Emergence, Mechanics, and Development: How Behavior and Geometry Underlie Cowrie Seashell Form

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1 Abstract

One successful approach to Biomathematics is to choose the simplest biologically interesting example of a complicated and confusing biological phenomenon and applying an analytical and mathematical lens to make sense of that logic. We present a comprehensive model of Cowrie Form in the hope of illuminating how mechanics and behavior can shape biological structures. Even if all the genes that underlie shell formation were known, we would still need models to explain how shells emerge from those genetic interactions. We report here how top-down behavioral information can feed-forward on the developmental trajectory of the seashell simultaneously with sensory feedback. In this system, biology seems to be working in an "allostatic" regime: not quite feedback, not quite feed-forward. Here we present progress on developing an analytical framework for biological control. Leaning on recent developments in the mechanics of thin elastic sheets we develop variational approaches to the nonlinear material deformations of the the soft bendable body part which 3D prints the shell and demonstrate how these deformations could underlie the shell form. With three interdependent models we make inroads towards recapitulate the three main facets of Cowrie Form: the deviation of the central spiral, the formation of apertural teeth, and the basal thickening of the shell. The Model presented here is an important first step to understanding the form of the most popular collected seashell family, speaks to broad conceptual difficulties that stand in the way of understanding the emergence of form and behavior from more basic instructions, and develops straight-forward approaches to solving elastica problems.