MPIDS Seminar

MAX-PLANCK-GESELLSCHAFT

Multi-scale approaches to study mechanics and polarity dynamics in biological tissue

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Understanding the large-scale properties of biological tissues is vital to elucidate mechanisms that guide animal development, cancer, and wound healing. A fundamental question in the field is how precisely large-scale tissue dynamics arise from the collective behavior of many cells. I will discuss this question first in the developing fruit fly wing, starting with a cellular polarity, which reorients during development. Describing this reorientation with a hydrodynamic model that is inspired by the physics of liquid crystals, I will show how different cell polarity systems interact with each other and with tissue flows in the wing. Afterward, to discuss fly wing mechanics, I will introduce a geometrical framework that precisely quantifies cellular contributions to large-scale tissue deformation. Based on this framework, I will present a visco-elastic continuum mechanical description for the fly wing, and show that both active oriented stresses as well as an unexpected delay in cell rearrangements contribute significantly to wing mechanics. A complementary approach to understand large-scale tissue mechanics uses cell-based tissue models, for instance so-called vertex models. I will discuss a transition of such vertex models between rigid and floppy tissue-scale behavior, which is induced by cell-scale parameters, both in 2D and 3D. In particular, I will show how this transition arises from a geometric minimal surface mechanism, which is fundamentally different from the mechanism creating rigidity in many other disordered materials. Furthermore, I demonstrate that universal relations exist between the minimal average cell surface and the fluctuations in cell surface and volume, and I use these relations to predict the behavior of the elastic moduli close to the transition. Finally, I will show that my approach is also applicable to other kinds of disordered materials, for instance to sub-isostatic spring networks. Taken together, the work presented helps to elucidate how tissue polarity patterns and rheology emerge from the interplay of large numbers of cells.

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