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A unified 3D phase diagram of growth induced surface instabilities

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ABSTRACT

Biological world metabolizes itself with germination, growth, development, and aging every second. A variety of fascinating morphological patterns arise on surfaces of growing, developing or aging tissues, organs and micro-organism colonies. The basic mechanism has been long believed to be the mechanical mismatch due to differential growth between layers with different biological compositions. These patterns have been observed in separate systems and topologically classified as crease, wrinkle-fold, period-double, ridge, delaminated-buckle, and coexistence states. However, a general and systematic understanding of their initiation and evolution remains largely elusive. We construct a unified 3D phase diagram that predicts initially flat tissue layers can transform to various instability patterns, systematically depending on three physical parameters: mismatch strain, modulus ratio between layers, and adhesion energy on the interface. Our phase diagram matches consistently with our mimic in vitro experiments and documented data in state-of-the-art literature.