Embryogenesis is an amazing choreography of highly regulated cells movements. The genetic programme drives these processes through the expression of developmental genes. But recent experiments of Emmanuel Farge’s team have demonstrated that, in Drosophila melanogaster, the mechanical constraints due to tissue deformation induces gene expression. Is this phenomenon an exception or a general mechanism of morphogenetic self regulation? To address this second hypothesis, it is necessary to integrate the biomechanical behaviour of the tissue in response to specific active deformations through the whole embryo.

The twist gene is a master regulator of embryo morphogenesis. It is involved in active cell deformations and in anterior gut tract formation. In artificially deformed embryos, the (normally ventral) expression of twist becomes ectopic.

To investigate biomechanical properties of early Drosophila embryo, I first designed a simple model of cells in a two dimensional tissue. Its numerical simulation shows basic properties of an epithelium: elasticity at low deformation and inelasticity at strong deformation that leads to complex fluid behaviour at large time scale.

It consists in a centre of interaction and springs radiating from it in the direction of the centres of interaction of neighbour cells. The neighbours of a cell can change because of geometrical rules dealing with interface surface. Unlike previous attempts to model living tissues, this one favours the cell as the base element, and so sticks to living matter where cell is the unit bridging bio molecular processes and macroscopic behaviour.

Visco-elastic properties through stretching at constant speed.

Visco-elastic properties through shear stress at constant speed on a cylinder.

The anterior pole twist gene expression is lost in a mutant where morphogenetic movements are disrupted, and can be restored by an artificial compression with a needle. Farge E. Current Biology; 2003.

The research project consists in generating a biomechanical in silico multi-cellular model of the whole Drosophila embryo at earliest stages of development, including the active differential shape morphing of cells.

What for?
- To investigate the rheology of an epithelium
- To mark out the active cell movements from the passive responsive ones
- To predict and quantify the correlation between gene expression and tissue deformations
- To suggest other possible mechanically driven processes
- To realize the first in silico embryo

Next Steps
- Thickening of the tissue to model three dimensional cells;
- Implementation of the motors of the morphogenetic movements at the scale of the cells;
- In silico morphogenesis simulation;
- Comparison with in vivo morphogenesis and optimisation of model parameters;
- Understanding the mechano-genetic interplay and self-organisation.