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Synthetic Motors and Nanomachines.

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A bistable and palindromically-constituted [3]rotaxane incorporating two mechanically-mobile rings interlocked around a linear dumbbell component, has been designed to operate like the sarcomeres of skeletal muscle. Contraction and extension occurs when the inter-ring distance of the two rings switch, ideally, between 4.2 and 1.4 nm upon redox stimulation either chemically or electrochemically in the solution phase. When the mobile rings of these artificial molecular muscles are bound onto the tops of gold-coated, micron-scale cantilever beams, their controllable nanometer motions have a chance to be amplified along the long axis of each cantilever. It turns out that $\sim$6 billion of the self-assembled [3]rotaxanes can bend the cantilevers in a bistable manner concomitant with the cycled addition of redox agents. The extent of bending is commensurate with 10's of pN of force per [3]rotaxane. Recent studies on a set of "single-shot" control [2]rotaxanes have provided additional evidence for the origins of the force generation as it arises from a molecule-based electrostatic repulsion energy of about 10 kcal/mol at 300 K. These findings will be presented in terms of the underlying thermodynamics and kinetics that have been utilized extensively to direct the design and synthesis of artificial molecular machines and which may also serve as a guide for the rational design of unidirectional molecular motors.