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Physical aspects of Drosophila gastrulation

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Drosophila gastrulation is a popular model used to study morphogenesis. Despite a long-standing effort to determine the physical nature of cell shape changes in this key model system, there is no consensus on the underlying biophysical mechanism. Any predictive model of a morphogenetic event requires the knowledge of material properties of the tissue undergoing morphogenesis. Using our previously developed methods to apply pulling force to a single cell of an early embryo, we were able to quantify the profile of tissue deformation and the dynamics of tissue recoil after the force is released. Comprehensive computational modeling suggest that these data can only be explained assuming that apical domains are much softer than both the lateral and the basal domains. Motivated by this prediction, we developed a novel protocol to probe individual cellular domains using iron microspheres. Strikingly, applying concentrated pulling force to apical and lateral cellular domains resulted in formation of remarkably long membrane tethers. Tether formation required orders of magnitude smaller force than our typical global tissue deformations when the force probe contacts the basal side. Our measurements thus suggest that cells are extremely rigid on their basal side, whereas lateral and basal domains are orders of magnitude softer, likely lacking stable membrane-associated cytoskeleton. Furthermore, using the newly developed AID-2 degron, we show that (nearly) complete depletion of myosin II has no effect on the mechanical measurements, indicating that the measured responses are passive. A novel 3D computational model integrating our experimental findings suggests that (1) cell elongation during the early phase of gastrulation is a passive process driven primarily by viscous shear forces, and (2) tissue invagination must require active tension in the lateral membranes as well as forces transmitted through the cytoplasm.

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