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Emergence and Dynamics of Polar Order in Developing Epithelia

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Planar Cell Polarity (PCP) is a conserved process in many vertebrate and invertebrate tissues, and is fundamental for the coordination of cell behavior and patterning. A well-studied example is the orientational pattern of hairs in the wing of the adult fruit fly Drosophila, which is an important model organism in biology. The Drosophila wing is an epithelium, i.e., a two-dimensional sheet of cells, which grows from a few cells to thousands of cells during the course of development. In the wing epithelium, planar polarity is established by an anisotropic distribution of PCP proteins within cells. The distribution of these proteins in a given cell affects the polarity of neighboring cells, such that at the end of wing development a large-scale PCP orientational order emerges. Here we present a theoretical study of planar polarity in developing epithelia based on a vertex model, which takes into account cell mechanics, cell adhesion, and cell division, combined with experimental results obtained from time-lapse imaging of the wing development. We show that in experiment, polarity order does not develop de novo at the end of wing development, but rather cells are initially polarized at an angle with respect to their final polarity axis. During wing development, the polarity axes of cells reorient towards their final direction. We identify a basic mechanism to generate such a large-scale initial polarization, based on the growth of a small number of cells with an initially random PCP distribution. Finally, we study the effect of shear and oriented cell division on dynamics of PCP order, showing that these two processes can robustly reorient the polarity axes of cells.