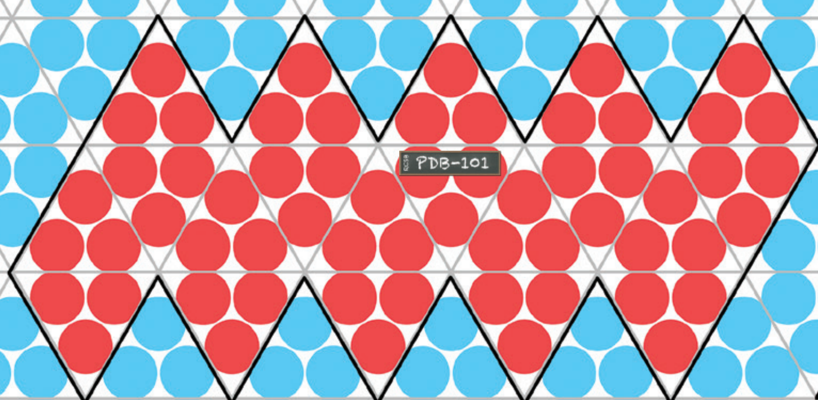


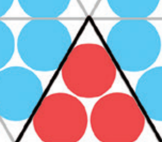
T=1

Satellite Tobacco Necrosis Virus

PDB entry **2buk**







Subunits are in perfect icosahedral symmetry.

Viral Quasisymmetry

Viruses are faced with a challenge: their genomes need to encode all of their proteins, but at the same time, these genomes need to fit into the tiny space of a viral capsid. In the 1960s, Donald Caspar and Aaron Klug discovered that viruses solve this problem using quasisymmetry.

Viral capsids are built using many identical copies of one or a few capsid proteins, arranged to form a shell with icosahedral symmetry. Some viruses, such as Satellite Tobacco Necrosis Virus, build a tiny capsid with perfect symmetry. Other viruses need more room, so they build larger capsids, but still only using one type of building block.With small changes in shape, the subunits form pentamers and hexamers, and these pack into larger, quasisymmetrical capsids.

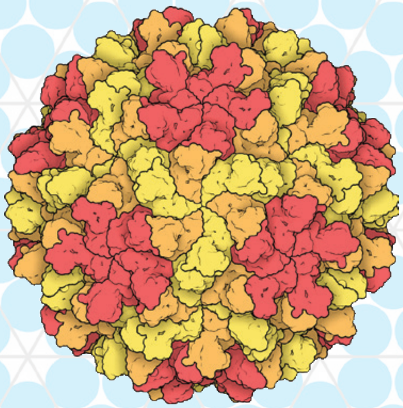
These paper models show a few examples of how quasisymmetry is used to build viruses of different sizes. The subunits are represented as circles, with ones that form pentamers in red and ones that form hexamers in shades of yellow and orange.
For each virus, a model of the atomic structure is also included.

Cut out the models and tape the edges together to form the icosahedral virus.

Learn more at **pdb101.rcsb.org**

200th Molecule of the Month

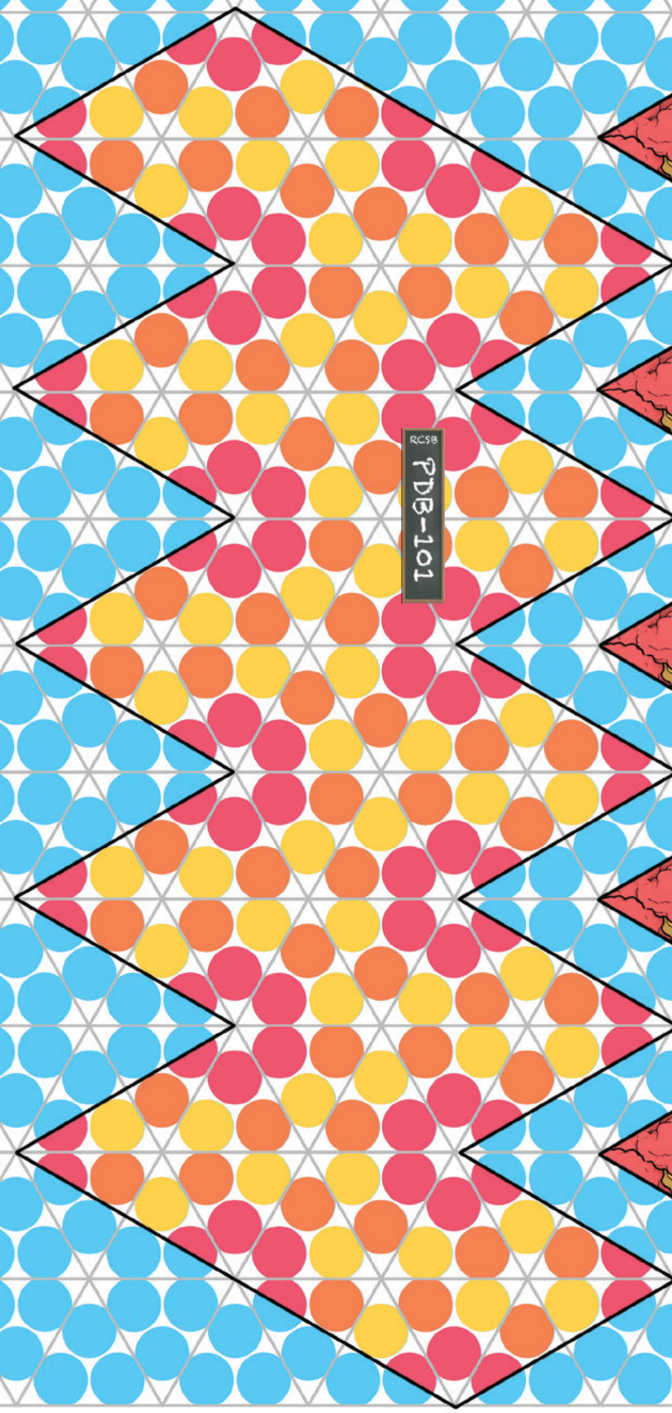
RCSB PDB-101

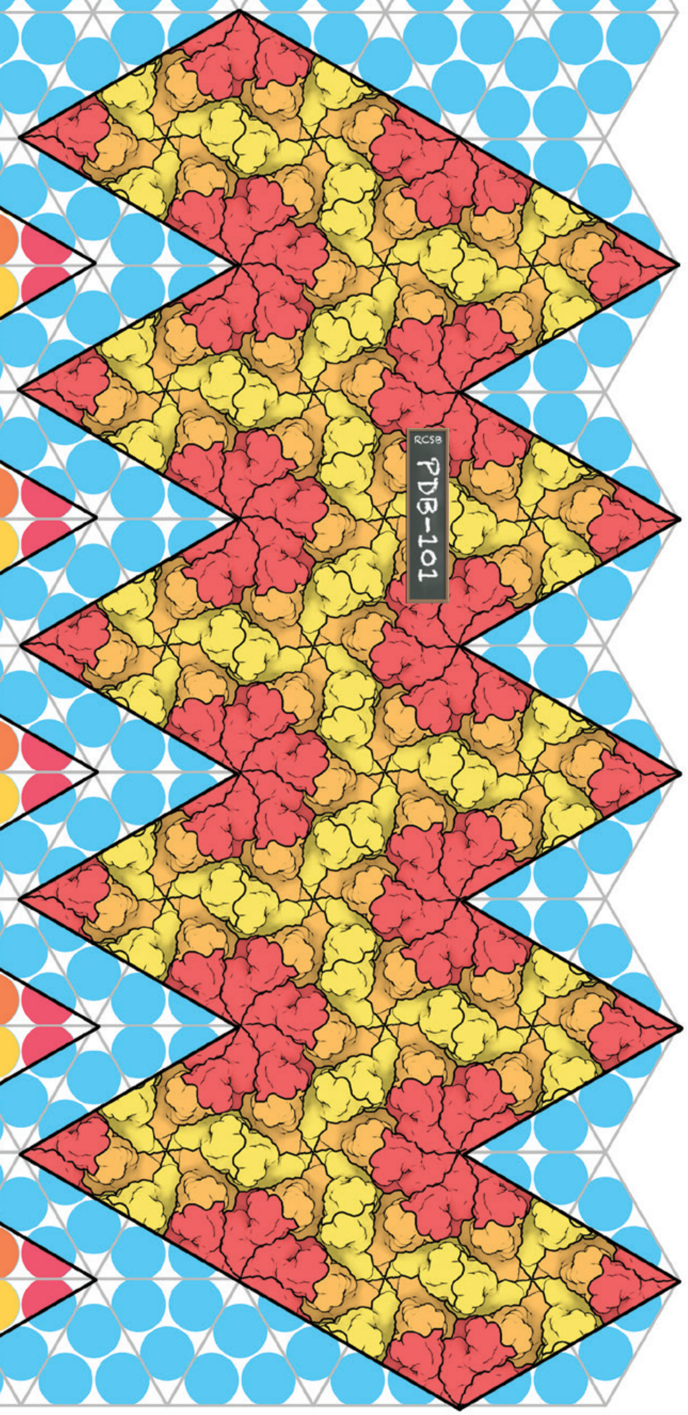


T=3

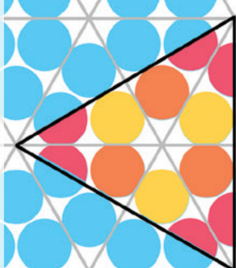
Tomato Bushy Stunt Virus

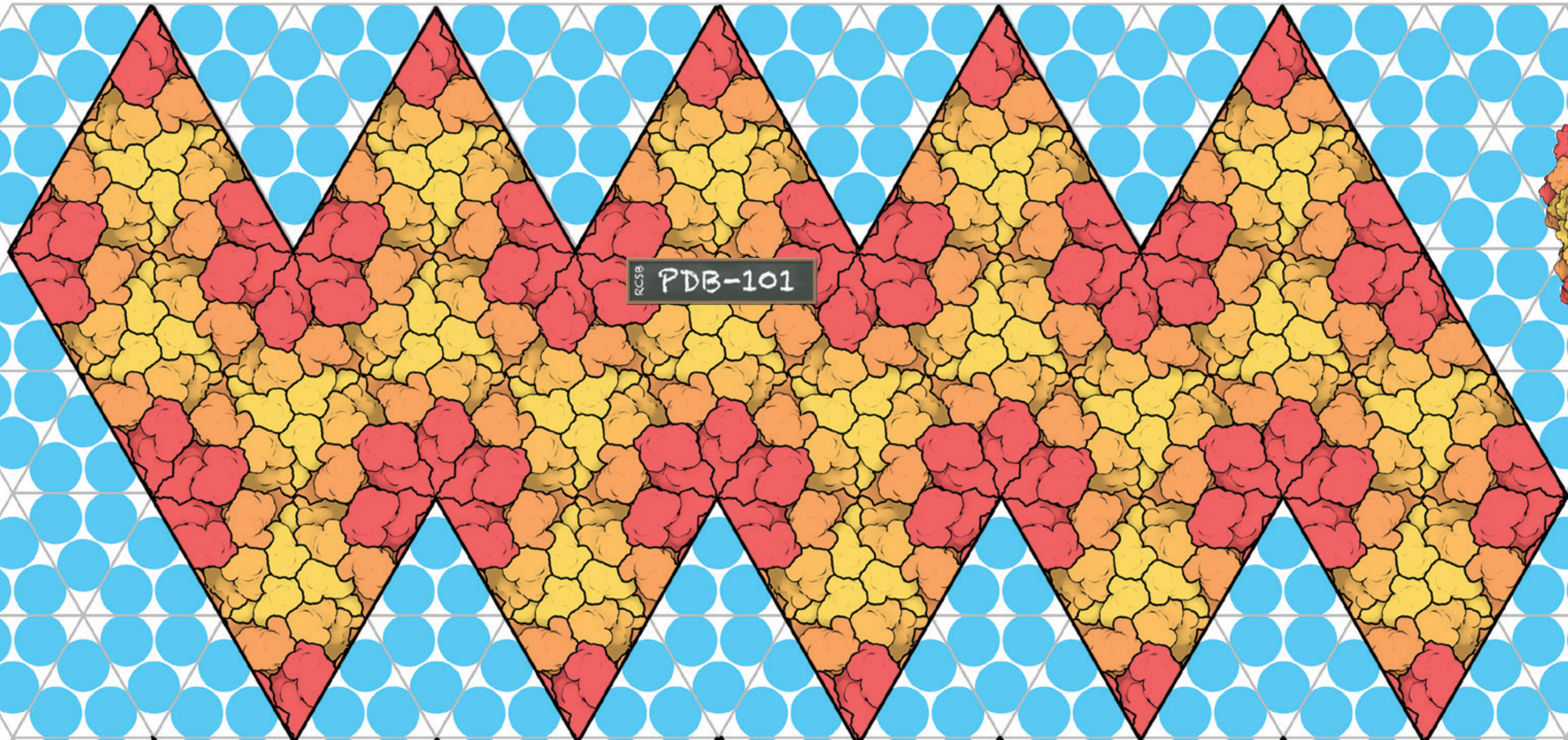
PDB entry **2tbv**

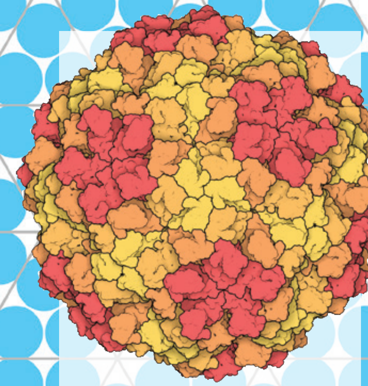




Subunits occupy three different positions: one type forms a five-fold interaction at the vertices of the icosahedron (shown in red), and two other types form a pseudo-six-fold interaction in the center of each icosahedral face (shown in yellow and orange).

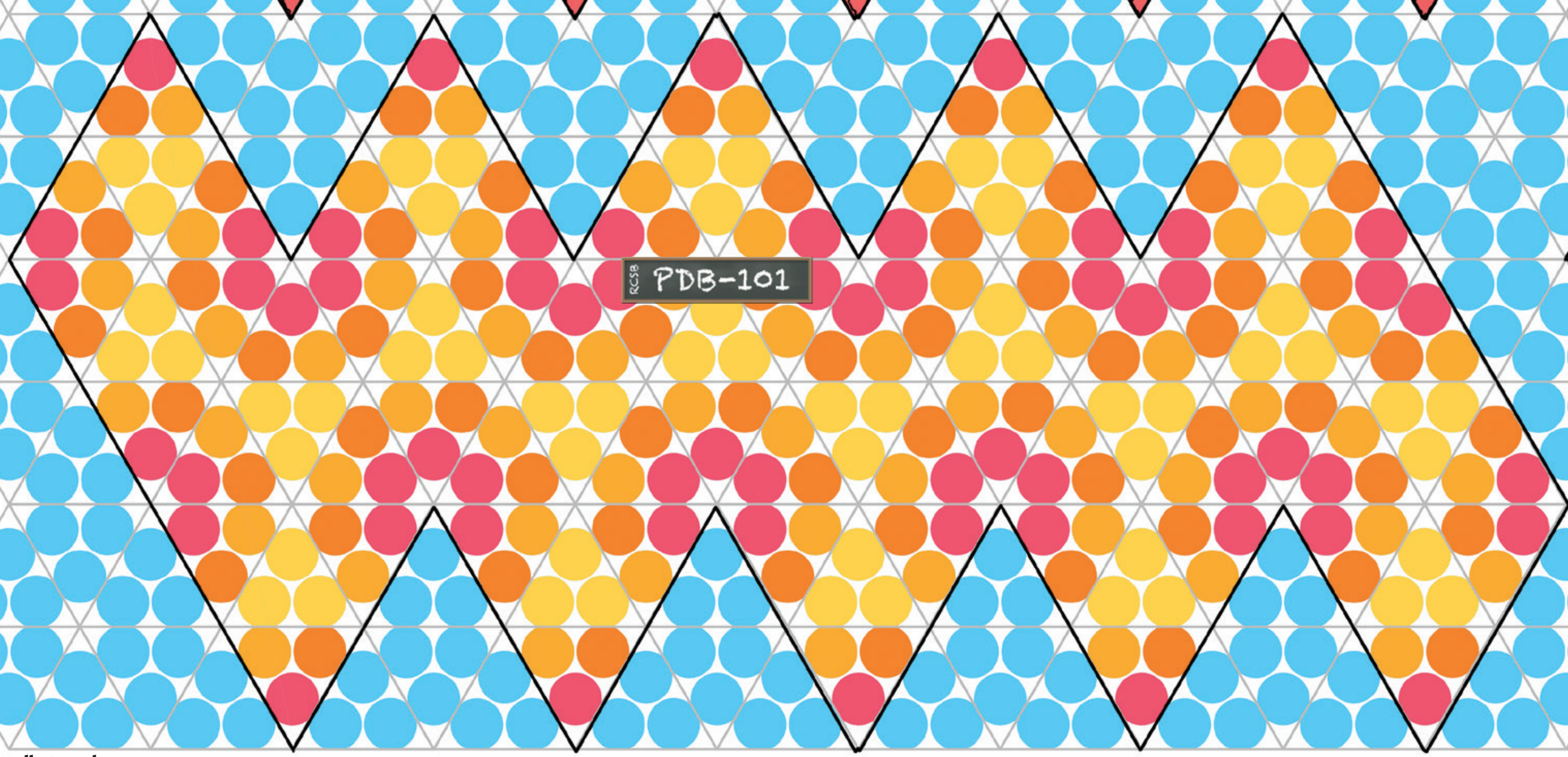


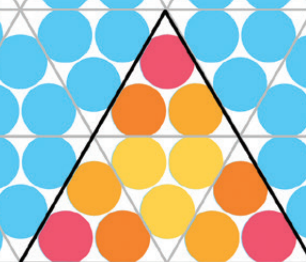




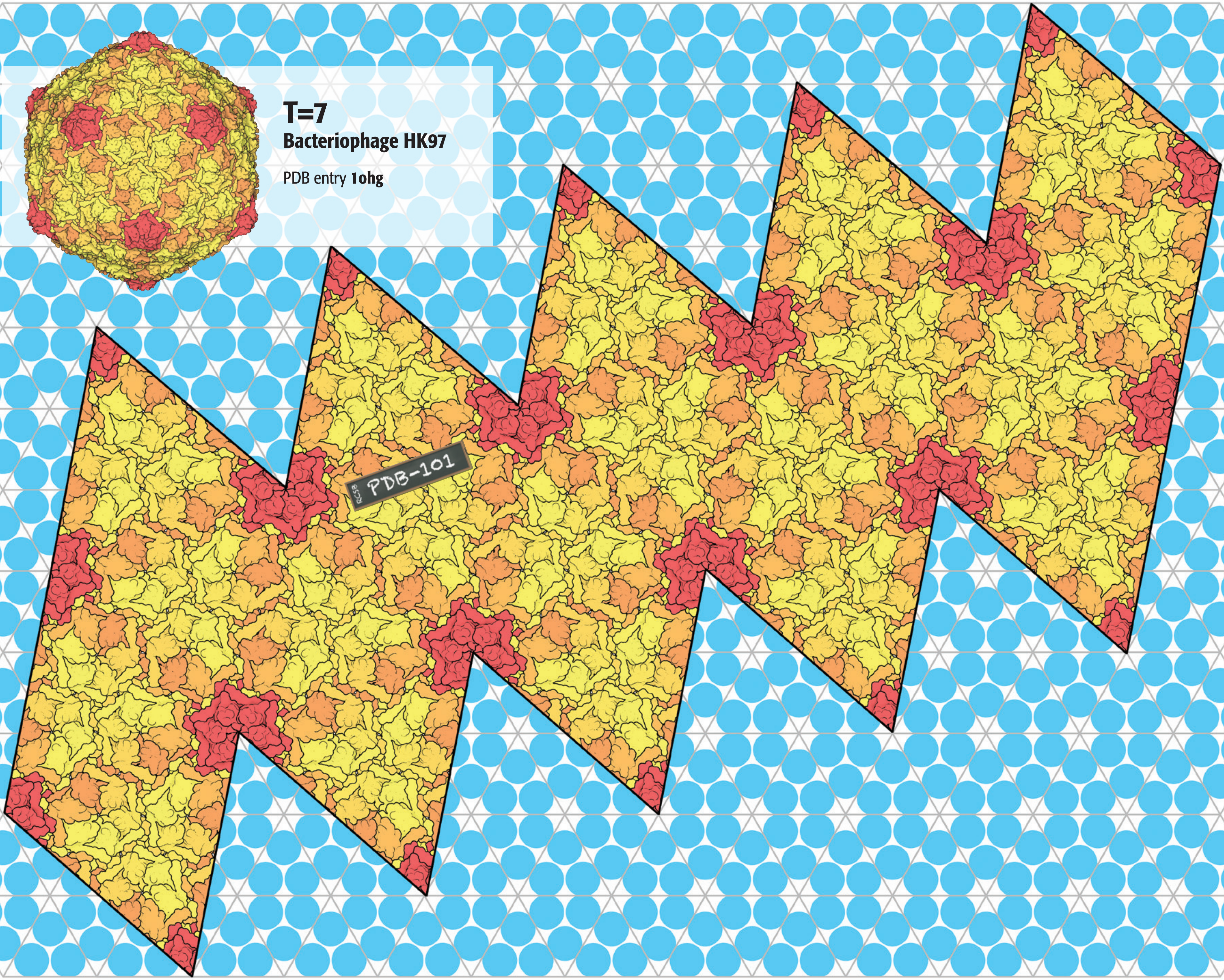
T=4
Nudaurelia capensis
Omega Virus

PDB entry **1ohf**





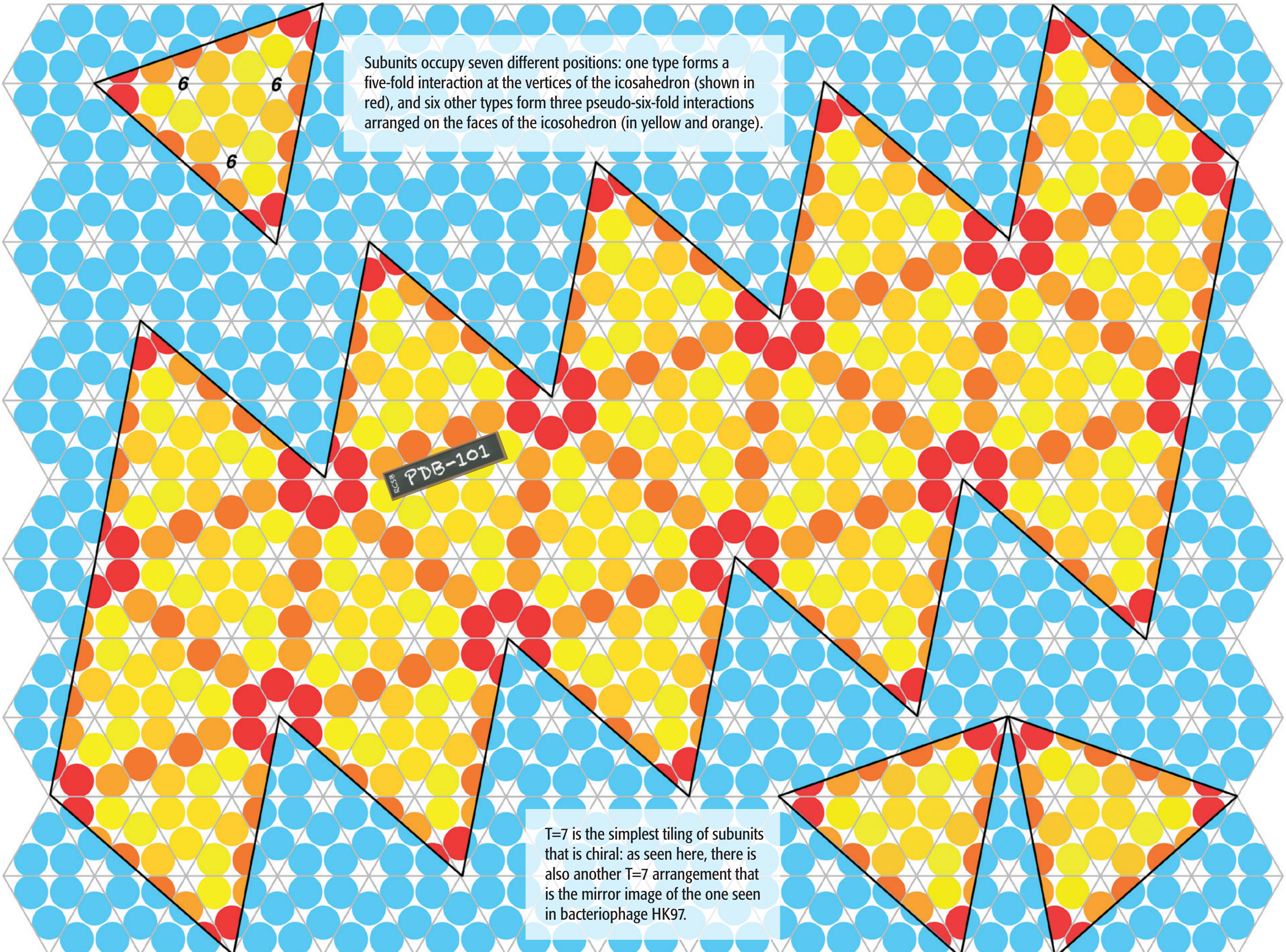
Subunits occupy four different positions: one type forms a five-fold interaction at the vertices of the icosahedron (shown in red), and three other types form a pseudo-six-fold interaction centered on each of the edges of the icosahedron (in yellow and orange).



T=7

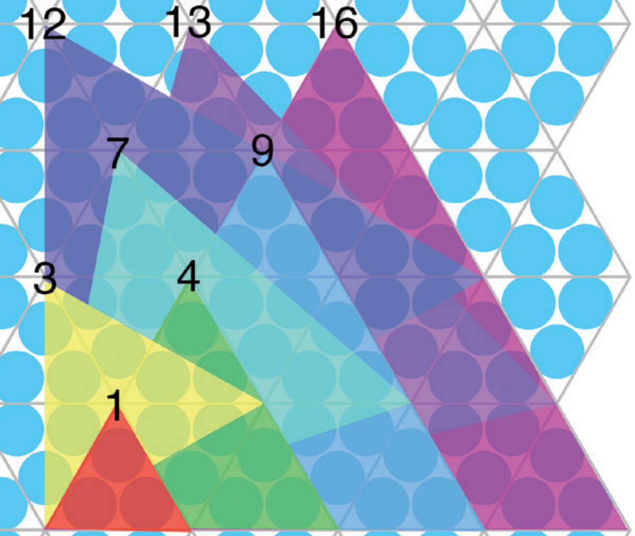
Bacteriophage HK97

PDB entry **1ohg**



Subunits occupy seven different positions: one type forms a five-fold interaction at the vertices of the icosahedron (shown in red), and six other types form three pseudo-six-fold interactions arranged on the faces of the icosohedron (in yellow and orange).

T=7 is the simplest tiling of subunits that is chiral: as seen here, there is also another T=7 arrangement that is the mirror image of the one seen in bacteriophage HK97.



Triangulation Numbers

Caspar and Klug found that only some arrangements of subunits can form quasisymmetrical capsids. To explain this, they developed the concept of a "triangulation number," which represents the number of unique environments that subunits occupy.

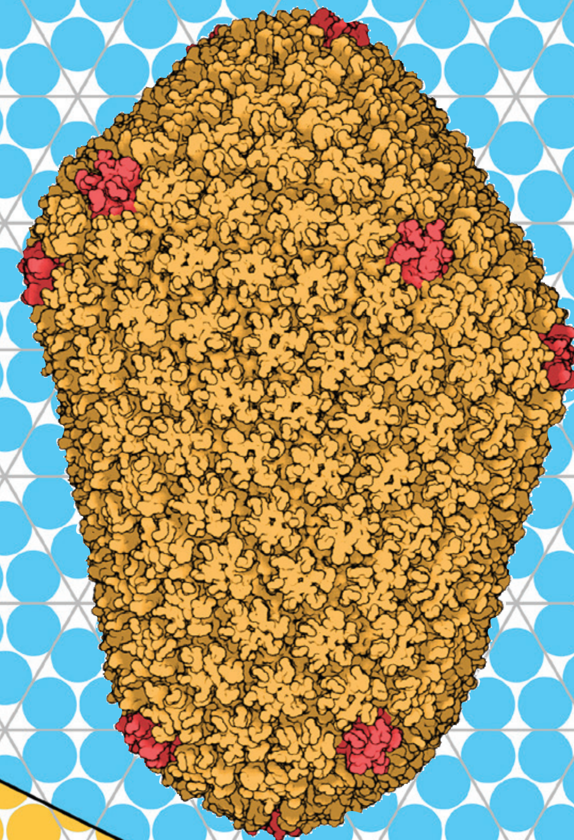
You can find the allowable triangulation numbers by tracing out equilateral triangles on this hexagonal net of subunits. The smallest triangulation numbers are shown above.

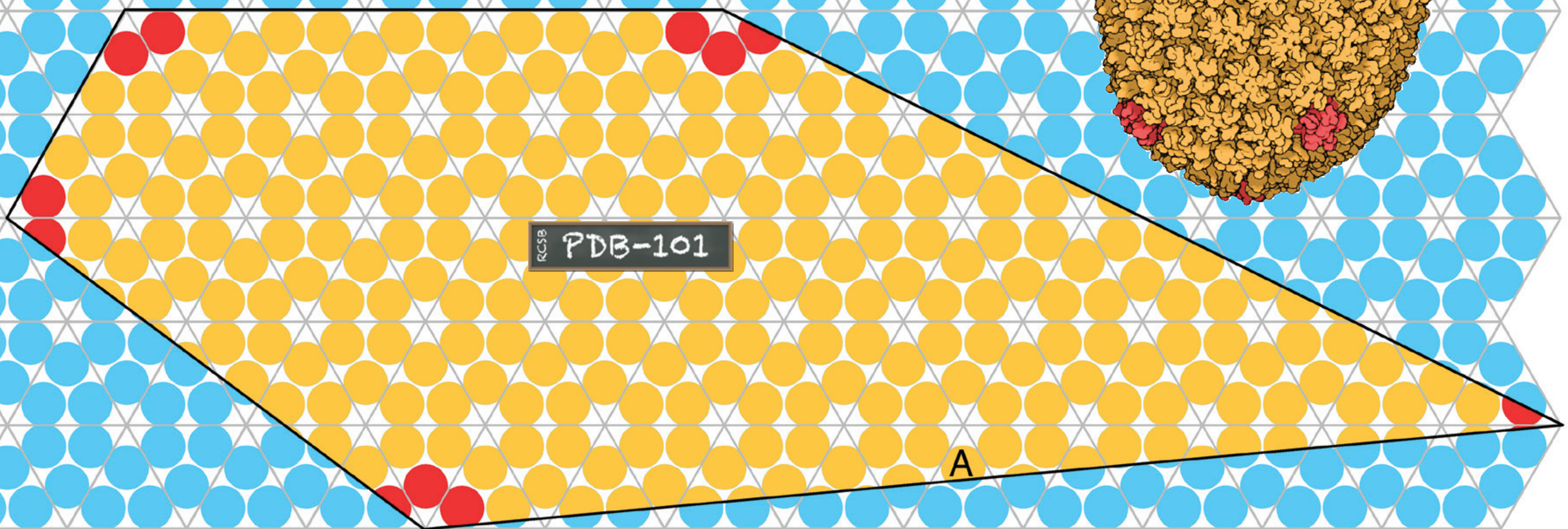
Try finding larger triangles, and cut out 20 copies to make larger viral capsids.

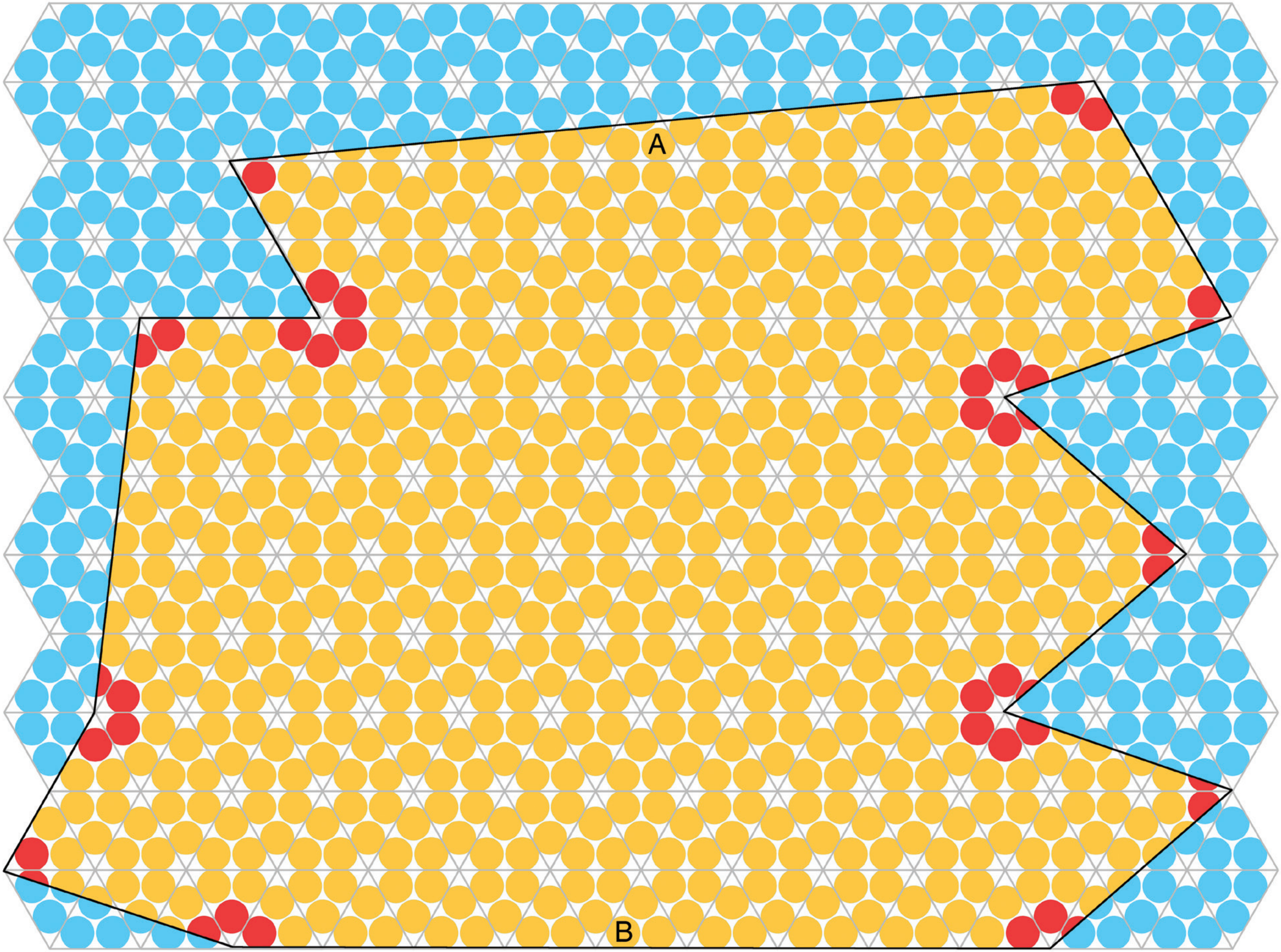
HIV Capsid

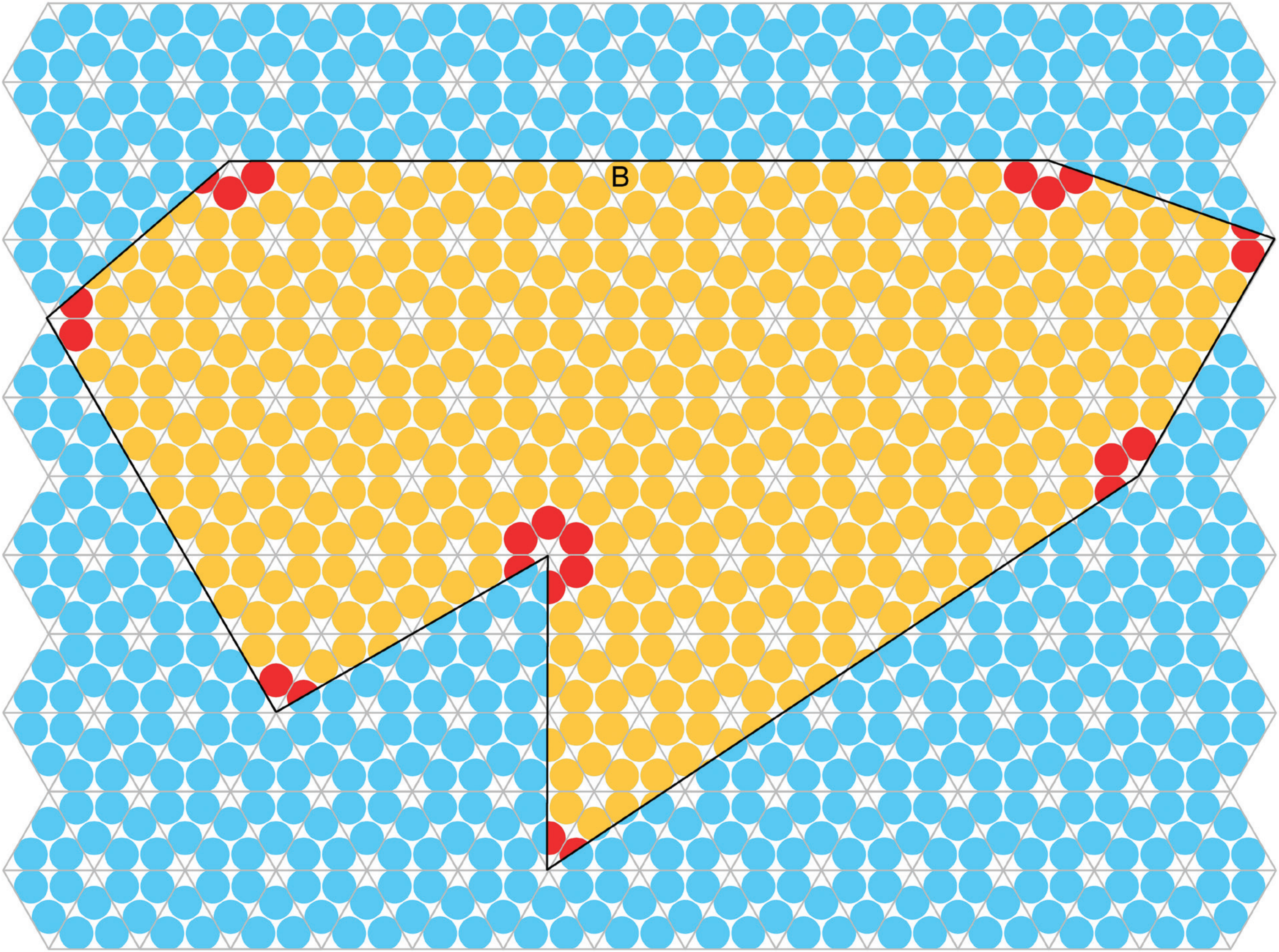
HIV also uses quasisymmetry to build a very large capsid to enclose its two strands of genomic RNA. As with the icosahedral viruses, the capsid protein forms pentamers and hexamers. However, these associate to form an irregular cone-shaped capsid, as shown here from PDB entry **3j3q**.

To build the paper model, cut out the three pieces, tape them together by lining up the letters on the edges, then fold and tape the model into the cone-shaped capsid.






A
B


B