Twist-bend coupling: A twist in DNA mechanics

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In several cases, DNA can be mechanically described by simple elastic models, resembling common objects from our macroscopic world. The inherent asymmetry of its double helix, however, grants it some unique properties without a macroscopic analogue. Here, we investigate both the origin and consequences of twist-bend coupling, an interaction that renders DNA easier to bend when twisted, and vice versa. This is found to have a non-trivial influence on its mechanics depending on the length scale at which the molecule is probed, in line with experimental findings.

DNA, the carrier of genetic information, is a remarkable macromolecule of clear biological importance, which also possesses interesting physical properties. Despite its complex chemical structure, its mechanical behavior is typically described by simple elastic models treating it as a twistable elastic rod, pretty similar to macroscopic objects from daily life. The research of our group has focused on an unexplored aspect of DNA mechanics, namely an interaction coupling the bending and twisting degrees of freedom. This twist-bend coupling, which makes DNA easier to bend when twisted and vice versa, originates from the asymmetry of the double helix [4], rendering it distinct from typical macroscopic objects. On the local scale (Fig. 1a), this interaction gives rise to twist waves (alternating regions of helical over- and undertwisting) in bent DNA, such as under the action of DNA-binding proteins, in line with experimental observations [5, 3]. On the global scale (Fig. 1b), twist-bend coupling leads to a "softening" of the double-helix, making it overall easier to bend and twist [1, 2]. This is expected to be particularly interesting in problems where both scales become relevant, such as the case of DNA supercoiling.

References

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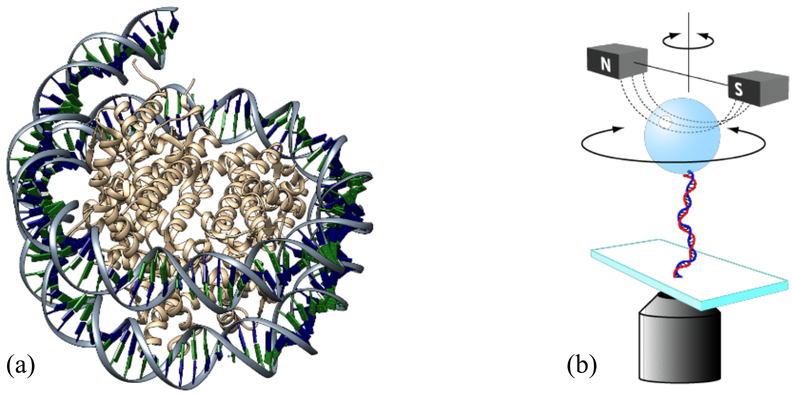

Figure 1: On the local scale, such as in X-ray crystallographic experiments of nucleosomal DNA (a), twist-bend coupling gives rise to twist waves. On the global scale, such as in magnetic tweezers experiments (b), it leads to an enhanced flexibility of the double helix.