DNA and RNA In and Out of Viral Capsids

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The genomic material of most bacterial viruses (bacteriophages) is double stranded (ds) DNA, while in animal and plant viruses it is generally single stranded (ss)RNA. The dsDNA in the protein capsid of the phage is extremely densely packed and drastically bent, resulting in internal pressures reaching ~50 atmospheres. The work of packaging is provided by a motor protein producing forces of up to ~100pN. Following a brief review of the relevant biophysical and experimental background, I will outline several theoretical treatments of DNA packaging in viral capsid. Particular emphasis will be given to resolving the puzzling difference between the predictions of continuum elastic theories according to which the major contribution to the packaging free energy arises from repulsive DNA-DNA interactions, as compared to computer simulation studies suggesting the packaging free energy is primarily entropic.

Due to partial matching of its bases, when ssRNA is free in solution it folds on itself into branched structures composed of short double stranded duplexes connected by flexible ss loops. Computational analyses show that the sizes of viral RNAs, as measured by their radius of gyration or their "maximum ladder distance", are comparable to the inner diameters of their viral capsids, and consistently are smaller than those of non-viral RNA of the same length. We shall describe a simple model of RNA folding and some basic statistical properties of this "branched polymer", such as the puzzling $R_g \sim N^{1/3}$ scaling of the radius of gyration of random sequence RNAs. We shall also explain the physical proximity of its 3' and 5' ends in most ssRNA structures.

The ssRNA in animal and plant viruses is not as densely packed as in phages. Its packaging within the viral capsid is a cooperative assembly process involving the RNA and the capsid proteins. Yet a clear correlation exists between the length of the packaged RNA and the size of its optimal protein shell. Several exciting experimental studies shedding light on this process have recently obtained in the group of Bill Gelbart and Chuck Knobler at UCLA and will be briefly described in my talk, along with some preliminary theoretical interpretations.

(Relevant references may be found in: http://www.fh.huji.ac.il/~abs/)