# Modelling chromatin with explicit ions: ion correlation effects and like charge attraction. Comparison with new experiments.

*Lars Nordenskiöld*

*School of Biological Sciences, Nanyang Technological University,*
*60 Nanyang Drive, Singapore 637551,*

MD (Langevin) computer simulations in continuum description of coarse-grained chromatin and nucleosome core particle (NCP) models have been performed. The 12-mer chromatin array is described in a model with a central spherical particle with DNA in the form of connected charged beads wrapped around this central histone octamer. Protruding out from the core are 8 positively charged flexible "histone tails". Additional DNA beads modelling the linker DNA, connects such core particles to form an array. Explicit mobile counterions of charge and size mimicking $Cl^-$, $K^+$, $Mg^{2+}$, and $Co(NH_3)_6^{3+}$ are included to describe the effects of counterion valence and results are compared with calculations using salt represented by a DH screening potential. The latter description is found to be inadequate for multivalent ions. The simulation results with explicit ions agree with experimental trends (below) and are in accordance with polyelectrolyte theory and a mechanism of condensation due to salt screening, attractive ion-ion correlations and histone tail bridging.

Analytical ultracentrifugation, dynamic light scattering and precipitation assay measurements of cation induced compaction (folding) of recombinant 12-mer chromatin arrays are presented. Furthermore, counterion induced aggregation of such arrays as well as of recombinant 147 bp NCPs were investigated. Effects of the N-terminal tails have also been studied. The potency of inducing compaction or aggregation, in all three systems follow the order: spermine$^{4+}$ > $Co(NH_3)_6^{3+}$ > spermidine$^{3+}$ > $Mg^{2+} \approx Ca^{2+} > Na^+ \approx K^+$. This trend is the same as that observed for the condensation behaviour (compaction as well as aggregation) of DNA, which indicates similarity in the underlying electrostatic mechanism causing condensation in DNA and in chromatin.