**Title: Extreme energy and power densities of peptidoglycan muscles**

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## Abstract

Water-responsive materials that mechanically deform in response to changing humidity have shown a great potential to generate high-energy actuation for robotics, shape-morphing, and energy harvesting devices. Here, we present that Bacillus subtilis' peptidoglycan exhibits water-responsive energy and power density of 72.6 MJ m-3 and 9.1 MW m-3, respectively, surpassing those of all existing actuators and natural muscles. When responding to RH changes, peptidoglycan reversibly and rapidly deforms as much as 27.2 % within 120 ms, and its actuation pressure reaches ~354.6 MPa. We estimated peptidoglycan's energy conversion efficiency to be ~66.8 %, comparable to the record-high efficiencies of mammalian muscles. Peptidoglycan's extreme water-responsiveness strongly correlates to its super-viscous nanoconfined water that efficiently translates water's movement to mechanical deformation, providing insights into efficiently harness hygroscopic energy.