THE DEVIL IN THE DETAILS: HOW DNA STRUCTURE, SEQUENCE, AND COUNTERIONS DRIVE BIOLOGY

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Most of what we know about the physical parameters of DNA derives from atomic structures and biophysical manipulations of DNA in its linear duplex form. This form of DNA is inert in cells and the measurements of bending rigidity, free energy, *etc.,* which are all derived from studies of the linear form *in silico* or in a test tube, are not applicable. Instead, DNA is maintained in a globally underwound conformation surrounded by counterions, proteins, and membranes. It is frequently separated into single strands. Thus, the linking number (*Lk*) of DNA is lower than that of linear DNA. ΔLk can be manifest as twist and writhe by the well-known equation $\Delta Lk = \Delta Tw + Wr$. Transiently, waves of extreme DNA underwinding and overwinding are generated during its replication, transcription, repair, and recombination. Depending upon the specific DNA metabolic event, these torsional stresses are either constrained, and therefore not allowed to writhe, or unconstrained, and writhed. Additionally, and importantly, DNA in cells contains no free ends. We have probed, using a combination of molecular dynamics simulations and biophysical characterizations, the effects of underwinding and overwinding DNA on its structure and how this structure influences counterions and protein recognition. We find dramatic sequence-dependent alterations in structure that alter the counterion distributions leading us to hypothesize the manifestation of these changes drives DNA replication, transcription, repair, and recombination. For an introduction to this topic, please see:

1. Fogg, J. M., Catanese, D. J., Jr., Randall, G. L., Swick, M. C., and Zechiedrich, L. (2009). Differences between positively and negatively supercoiled DNA that topoisomerases may distinguish. *Proc. Institute Math. App.* **150**, 73-123 in *Mathematics of DNA Structure, Function, and Interactions* (Benham, C.J., Harvey, S., Olson, W.K., De Witt L. Sumners, D.W.L., and Swigon, D., Eds.).
2. Liu, Z., Deibler, R. W., Chan, H. S., and Zechiedrich, L. (2009). The why and how of DNA unlinking. *Nucleic Acids Res.* **37**, 661-671.
3. Laboratory webpage: http://www.bcm.edu/labs/zechiedrich/