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# Bioinspired shape shifting of liquid-infused ribbed sheets

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## Abstract

At small scales, capillary forces can deform flexible structures. A common everyday example of this phenomenon is the aggregation of wet hair into bundles. With the miniaturization of technologies, these capillary forces have become at the core of numerous strategy owing to avoid them as they can lead to the catastrophic collapse of slender structures obtained by lithography. But, changing of perspective, it can also appear as an ingenious self-assembly solution to achieve targeted shapes or movements at scales where conventional techniques fail.

Until now, studies have mainly focused on elastocapillary deformation of either thin free membranes in contact with a drop (capillary origami, Py *et al.*, PRL 2007) or networks of slender structures fixed on a rigid substrate (Pokroy *et al.* Science 2009). Here, taking inspiration from the fern sporangium that uses the capillary pressure at the scale of the cells to unbend its whole structure and release spores as it dries (see Fig.1(a)), we focus on the case of initially liquid imbibed flexible textured sheets, consisting in an array of grooves and ribs attached to a thin membrane that deforms as the structure dries (see Fig.1(b)).

Combining an analytical model together with precision experiments, we find the combination of physical parameters – geometry and elasticity of the sheet, surface tension of the liquid – for which the whole structure deforms. In this regime, the sheet curls until neighbouring ribs enter in contact. The final curvature of the curled structure may thus be accurately predicted as a function of the local geometry of the ribs. Harnessing this simple geometric control over the final curvature, we then derive an inverse design model to accurately program complex self-shaping structures by spatially varying the geometry (see Fig.1(c)) and orientation of the ribs.

This novel approach opens a new avenue within the field of elastocapillary self-assembly: as opposed to the self-assembly of textures on rigid substrates, here, the capillary forces lead to a global shape transformation (from 2D to 3D) and in contrast to capillary origami, the deformation process takes place locally, at the scale of the textures, allowing for a fine control over the local deformation. Moreover, using a photosensitive solution as the evaporating liquid, we show that the obtained 3D structures can be additionally cured and "frozen" into their deformed shape. The physics underlying this phenomenon is mostly independent of the

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liquid and the material properties and this strategy is particularly adapted to down-scaling. We thus expect our findings to have a strong application potential in the micro- and nano-fabrication of detailed 3D structures.