Chapter 9

The Aggregative Properties of Phage Proteins

The study of the ultrastructure of bacteriophages at the current level has shown that their protein components are built from subunits arranged in a definite manner.

These investigations confirmed the hypothesis put forward initially by Watson and Crick in 1956 [22, 134], according to which the envelope of simple viruses must consist of similar protein subunits, because the nucleic acids of these viruses possess a comparatively small stock of information insufficient for synthesis of qualitatively different proteins. The uniformity of the protein subunit places limitations on the design of virus particles, as a result of which the capsids of simple viruses are represented either as rod-shaped structures with a helical arrangement of the subunits or as polyhedra with various types of cubic symmetry. Watson and Crick suggest that their ideas are applicable also to single components of the phage particle.

Identical subunits are aggregated in accordance with the principle of close packing, each subunit being surrounded by other subunits resembling it.

As Crick and Watson [22] claim, the increase in size of a protein structure is a process which can be called crystallization. The concept of crystallization of protein subunits is also accepted by Dulbecco (see the discussion to Crick and Watson's paper [22]). He considers that the crystallization principle can explain successfully some of the experimental data concerning phenotype combination in viruses. For example, the protein envelope of the phage 217
particle formed in the cell during simultaneous infection by two phages may be a combination of the two parent forms. Furthermore, the composition of the proteins determined by this property is independent of the genetic characteristic of the DNA of the phage particle. In Dulbecco's opinion, this is proof that the protein components of phage are built from units which are made independently and are joined to the DNA only later.

Kellenberger [229, 230] postulates the existence of morphopoietic factors in the cell, which influence the final assembly of the phage virion.

The experiments of Schramm [332, 333] and of Harrington and Schachaman [193] showed that disintegration of particles of tobacco mosaic virus (TMV) into smaller protein units and nucleic acid can be produced in vitro. The protein units of TMV are capable of spontaneous aggregation into rod-like structures similar in their morphology to virus particles.

It was later shown [175, 334] that the separate components of a virus can be reassembled into active virus particles. According to Caspar [122], the TMV particle can be regarded as a crystal of limited size. Like a crystal, it can dissolve and recrystallize. Caspar claims that reconstruction of the virus particle is determined by the property of the protein subunits to aggregate into a helical structure, resembling the structure of a complete virus with nucleic acid. Interaction with nucleic acid determines the size of the virus particle and contributes to its stability.

After degradation of the TMV capsid in an alkaline medium, small aggregates consisting of a few subunits remain. Such aggregates are possibly centers of crystallization for reconstruction of the virus particle.

The mechanism of the spontaneous organization observed in vitro, in all probability, may also take place in vivo. Caspar accordingly suggests that there is no need for a special organizing factor for the union of individual virus particles during their synthesis.

The ability of virus proteins to organize themselves is evidently due to the presence of free energy bonds in some subunits. The stability of the aggregates is determined by geometrical affinity between individual subunits and by changes in the free energy bonds in the course of their interaction. A specific bond between