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Organizing the bacterial chromosome for division

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The chromosome is highly organized in space in many bacteria, although the origin and function of this organization remain unclear. This organization is further complicated by the necessity for chromosome replication and segregation. Partitioning proteins of the ParABS system mediate chromosomal and plasmid segregation in a variety of bacteria. This segregation machinery includes a large ParB-DNA complex consisting of roughly 1000 ParB dimers, which localizes around one or a few centromere-like *parS* sites near the origin of replication. Despite the apparent simplicity of this segregation machinery as compared to eukaryotic segregations systems, puzzles remain: In particular, what is the nature of interactions among DNA-bound ParB proteins, and how do these determine the organizational and functional properties of the ParB-DNA partitioning complex? A crucial aspect of this question is whether ParB spreads along the DNA to form a filamentous protein-DNA complex with a 1D character, or rather assembles to form a 3D complex on the DNA. Furthermore, it remains unclear how the presence of only one or even a few *parS* sites can lead to robust formation and localization of such a large protein-DNA complex. We developed a simple model for interacting proteins on DNA, and found that a combination of 1D spreading bonds and a 3D bridging bond between ParB proteins constitutes the minimal model for condensation of a 3D ParB-DNA complex. These combined interactions provide an effective surface tension that prevents fragmentation of the ParB-DNA complex. Thus, ParB spreads to form multiple 1D domains on the DNA, connected in 3D by bridging interactions to assemble into a 3D ParB-DNA condensate. Importantly, this model accounts for recent experiments on ParB-induced gene-silencing and the effect of a DNA "roadblock" on ParB localization. Furthermore, our model provides a simple mechanism to explain how a single *parS* site is both necessary and sufficient for the formation and localization of the ParB-DNA complex.