Role of force and torque constraints in regulation of DNA-protein interactions

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Organization and maintenance of chromosomal DNA inside living cells is accomplished by a plethora of DNA-binding proteins, which not only fold DNA into a highly-ordered chromatin structure, but also function as global gene transcription regulators that determine the cell fate. Recent single-molecule studies have shown that formation of nucleoprotein complexes by DNA-binding proteins can be strongly modulated by an intricate interplay between the entropic elasticity of DNA and its global topology, which is closely related to the mechanical constraints applied to the DNA. However, the exact effect of such constraints on DNA-protein interactions is very difficult to quantify using the existing theoretical methods and tools.

To this aim, we have developed a general theoretical framework utilizing advanced transfer-matrix calculations that allows one to accurately describe DNA-protein interactions under force and torque constraints. This makes it possible not only to solve the structure and global conformation of DNA under a broad range of experimental conditions, but also to interpret complex experimental data, which is frequently obtained in single-molecule studies of DNA-protein interactions. Potential applications of the developed theoretical approach are demonstrated by predicting how the force and torque constraints applied to DNA affect the DNA-binding properties of the major types of DNA-architectural proteins.

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