The effect of volume exclusion on the formation of DNA minicircle networks

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Abstract

The mitochondrial DNA of Trypanosomes, known as kinetoplast DNA (kDNA), is organized into several thousands of minicircles that are topologically linked, forming a large chainmail-like network. How and why minicircles form a network in some but not in other kinetoplastid organisms, remain unanswered questions. Motivated by these questions, in our earlier studies we introduced some simple analytical and numerical models to study networks of topologically linked minicircles. In these earlier studies, we used three key parameters, namely the mean minicircle valence (*i.e.* the number of minicircles topologically linked to any given minicircle in the network), the critical percolation and mean saturation densities to characterize the topological properties of the minicircle network and how these properties change with respect to the minicircle density changes. Using these models we showed, both theoretically and numerically, that high minicircle density leads to the formation of a linked minicircle network. Our previous studies however did not incorporate the DNA excluded volume due to electrostatic interactions and one would ask how these descriptors of the network change in this new scenario. We here characterize, using a numerical approach, the effects of volume exclusion on the properties of the network. We find that (1) the linking probability of two minicircles does not decrease linearly with the distance between the two minicircles, (2) the mean valence grows linearly with the density of minicircles and decreases with the thickness of the excluded volume, (3) the critical percolation and mean saturation densities grow linearly with the thickness of the excluded volume. Our results therefore validates our descriptors and suggest that the role of volume exclusion on the formation of kDNA networks is milder than what was initially proposed.

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