Long range cell-cell interactions through substrate strain fields

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ABSTRACT

It is well known that cells communicate with each other through biochemical and electrical means employing various autocrine and endocrine signalling pathways. Here we show, using rat cardiomyocytes, that distant cells can communicate with each other through long-range strain fields alone. A beating cardiomyocyte, adhered to an elastic substrate, generates force and deforms the substrate. A distant neighbor, isolated chemically and electrically, is subjected to the strain field of the beating cell. A tensile strain results in calcium influx through its stretch sensitive ion channels. This influx interferes with its dynamics. The two neighbors thus get coupled and behave as coupled oscillators. Over time, they synchronize their dynamics. We model the two cells as coupled oscillators where the coupling is enforced through strain dependent calcium influx. The model predictions are verified by culturing cardiomyocytes on two sides of an elastic impermeable film. The circular film is held around its periphery by a glass ring. The cells on each side of the film synchronize their beating through biochemical and electrical signaling. Thus, each side behaves as a single isolated actuator. They are coupled with each other through the elasticity of the film. Over time, these actuators beat in synchrony with a phase lag between them, as predicted by the model. We employ the model to explore a possible biological machine, a biohybrid flagellar swimmer with a series of isolated cardiomyocytes on an elastic beam. A slender body hydrodynamic model predicts that such swimmers can achieve swimming speeds comparable to the natural flagellar swimmers.