Nucleosome-like Structure from Dendrimer-induced DNA Compaction

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Abstract

Genomic DNA in eukaryotes wraps around histone proteins to package into the limited space of cell nucleus. Since the precise structure of chromatin is not known in detail, attempts have been made to understand DNA-histone interaction and the associated self-organization behavior using synthetic model systems. Using small angle X-ray and neutron scattering, here we show that the electrostatic attraction between DNA and polyamidoamine (PAMAM) dendrimer of generation six (G6), which is geometrically similar to histone, led to the formation of beads-on-string structure, where DNA wrapped around the spherical dendrimer macrocations to yield the “chromatin-like fiber” composed of the interconnected “nucleosome-like particles”. A “wormlike chromatin-like fiber model” was introduced to obtain the theoretical scattering patterns closely resembling the experimentally observed ones, from which the pitch length of the DNA superhelix wrapping around the dendrimer and the interparticle distance of the nucleosome-like particles were deduced. The pitch length (ca. 3 nm) was similar to that associated with the nucleosome; however, the wrapping of DNA around the dendrimer was not tight, but showed obvious fluctuations of the superhelix radius. The interparticle distance in the chromatin-like fiber was close to that of the dendrimer diameter, indicating that the linker DNA was very short. On the other hand, the SAXS profile in the intermediate to high q region of the nucleosome array in aqueous solution was fitted very well by the form factor of the mono-nucleosome particle based on the rigid crystal structure model. This means that the fluctuation of the beads-on-string structure of nucleosome was strongly suppressed and the linker DNA was long. The comparison between the structure features of the dendriplex and those of the nucleosome revealed that the attraction free energy arising from the electrostatic interaction energy and the counterion entropy was not sufficient to stabilize the beads-on-string structure and regulate the length of linker DNA in chromatin. Additional binding forces and regulation factors are hence involved in creating the chromatin structure in vivo.

Keywords – DNA, PAMAM dendrimer, nucleosome, beads-on-string structure

References