PHYSICS COLLOQUIUM:

Cracking and buckling: Defect driven mechanics of collagen and DNA

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Date:
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Time:
10:30 AM-11:50 AM

Link:
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About The Speaker:

Keir Neuman graduated cum laude with a B.A. in physics and applied math from the University of California, Berkeley in 1994 and received his Ph.D. in physics from Princeton University in 2002. He did postdoctoral research with Steven Block at Stanford University from 2002 to 2004, and was a Human Frontiers Fellow with David Bensimon and Vincent Croquette at the Laboratoire de Physique Statistique at the École Normale Supérieure in Paris, France from 2004 to 2007. Dr. Neuman joined the National Institutes of Health as a tenure-track Investigator in 2007 and was promoted to senior investigator in 2015. The Neuman lab employs single-molecule manipulation (optical and magnetic tweezers) and single-molecule fluorescence approaches to perform biophysical measurements of DNA topology, DNA topoisomerases and helicases, and collagen processing by matrix metalloproteinases.

Abstract:

Defects in macroscopic beams decrease the mechanical stability and promote buckling and cracking under compressive and torsional stress. For example, a twisted hose will buckle and form an interwound plectoneme at a pre-formed kink. At the microscopic scale of biological polymers such as collagen and DNA, defects on the scale of thermal energy can result in unusual behaviors with important physiological consequences. I will describe a spontaneous periodic buckling phenomenon in fibrillar type I collagen that exposes the otherwise impervious surface of collagen to binding and degradation by matrix metalloproteinases (MMPs). These spontaneous defects migrate over the surface of the collagen while maintaining their periodicity that far exceeds the intrinsic length scales of collagen. The dynamic yet periodic defects can be explained with a simple internal strain model that provides a mechanistic explanation for the inhibition of MMP degradation by the application o f external load. Defects in DNA occur spontaneously due to damage and errors in replication or repair. We find that supercoiling can localize a single mismatch in many thousands of base-pairs of DNA and we propose that this may be a mechanism to facilitate mismatch and damage recognition by repair enzymes. Furthermore, the unusual buckling kinetics at mismatches and the direct observation of an intermediate state provide strong evidence supporting a recently proposed torsional buckling pathway.

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