Anisotropic actomyosin organisation driving of morphogenetic flow in three-dimensions

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Morphogenesis is a three-dimensional process during which an organism undergoes complex deformations to acquire a given shape and organisation. The genetic patterning of Drosophila embryos and the way this regulates key molecules and complexes, such as actomyosin, is well described. How the motor Myosin II generates local mechanical action is understood, however, the way this is integrated at the scale of the embryo to drive morphogenetic movements is still to be characterised. Axis extension in Drosophila is a good model system for this, since it involves the deformation of the whole of the embryonic epithelium. It is dependent on a well-characterised anisotropic myosin recruitement pattern in the germband tissue, where actomyosin organises in oriented supracellular cables through a planar-polarisation mechanism.

In order to resolve the stresses and deformations produced at the scale of the whole embryo, we develop a novel finite element technique which allows us to solve the three-dimensional mechanical balance resulting from a given global distribution of myosin-generated prestress. Our prediction of local mechanical behaviour is based on a rheological law recently validated for cortical actomyosin (1,2) and extend to the case when myosin generates an anisotropic prestress (3).

Numerical simulations confirm that the planar-polarised arrangement of myosin in the germband can trigger embryo-scale flows similar to those observed experimentally. Interestingly, this mechanical behaviour is shown not to rely necessarily on cell intercalation, but rather on the anisotropy of myosin action, which can entail cell elongation as well as intercalation. We also show that the mechanical balance that leads to axis extension towards the posterior of the embryo is crucially dependent on the embryo's geometry, including the presence anteriorly of the cephalic furrow, which can act as a guide for morphogenetic movements.

1. Étienne et al., PNAS 112:2740, 2015.
2. Machado et al., BMC Biol. 13:98, 2015.
3. Dicko et al., PLoS Comp Biol, 13(3):e1005443, 2017.

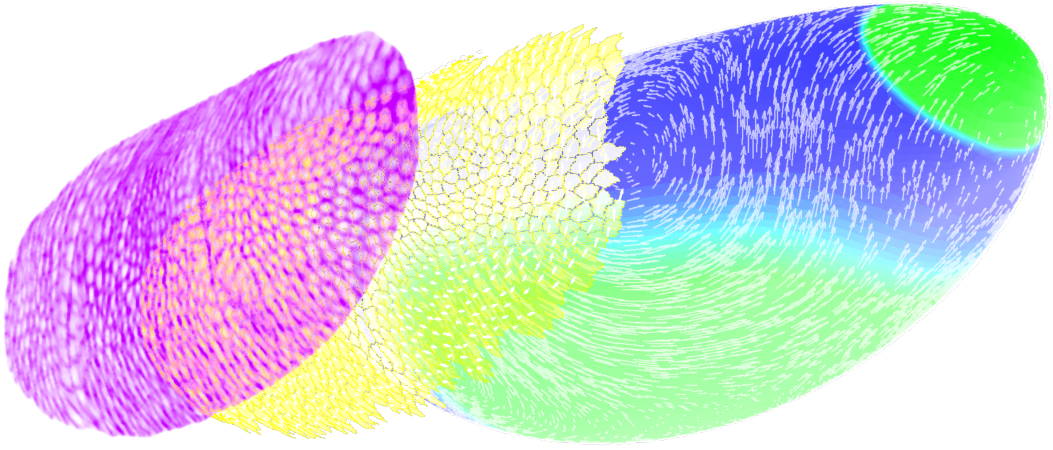

Figure 1: Myosin distribution (colour-coded in green on right-hand side image) and a mechanical model are predictive of a morphogenetic flow (arrows, right-hand side image) comparable to the experimentally observed flow (central image), obtained from the tracking of the dynamics of cell contours (left image).