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Modeling crawling cell movement on soft engineered substrates[1]

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Self-propelled motion, emerging spontaneously or in response to external cues, is a hallmark of living organisms. Systems of self-propelled synthetic particles are also relevant for multiple applications, from targeted drug delivery to the design of self-healing materials. Self-propulsion relies on the force transfer to the surrounding. While self-propelled swimming in the bulk of liquids is fairly well characterized, many open questions remain in our understanding of self-propelled motion along substrates, such as in the case of crawling cells or related biomimetic objects. How is the force transfer organized and how does it interplay with the deformability of the moving object and the substrate? How do the spatially dependent traction distribution and adhesion dynamics give rise to complex cell behavior? How can we engineer a specific cell response on synthetic compliant substrates? Here we present a phase-field model for a crawling cell by incorporating locally resolved traction forces and substrate deformations. The model captures the generic structure of the traction force distribution and faithfully reproduces experimental observations, like the response of a cell on a gradient in substrate elasticity (durotaxis). It also exhibits complex modes of cell movement such as "bipedal" motion. Our work may guide experiments on cell traction force microscopy and substrate-based cell sorting and can be helpful for the design of biomimetic "crawlers" and active and reconfigurable self-healing materials.

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