Molecular Archimedean Screw: A torque transfer molecular machine

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Machines based on torque transfer have played a central role in the development of our technology, from ancient Archimedean water pumps and windmills to modern jet engines. Miniaturizing such machines to the molecular scale could enable new nanoscale functionalities and reveal unexplored physical effects. Here we report the realization of a molecular Archimedean screw, consisting of a single helical molecule suspended between atomically sharp electrodes. This molecular machine operates both as a turbine driven by electric current and as a mechanical current booster. An applied voltage induces cyclic molecular motion with 100% directional preference, reversible upon inversion of the voltage polarity. Above a threshold voltage, the device exhibits a pronounced enhancement of electrical current. This current amplification is mechanically tunable: stretching or compressing the molecular helix shifts the onset of the effect. Calculations show that current-induced molecular rotation explains both the cyclic motion and the enhanced conductance, associated with a transition from stochastic cyclic jumps to continuous molecular rotation that enables access to highly conducting configurations. This work establishes a prototype for a new class of torque-transfer molecular machines with perfect turbine unidirectionality and mechanically controlled current boosting.