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Active osmotic exchanger for advanced filtration at the nano scale

SOPHIE MARBACH, LYDERIC BOCQUET, Department of Physics, Ecole Normale Superieure, Paris — One of the main functions of the kidney is to remove the waste products of an organism, mostly by excreting concentrated urea while reabsorbing water and other molecules. The human kidney is capable of recycling about 200 liters of water per day, at the relatively low cost of 0.5 kJ/L (standard dialysis requiring at least 150 kJ/L). Kidneys are constituted of millions of parallel filtration networks called nephrons. The nephrons of all mammalian kidneys present a specific loop geometry, the Loop of Henle, that is believed to play a key role in the urinary concentrating mechanism. One limb of the loop is permeable to water and the other contains sodium pumps that exchange with a common interstitium. In this work, we take inspiration from this osmotic exchanger design to propose new nanofiltration principles. We first establish simple analytical results to derive general operating principles, based on coupled water permeable pores and osmotic pumps. The best filtration geometry, in terms of power required for a given water recycling ratio, is comparable in many ways to the mammalian nephron. It is not only more efficient than traditional reverse osmosis systems, but can also work at much smaller pressures (of the order of the blood pressure, 0.13 bar, as compared to more than 30 bars for pressure-retarded osmosis systems). We anticipate that our proof of principle will be a starting point for the development of new filtration systems relying on the active osmotic exchanger principle.

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