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Reversibility in locomotion in granular media[1] WILLIAM SAVOIE, DANIEL GOLDMAN, Georgia Tech — A recent study of a self-deforming robot [Hatton et al, PRL, 2013] demonstrated that slow movement in dry granular media resembles locomotion in low Re fluids, in part because inertia is dominated by friction. The study indicated that granular swimming was kinematically reversible, a surprise because yielding in granular flow is irreversible. To investigate if reciprocal motions lead to net displacements in granular swimmers, in laboratory experiments, we study the locomotion of a robotic "scallop" consisting of a square body with two flipper-like limbs controlled to flap forward and backward symmetrically (a flap cycle). The body is constrained by linear bearings to allow motion in only one dimension. We vary the the flapping frequency f, the body/flipper burial depth d, and the number of flaps N in a deep bed of 6 mm diameter plastic spheres. Over a range of f and d, the $N = 1$ cycle produces net translation of the body; however for large N, a cycle produces no net translation. We conclude that symmetric strokes in granular swimming are irreversible at the onset of self-deformation, but become asymptotically reversible.

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