Integer topological defects steer cell flows during tissue morphogenesis

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Morphogenesis, involving tissue growth and reshaping, is directed by cellular collective flows and forces, which can respond to orientation cues. In vitro, anisometric cells have been found to align with each other giving rise to macroscopic (multicellular) nematically-oriented domains, at the interface of which topological defects are located [1-3]. Although they have a clear effect on the morphology and dynamics of cell monolayers, the functionality of topological defects in morphogenesis remains hypothetical [1,2]. Here, we study the organization of muscle cells (myoblasts) under circular confinement, which enforces a total topological charge S=+1 [3], to investigate the influence of topological defects on the formation of muscle-like structures. Under strong confinement, we find that a single integer topological defect is formed at the geometrical center, around which muscle cells self-assemble giving rise to two different phases: rotating spiral-like arrangements or quasi-static aster-like arrangements. Cells around defects feature well-defined orientations that facilitate the generation of center-symmetric flows and compressive cell-cell stresses at the defect core. The resulting biomechanical stimulation, which is known to play a critical role in the regulation of myogenesis [4,5], triggers early differentiation of myoblasts, predominantly where the defect core resides. Alternatively, non-fusion-competent cells are extruded and accumulated at the center of the cellular domains, leading to the growth of 3D cellular structures. Using a hydrodynamic description of active polar gels with suitable boundary conditions [6], we describe the link between the cellular flows and the director field and predict the cell-cell forces and cell density for both topological configurations, in agreement with experimental observations.

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