Balbi, V.; **Kuhl, E.**; **Ciarletta, P.**

Morphoelastic control of gastro-intestinal organogenesis: theoretical predictions and numerical insights. (English) Zbl 1349.74259

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Summary: With nine meters in length, the gastrointestinal tract is not only our longest, but also our structurally most diverse organ. During embryonic development, it evolves as a bilayered tube with an inner endodermal lining and an outer mesodermal layer. Its inner surface displays a wide variety of morphological patterns, which are closely correlated to digestive function. However, the evolution of these intestinal patterns remains poorly understood. Here we show that geometric and mechanical factors can explain intestinal pattern formation. Using the nonlinear field theories of mechanics, we model surface morphogenesis as the instability problem of constrained differential growth. To allow for internal and external expansion, we model the gastrointestinal tract with homogeneous Neumann boundary conditions. To establish estimates for the folding pattern at the onset of folding, we perform a linear stability analysis supplemented by the perturbation theory. To predict pattern evolution in the post-buckling regime, we perform a series of nonlinear finite element simulations. Our model explains why longitudinal folds emerge in the esophagus with a thick and stiff outer layer, whereas circumferential folds emerge in the jejunum with a thinner and softer outer layer. In intermediate regions like the feline esophagus, longitudinal and circumferential folds emerge simultaneously. Our model could serve as a valuable tool to explain and predict alterations in esophageal morphology as a result of developmental disorders or certain digestive pathologies including food allergies.

MSC:

74L15 Biomechanical solid mechanics

Software:

ABAQUS

Full Text: DOI

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