

## Architecture of the Bacteriophage Genome: Polymorphism and Phase Transitions

A. Leforestier<sup>1\*</sup>, BK. Sung<sup>1,2</sup>, A. Siber<sup>3</sup>, R. Podgornik<sup>4</sup>, F. Livolant<sup>1</sup>

<sup>1</sup> Laboratoire de Physique des Solides, CNRS UMR8502, Bât 510, Université Paris-Sud, 91405 Orsay Cedex, France

<sup>2</sup> Biomedical Physics Laboratory, Department of Physics and Astronomy, Seoul National University, Seoul 151-747, Republic of Korea

<sup>3</sup> Institute of Physics, Bijenička cesta 46, 10000 Zagreb, Croatia

<sup>4</sup> Theoretical Physics Department, J. Stefan Institute, SI-1000 Ljubljana, Slovenia

\* Correspondence: amelie.[leforestier@u-psud.fr](mailto:leforestier@u-psud.fr)

Double-stranded DNA bacteriophage genomes are densely packaged into capsids until the ejection is triggered upon interaction of the tail with the bacterial receptor. Using cryo-electron microscopy, we describe the organization of the genome in the full capsid of T5, and explore its conformational changes as a function of the ionic and aqueous environment as well as the length of molecule. In the full capsid, monodomains of hexagonally crystallized DNA segments initially form a 3D lattice of defects. Upon progressive ejection, the genome undergoes a series of phase transitions, turning liquid crystalline and finally isotropic. The addition of a DNA condensing agent (either multivalent cations that diffuse through the capsid wall or polymers such as PEG that does not permeate the capsid) provokes the condensation of the DNA chain into toroidal globules. We show that the nature and the concentration of the condensing agent tune both the DNA-DNA interactions between segments of the chain and the interactions between the capsid proteins and the DNA molecule, leading to a variety of shapes and compactness. We'll discuss these results with respects to the different forms that may be assumed by a DNA molecule inside the capsid at different stages of the infectious cycle of the phage (ejection, packaging).

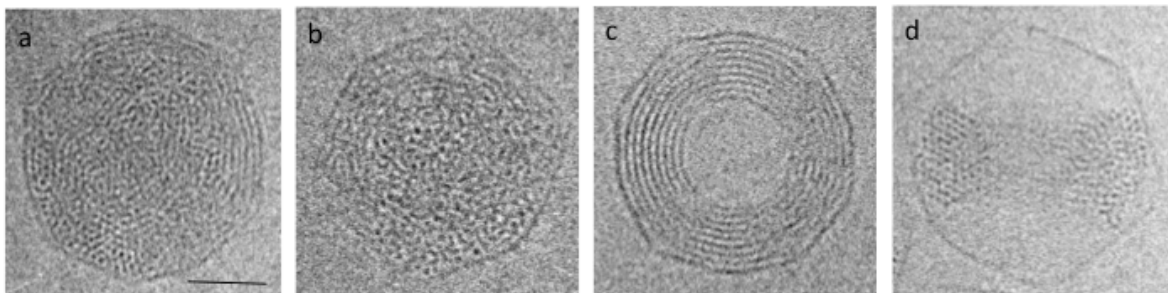


Image gallery of DNA conformations inside the T5 bacteriophage capsid. (a) Full capsid. (b) Capsid after partial ejection (40%) of the genome showing a cholesteric organisation. (c, d) Partially filled capsid after DNA condensation by spermine, showing toroidal conformations in top and side views. Scale bar 20 nm.

### References

A. LEFORESTIER, F. LIVOLANT (2009) Structure of toroidal DNA collapsed Inside the phage capsid. *Proc Natl Acad Sci U S A*. 106(23):9157-62.

A. LEFORESTIER, F. LIVOLANT (2010) The Bacteriophage Genome Undergoes a Succession of Intra-Capsid Phase Transitions upon DNA Ejection. *Journal of Molecular Biology*, 396, 384-395.

A. LEFORESTIER, A. SIBER, F. LIVOLANT, R. PODGORNIK (2011) Protein-DNA interactions determine the shapes of DNA toroids condensed in virus capsids? *Biophys. J.*, sous presse