Organ architecture is often composed of multiple concentric tissue layers. Morphogenesis folds these organs into a specific shape that is required for proper function. Genetic signals that determine cell fate have been uncovered - yet the dynamic interplay of tissue layers giving rise to specific form remains elusive. We combine multi-layer analysis of cellular dynamics on evolving surfaces with physical modeling to obtain testable quantitative descriptions of how genetic patterning controls physics giving rise to shape. I will discuss two examples: (I) Quantitative analysis of visceral organogenesis in D. melanogaster reveals how a hox code in the mesoderm triggers a dynamic molecular mechanism to control physical processes in the adjacent endoderm layer. (II) A chip-based culture system enables self-organization of micro patterned stem cells into precise three-dimensional cell-fate patterns and form. This system recreates aspects of neural tube folding, and indicates basal interactions between non-neural and neural ectoderm are required for tube closure.

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