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Sand swimmers: In silica *in silico*

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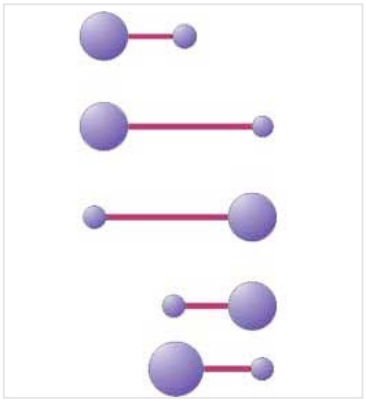
Swimming and flying are complicated processes to model, but at least the laws of fluid dynamics are known. In contrast, sand is a trickier medium to understand than water or air, because it can behave as a solid or as a fluid. Moreover, the presence of a 'swimmer' — such as the sand skink *Plestiodon reynoldsi* (pictured), seeking refuge from the heat of the Sun — changes the local properties of the sand, creating pockets of air and affecting the force chains between the granules. Consequently, there are no analytical equations of motion. To better understand the mechanism of swimming through a solid yet shifting medium, Takashi Shimada and colleagues have simulated the locomotion of a sand swimmer (*Phys. Rev. E* **80**, 020301; 2009), using a 'push-me-pull-you' model (pictured moving to the right) introduced by Joseph Avron and colleagues (*New J. Phys.* **7**, 234; 2005).



In essence, the push-me-pull-you model describes two disks connected by a spring. The disks inflate and shrink. To move forwards in fluid-like sand, the smaller anterior disk inflates as the spring lengthens. The initially fully inflated posterior disk acts as an anchor in solid-like sand. Once the anterior disk is fully inflated, it then acts as the anchor while the posterior disk shrinks and moves forwards as the spring contracts. To complete the move, the posterior disk inflates again, ready for the next stroke. Thus, a sand swimmer must deal with solidification near the anchor and fluidization near the moving disk at the same time.

The simulation's surprising result is that the optimal swimming frequency for maximum velocity is different from that for maximum efficiency. For example, if the swimmer moves too fast, the large voids created cause the swimmer to lose traction and slip. Hence the most efficient swimmer swims slowly. But move too slowly and the sand re-solidifies before any forward motion can be completed. Unexpectedly, the simulation also provides information on the fundamental time scales associated with granular packing.

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