Extreme deformation of solids and structures: folding and energy release

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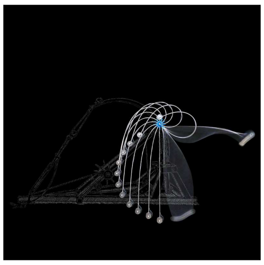
How forms can emerge during extreme deformation of an elastic solid or an elastic structure? Buckling and instability has been advocated as a possible explanation of morphogenesis, describing the emergence of brain convolutions, of geological structures, and of the undulations of marine shells. Folding is a process in which bending localizes into sharp corners separated by almost undeformed elements. This process is rarely encountered in nature and is difficult to be described within the realm of the Cauchy theory of elasticity. On the other hand, it is shown that folding can be understood as a constitutive instability of a constrained-Cosserat elastic material occurring at the elliptic boundary [1, 2].

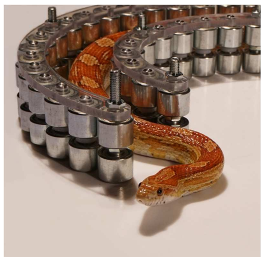
The nonlinear theory of elastic rods is a framework for describing bifurcation and instabilities of a number of interesting structures, showing for instance configurational forces analogous to those acting on dislocations in solids. We address the self-encapsulation problem, namely, how the rod can be loaded to assume the shape of a drop, which is suggested by the fact that elastica governs not only bifurcation of rods, but also the oscillating pendulum and the shape of a pendant drop [3]. Moreover, snaking of an elastic rod, a model for serpentine locomotion, is shown to involve configurational forces that can be calculated and experimentally determined [4]. Finally, a simple model of a soft robot arm is analyzed showing a snap-back instability with related energy release [5].

Rock and shell folding



The elastica catapult

Dripping of a rod



Rod snaking

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