The 3D Structure of Epithelia Monolayers: Biology meets Math and Physics

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Building and shaping tissues and organs relies on the ability of cells to efficiently pack together and regulate their interactions. Over the last years we have been working on the physical and mathematical aspect of this problem. Our contributions include the understanding of the role of cell size for regulating the signalling noise [1], the interplay of mechanical properties and patterning to achieve shape remodeling [4], the interaction between different cell populations [5], the development of tissue simulation codes for mechanobiology experiments [3], and the 3D organization of epithelial cells [2, 6]. As for the latter topic, we have shown that epithelial cells display a previously undescribed geometrical shape when tissues are subjected to bending (curvature): the scutoid (Fig. 1).

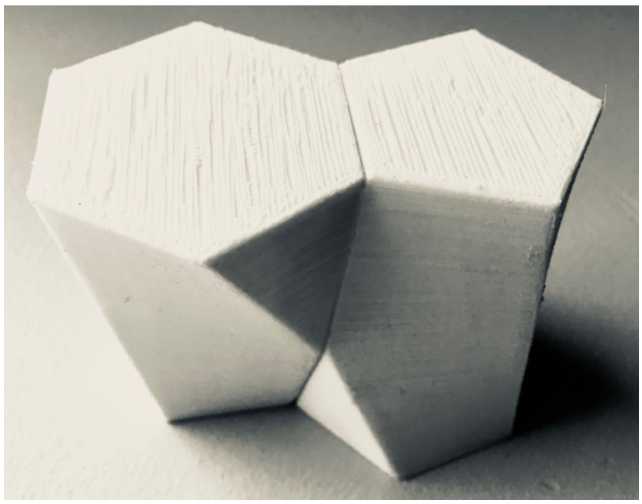

Fig. 1. Scutoids are novel shapes that allow epithelial cells to pack efficiently (from an energetic viewpoint) in tissues subjected to bending or folding.

The scutoidal shape allows cells to pack minimizing their energy and this discovery has opened the door to a deeper understanding of morphogenesis. Yet, further consequences of this new paradigm in terms of the 3D cellular organization have remained elusive. Recently, we have addressed this problem using a combination of experiments, mathematical analyses, computer simulations, and biophysical approaches. In that context we have shown that the thickness and curvature of epithelial tissues are linked to the cellular connectivity via energetic cues. This principle explains how the topological and physical constraints inherent to living matter contribute to build functional complex shapes and lead to the self-organization of tissues.

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