PART I Chapter 4 T=4 structures

Simplicity on the way.

4.1 Bilateral and morphotropic symmetries. The Cowpeas and the links.

We are now approaching the big structures. And we can see a link from the smallest to the biggest capsids.

We start with the two Cowpea capsids, one in pT=3, and one T=3. One with a topology the same as Blue Tongue (see 8.3.1 chap 8, Conclusions), in fig 4.1.1 here, and one has typical bilateral symmetry in 4.1.2.

Cowpea mosaic virus is step 5 in the Blue Tongue series, Herpes is step 7, and PRD and Adenovirus Type 5 are both step 9. Blue Tongue itself is step 6.

A close analysis of the Nduarelia as done in fig 4.1.3 shows a new polyhedron clearly based on the new type of disk for this capsid. The polyhedron of 53 symmetry is described as an expanded great rhombicosidodecahedron that makes it possible for evolution to stay around the bilateral symmetry concept longer. As it is related in structure to the Semliki virus we name it the Nduarelia-Semliki- polyhedron. Also the Cowpea mosaic virus structure is important and we name it the Cowpea polyhedron.

Fig 4.1.1 Cowpea mosaic (Cowpea polyhedron)  
Great rhombicosidodecahedron three different edges via rotation  
2 Cowpea Chlorotic Mottle

Fig 4.1.3. The Nduarelia-Semliki- polyhedron with decagons, hexagons and triangles. Slightly bigger than the great rhombicosidodecahedron. TT polyhedron added in black to right. See also 4.2.5.
We show below that *Bacteriophage alpha 3* has great similarities with the *PRD* and the *ADENOVIRUS TYPE 5* in figs 4.1.4-7. So a link is there over to the real big block structures with the Blue Tongue structures and then also the Rossmann series. There is a calculated net structure in 4.1.6 with a perfect agreement with the PRD structure, and also is very good as compared with the *Bacteriophage alpha 3* structure in 4.1.7.

4.1.4 *PRD* size 630 Å

5 *ADENOVIRUS TYPE 5* size 884 Å

4.1.6 From equation 3.3.3 in Part II

4.1.7 *Bacteriophage alpha 3*

We learn that the two Cowpeas form a link between the very small (Satellite Panicum Mosaic Virus of size 159 Å) and very big capsid (Mimi virus of size 5000Å). They form a link between the bilateral capsid structures (small and averaged sized) and the morphotropic capsid structures (big or very big ones).

There are of course more examples; one is the Blue Tongue series itself. And obviously the *Bacteriophage alpha 3* and Nudaurelia both form links between the bilateral and the morphotrophic capsid structures.

There are three different capsid structures, *Nudaurelia, Human Hepatitis* and *Semliki*, to discuss in this chapter. They lay the ground for the description with the two different structures in chapter 5 for T=7.

For T=3 we needed two different molecules in 3 asymmetric units that with 3 fold symmetry produced a six-ring of a disk. The ring itself consists of 2 different molecules.
For $T=4$ (Nudaurelia, Human Hepatitis and Semliki) we need three different molecules that with 2 fold symmetry produce a six fold ring of a disk. The ring itself consists of 3 different molecules. The Semliki has a simple asymmetric unit that in a 2-fold rotation produces a beautiful structure. This is, as we will see a route for the construction of very big structures.

The chemistry is that Nudaurelia and Human Hepatitis are built of resp $\beta$ sheets and $\alpha$ helices. The important Semliki is built of $\beta$ sheets.

We give an example from the beginning, the BMV with its disk of 3 fold symmetry in fig 4.1.8, as compared with the new disk for Nudaurelia with 2-fold symmetry in fig 4.1.9.

![Fig 4.1.8 BMV disk](image1)

![Fig 4.1.9 Nudaurelia disk](image2)

### 4.2 Nudaurelia Capensis Omega

The Refined Structure of Nudaurelia Capensis Omega Virus Reveals Control Elements for a $T=4$ Capsid Maturation


Ave diameter 399 Å

![Fig 4.2.1 Nudaurelia](image3)

![2 Asymmetric unit](image4)
As we have four different molecules with 3 available for the disk we see from fig 4.2.3 that the disk after the 2-fold axis is the one to choose. And to right we have cut out the actual disk. With the new choice of disk it is easy to realize the similarity with *Bacteriophage alpha 3* (T=3) and a link between T=4 and T=3.

Finally we give the detailed net for the *Nudaurelia* polyhedron below in 4.2.5 and disk descriptions of the two structures in figs 4.2.6-7.

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**Fig 4.2.3** Electron density of *Nudaurelia* after 3 and 2 fold axes

4 Disk as extracted from 4.2.3

**Fig 4.2.5.** The *Nudaurelia-Semliki* polyhedron

**Fig 4.2.6** *Bacteriophage alpha 3*

7 *Nudaurelia*
4.3 Human Hepatitis

Crystallization of Hepatitis B Virus Core Protein Shells: Determination of Cryoprotectant Conditions and Preliminary X-Ray Characterization

Ave diameter 312 Å

With the two last structures of this T=4 group we have found descriptions using new, advanced and ‘clean’ polyhedra.

The structure of Human Hepatitis is of extreme beauty but also of some complexity. It is entirely built of α-helices as is clear from the figures below. With the buttons sticking out from the spherical surface as seen in the Viper surface in fig 4.3.1 the structure is clearly very well described by our new polyhedron Tri-pent-hex I as shown in fig 4.3.3, as well as the Viper picture in fig 4.3.2. The buttons are invariably composed of pairs of molecules, of red-blue, or yellow-green spikes. In detail we draw the nets in fig 4.3.4-7. The heavy black line in 4.3.8 is one of the two polygon edges in Tri-pent-hex I in 4.3.3, or in the Viper drawing 4.3.1 The heavy black lines in 4.3.9 are examples of the other of the two polygon edges in Tri-pent-hex I. We conclude that the detailed structure agrees very well with the highly symmetrical polyhedron in 4.3.1 and 3. The Human Hepatitis disks in electron density, and in Viper terms are shown in 4.3.11 and 12. The two last figures in 13 and 14 are the inner parts of the disks of Human Hepatitis and the HK viruses (see below).

Fig 4.3.1 The Viper surface.  2 The net  3 Tri-pent-hex I, a new polyhedron
4.3.4 The asymmetric unit

5 Electron density after 2 fold axis

Fig 4.3.6 Electron density after 3 fold axis

7 Electron density after 5 fold axis

8 One of the two Tri-pent-hex I polyhedron edges in asymmetric unit

9 The other of the two Tri-pent-hex I polyhedron edges, now after 3 fold axis
4.4 Semliki Forest virus

Cryo-electron microscopy reveals the functional organization of an enveloped virus, Semliki Forest virus.

The disk concept is becoming obvious – the asymmetric unit forms half the disk (figs 4.4.1-3).

We give the important part around the 3 fold axis (fig 4.4.5) and from its net (6) we derive the new polyhedron we have named Nuduarelia-Semliki polyhedron. Which may be regarded as a truncation of the truncated triacontahedron as demonstrated in figs. 4.4.8-9. A truncation similar to the truncation of the icosidodecahedron to obtain the great rhombicosidodecahedron.
Polyhedral models of this beautiful structure after 5 and 2 fold axes are shown in figs 4.4.7-8. The structure is particular simple in the way the squares and triangles surround the pentagons, and the hexagons. There are four kinds of polygons, three kinds of edges and two kinds of corners in the *Nuduarelia-Semliki* polyhedron.
We also give the two polyhedra, the truncated triacontrahedron and the truncated icosahedron here together for comparison, in Wikipedia shape.

Finally we give the Viper models in 4.4.11 and 12. In 4.4.12 there is the net drawn from the *Nuduarelia-Semliki polyhedron*. 