The cell as a liquid motor: intrinsic mechanosensitivity emerges from collective dynamics of actomyosin cortex

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Living cells respond actively to the mechanical properties of their environment. In addition to biochemical mechanotransduction, evidence exists for a purely mechanical sensitivity to the stiffness of the surroundings at the cell-scale. Using a minimal model that describes the collective behaviour of actin, actin crosslinkers and myosin, we show that the mechanosensitive response of cells spreading between distant elastic microplates is entirely and quantitatively predicted by the behaviour of the actomyosin cortex as a contractile viscoelastic fluid [1]. Indeed, our modelling of actomyosin shows that it is a liquid that exhibits emergent elastic-like properties when in series with a spring. The maintenance of a given shape for such an emergent material results from a balance between actin polymerisation and a cell-scale contractility-driven retrograde flow. The energetic cost of these antagonistic phenomena yields a power curve of cell action against a load similar to Hill's law for muscles: in particular, an internal friction sets the maximum speed of contraction of both cells and muscles, when myosins do not have time to detach after pulling, just as rowers lifting their oar too slowly after their stroke. Conversely the maximum force corresponds to the force at which myosin motor energy is entirely dissipated by their relaxation when crosslinkers eventually unbind from actin.

[1] J. Étienne(*), J. Fouchard, D. Mitrossilis, N. Bufi, P. Durand-Smet and A. Asnacios, 2015. Cells as liquid motors: Mechanosensitivity emerges from collective dynamics of actomyosin cortex. Proc. Natl. Acad. Sci. USA 112(9):2740--2745. (*) Corresponding author.