the checkpoints commonly taught in introductory biology courses.

The implications of this result for human health and disease are numerous. In normal development, mechanical cues are known to organize cells within a growing tissue. Presumably, growing cells use this pushing mechanism to create the space required for repeated replication, sustained growth and robust patterning. As another example, consider the abnormal environment of a tumour, which is compressed both by the pre-existing tissue and by excessive deposition of new extracellular matrix. In the regions of highest compression, tumour growth would favour those cells able to generate abnormally large pushing forces. It follows that local differences in compression would induce heterogeneity in the population of cells within the tumour, which could in turn produce heterogeneity in response to cancer treatments and result in a wide range of patient outcomes. ❐

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Published online: 9 April 2018
https://doi.org/10.1038/s41567-018-0114-z

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NONLINEAR MECHANICS

Roll up your sleeves

When you push up your sleeves, wrinkles form, which eventually evolve into ridges (pictured). As familiar as you may be with this phenomenon, have you ever thought about its underlying mechanism? It involves the complex nonlinear mechanical behaviour of large deformations and surface instabilities, which in turn give rise to a sophisticated morphological evolution. And now, Yifan Yang and co-workers have revealed a hitherto unknown post-buckling behaviour that involves multiple bifurcation transitions (*Phys. Rev. Lett.* https://doi.org/10.1103/PhysRevLett.120.215503; 2018).

The process is slightly simpler when examined in a planar geometry: think of compressing a sheet of paper on a table from both ends. Under lateral compression, the paper bends to form one single fold in a localized region, thereby buckling out of the plane. For sleeves, however, the curved surface of the human arm makes the process even more intricate.

To meet this challenge, Yang et al. established a model of a soft shell sliding on a rigid cylinder. They traced the entire evolution of the surface patterns and identified different phase regions by capturing successive bifurcations. Under compression, the shell initially buckled into periodic axisymmetric wrinkles at a critical threshold. It then underwent a wrinkle-to-ridge transition upon further axial compression, whereby one single ridge grew at the expense of the intermediate wrinkles. Upon further compression, a third bifurcation occurred when the amplitude of the ridge reached its limit, and the symmetry was broken with the ridge sagging into a recumbent fold, thus releasing strain energy in its vicinity.

Credit: Bombaert Patrick/Alamy Stock Photo

In contrast to buckling in a planar geometry, the effect of the curvature turns out to be crucial for driving the multiple successive bifurcations in the morphological evolution of soft shells, especially for the primary supercritical unbuckled-to-wrinkled transition. The wrinkle and ridge patterns can coexist and be flexibly alternated through compressing and uncompressing.

Another important factor that determines the instability mode selection is the imperfection experienced by the shell. In the study by Yang et al., direct support from the core eliminated the imperfection sensitivity of the shell and led to stable axisymmetric patterns, whereas a gap between the core and the shell induced the appearance of unstable diamond-like patterns.

Understanding the nonlinear morphological transitions of soft matter holds potential for multifunctional surface fabrication, and hence widespread applications. Roll up your sleeves, there is more work to do in this area. ❐

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Published online: 4 June 2018
https://doi.org/10.1038/s41567-018-0178-9