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Compression-triggered instabilities of multi-layer systems: From thin elastic membranes to lipid bilayers on flexible substrates

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Instabilities are triggered when elastic materials are subjected to compression. We explore new features of two distinct systems of this type. First, we describe a two-layer polymeric system under biaxial compressive stress, which exhibits a repetitive wrinkle-to-fold transition that subsequently generates a hierarchical network of folds during reorganization of the stress field. The folds delineate individual domains, and each domain subdivides into smaller ones over multiple generations. By modifying the boundary conditions and geometry, we demonstrate control over the final network morphology. Some analogies to the venation pattern of leaves are indicated. Second, motivated by the confined configurations common to cells, which are wrapped in lipid bilayer membranes, we study a lipid bilayer, coupled to an elastic sheet, and demonstrate that, upon straining, the confined lipid membrane is able to passively regulate its area. In particular, by stretching the elastic support, the bilayer laterally expands without rupture by fusing adhered lipid vesicles; upon compression, lipid tubes grow out of the membrane plane, thus reducing its area. These transformations are reversible, as we show using cycles of expansion and compression, and closely reproduce membrane processes found in cells during area regulation. The two distinct systems illustrate the influence of the substrate on finite amplitude shape changes, for which we describe the time-dependent shape evolution as the stress relaxes. This talk describes joint research with Manouk Abkarian, Marino Arroyo, Pilnam Kim, Mohammad Rahimi and Margarita Staykova.