# Simulating Organogenesis in COMSOL Multiphysics®: Image-Based Modeling

D. Iber[1], Z. Karimaddini[1], E. Unal[2], A. Schwaninger[3], D. Menshykau[1]

[1]D-BSSE, ETH Zurich, Switzerland; Swiss Institute of Bioinformatics (SIB), Switzerland
[2]DBM University of Basel, Switzerland; D-BSSE, ETH Zurich, Switzerland
[3]D-BSSE, ETH Zurich, Switzerland

## Abstract

Organogenesis is a highly dynamic process that is tightly regulated during embryogenesis. Many of the individual regulatory components, such as signaling molecules and their receptors, as well as their regulatory interactions have been identified in experiments. However, an integrative mechanistic understanding of the regulatory network is missing [1].

In a series of papers on simulating organogenesis in the COMSOL Multiphysics® software [2-5], we have discussed methods to efficiently solve models for organogenesis on static and growing domains as well as models, which consider cells explicitly. Initially, these models were formulated on idealized geometries. Recently, we have started to taken advantage of advancements in imaging techniques, which now provide us with detailed imaging data of organogenesis [6]. This now allows us to simulate our models on realistically growing embryonic domain in COMSOL Multiphysics® [7].

In this paper, we show how to use the image-based data for simulations of organogenesis in COMSOL. As an example, we use limb bud development, a classical model system in mouse developmental biology (Figure 1). In the first step, computer readable geometries must be extracted from the 3D images and must then be imported into COMSOL; we show how to accomplish this also for complex geometries comprising several subdomains. In a second step, the displacement fields between two consecutive image frames must be calculated [8] and imported into COMSOL Multiphysics. Finally, the imported displacement fields can be used to simulate the domain shape evolution in COMSOL. Given the large number of stages that we use, we implement our models using the LiveLink™ for MATLAB® add-on. We use the ALE interface, which supports the solution of the PDEs that describe our signaling model even on strongly deforming domains. The simulation results can be compared to experimental data, and parameter values can be optimized to obtain an optimal match of model predictions and experimental results [4].

We conclude that the image-based modeling approach allows us to build realistic models of highly dynamic developmental processes, and allows us to study the combined impacts of patterning and growth.

## Reference


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