

Electrostatic correlation-induced like-charge macromolecular attraction

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The characterization of electrostatic macromolecular interactions is crucial for the optimization of modern biological applications involving DNA molecules. In particular, the understanding of like-charge polymer-membrane and interpolymer attraction is a key step for improving the current gene therapeutic techniques. The like-charge attraction effect cannot be explained from the perspective of mean-field (MF) electrostatics that always predicts repulsion between similarly charged molecules. In this talk, I will introduce a beyond-MF test charge theory that allows to enlighten charge correlation effects driving the like-charge attraction phenomenon.

In the first part of the talk, I will characterize the recent experimental observation of DNA adsorption onto similarly charged substrates. Within the one-loop test charge theory, I will consider the electrostatic coupling between a polyelectrolyte and a like-charged membrane. The counterions adsorbed by the membrane locally enhance the electrostatic screening of the polymer and lowers the polymer self-energy in the vicinity of the membrane surface. At strong membrane or polymer charges, this effect dominates the MF-level DNA-membrane repulsion and results in the binding of the DNA molecule to the negatively charged substrate. Within the same theoretical framework, I will show that this enhanced polymer screening mechanism also explains several features of the experimental phase diagrams on the condensation of like-charged polymer solutions. The addition of multivalent counterions to the solution turns the interpolymer interactions from repulsive to attractive. Upon the rise of the monovalent salt density, the MF-level shielding of the average potential weakens the multivalent cation binding and suppress like-charge attraction. Due to the same shielding mechanism, the multivalent cations that trigger like-charge condensation at low densities results in the precipitation of the polymer aggregates at large densities. This reentrant behaviour can be beneficial to gene delivery methods where the control over polymer-DNA interactions is the key factor.

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