C. Jarzynski, Physics Colloquium, Univ of Wisconsin, Madison, November 19, 2021

Scaling down the laws of thermodynamics

Thermodynamics provides a robust conceptual framework and set of laws that govern the exchange of energy and matter. Although these laws were originally articulated for macroscopic objects, nanoscale systems also exhibit "thermodynamic-like" behavior – for instance, biomolecular motors convert chemical fuel into mechanical work, and single molecules exhibit hysteresis when manipulated using optical tweezers. To what extent can the laws of thermodynamics be scaled down to apply to individual microscopic systems, and what new features emerge at the nanoscale? I will describe some of the challenges and recent progress – both theoretical and experimental – associated with addressing these questions. Along the way, my talk will touch on non-equilibrium fluctuations, "violations" of the second law, the thermodynamic arrow of time, nanoscale feedback control, strong system-environment coupling, and quantum thermodynamics.