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Numerical simulation of mechanotransduction in drosophila embryos including mesoderm large strain

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ABSTRACT

During embryogenesis, the shape of the embryo evolves due to morphogenetic movements that are controlled by so-called “patterning genes”. Patterning genes can induce mechanical constraints but one may wonder whether these constraints may act as feedback influencing the expression of some of these genes. Our study is focused in particular on germ band extension (GBE) which occurs on stage 8 trough stage 11 and it is induced by cell rearrangement and intercalation. This leads to an increasing of mesoderm length towards the posterior pole and a width narrowing at the ventral part of the embryo, while a compression is observed at the anterior pole. Recent works have shown that such compression can influence the expression of one of patterning genes called “twist”.

One of the objectives of the present work is to estimate at least qualitatively, thanks to numerical simulations, the magnitude of pressure forces involved during drosophila embryogenesis and cell intercalation effects on mesoderm invagination to infer further biological scenarios.

To model such a phenomenon, a finite element model reproducing a thin mesoderm membrane surrounded by a rigid shell with unilateral contact condition in between has been developed. This membrane encloses itself the yolk which may be considered to stay under uniform pressure which is thus not meshed but which implies a non-local pressure condition because of the volume conservation condition.

Finally large strains during mesoderm invagination are considered. The total deformation is multiplicatively split into two parts: a biological deformation, which involves an elongation and a shortening tangentially to the mesoderm and thus the use of curvilinear coordinates, and a mechanical deformation in response to the latter.

The talk will detail the mechanical and numerical formulation of the highly non-linear problem and presents three-dimensional simulations of it, with special emphasis on the incorporation of cell deformation into a sound mechanical framework.

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