

Giving Chemistry Direction

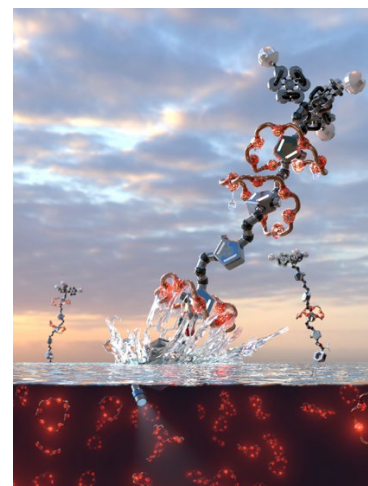
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In recent years examples of synthetic molecular machines and motors¹ have been developed,² all be they primitive by biological standards. Such molecules are best designed to work through statistical mechanisms. In a manner reminiscent of Maxwell's Demon,³ random thermal motion is rectified through ratchet mechanisms,³⁻⁸ giving chemistry direction.

It is increasingly being recognised that similar concepts can be applied to other chemical exchange processes.⁹ Ratchet mechanisms—effectively chemical engines¹⁰ in which catalysis^{4,6,7} of 'fuel' to 'waste' is used to drive another chemical process—can cause directional impetus in what are otherwise stochastic systems, including reversible chemical reactions. This is ushering in a new era of non-equilibrium chemistry, providing fundamental advances in functional molecule design and the first examples of molecular robotics,^{11,12} overturning existing dogma and offering fresh insights into biology and molecular nanotechnology.



For a musical introduction, see 'Nanobot': <https://bit.ly/2M5Zwdl>

- [1] *The Nobel Prize in Chemistry 2016—Advanced Information*. Nobelprize.org. Nobel Media AB 2014. Web. 6 Oct, 2016, http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2016/advanced.html. [2] "Rise of the molecular machines", *Angew. Chem. Int. Ed.* **54**, 10080 (2015). [3] "A molecular information ratchet", *Nature* **445**, 523 (2007). [4] "An autonomous chemically fuelled small-molecule motor", *Nature* **534**, 235 (2016). [5] "Rotary and linear molecular motors driven by pulses of a chemical fuel", *Science* **358**, 340 (2017). [6] "A catalysis-driven artificial molecular pump", *Nature* **594**, 529 (2021). [7] "Autonomous fuelled directional rotation about a covalent single bond", *Nature* **604**, 80 (2022). [8] "A tape-reading molecular ratchet", *Nature* **612**, 78 (2022). [9] "Design, synthesis and operation of small molecules that walk along tracks", *J. Am. Chem. Soc.* **132**, 16134 (2010). [10] "Chemical engines: Driving systems away from equilibrium through catalyst reaction cycles", *Nat. Nanotechnol.* **16**, 1057 (2021). [11] "Sequence-specific peptide synthesis by an artificial small-molecule machine", *Science* **339**, 189 (2013). [12] "Stereodivergent synthesis with a programmable molecular machine", *Nature* **549**, 374 (2017).