



# **Computational Systems Biology: Chapter 16. Computational Modeling and Simulation of Animal Early Embryogenesis with the MecaGen Platform**

*Julien Delile, René Doursat, Nadine Peyriéras*

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We propose a theoretical, yet realistic agent-based model and simulation platform of animal embryogenesis, called MecaGen, centered on the physico-chemical coupling of cell mechanics with gene expression and molecular signaling. This project aims to investigate the multiscale dynamics of the early stages of biological morphogenesis. Here, embryonic development is viewed as an emergent, self-organized phenomenon based on a myriad of cells and their genetically regulated, and regulating, biomechanical behavior. Cells' mechanical properties (such as division rate, adhesion strength, or intrinsic motility) are closely correlated with their spatial location and temporal state of genetic and molecular dynamics (such as internal protein and external ligand concentrations) and affect each other concurrently. In a second part, we illustrate our model on artificial data (gene regulation motifs and cell sorting), then demonstrate a customization and application to a real biological case study in the zebrafish early development. We use as an example the episode of intercalation patterns appearing during the first phase of epiboly and the movements of the deep cells between the yolk and the enveloping layer. A domain of the model's multidimensional parameter space is explored systematically, while experimental data obtained from microscopy imaging of live embryos is used to measure the "fitness" of the virtual embryo and validate our hypotheses.



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