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Kinesin motor protein as an electrostatic ratchet machine
GEORGE TSIRONIS, University of Crete and FORTH, ALEIX CIUDAD, JOSE MARIA SANCHO, University of Barcelona — Kinesin and related motor proteins utilize ATP fuel to propel themselves along the external surface of microtubules in a processive and directional fashion. We show that the observed step-like motion is possible through time varying charge distributions furnished by the ATP hydrolysis circle while the static charge configuration on the microtuble provides the guide for motion. Thus, while the chemical hydrolysis energy induces appropriate local conformational changes, the motor translational energy is fundamentally electrostatic. Numerical simulations of the mechanical equations of motion show that processivity and directionality are direct consequences of the ATP-dependent electrostatic interaction between the different charge distributions of kinesin and microtubule. Treating proterins as continuous dielectric media and using a Green's function formalism we find analytical expressions for the electrostatic energy in the vicinity of the protein surfaces. We calculate the Bjerrum length in the interior of the protein and analyze its dependence on the charge proximity to the protein interface. We apply these results to kinesin and estimate the pure electrostatic ATP-ADP interaction to be larger than 2k T.

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