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Using Chaste to simulate a multiscale problem in developmental biology

During somitogenesis the posterior PSM segments at regular time time intervals into blocks of epithelial cells called somites. A clock and wavefront mechanism is the widely accepted model for this process, with cellular clocks and a travelling molecular wavefront determining when and where the somites form, respectively.

Recent experimental findings in zebrafish have highlighted the fundamental role of Notch-Delta signalling in the coupling of neighbouring cellular oscillators. Using the framework of phase coupled oscillators to model the Notch-Delta coupled molecular oscillators, we demonstrate how oscillator coupling alone is sufficient to yield a range of experimentally observed results. A notable feature of the considered phase-coupled framework is that the clock and wavefront are not separate entities, rather the wavefront that slows clock oscillations is a gradient in clock phase.

Cell movements in the chick PSM have recently been quantified: cells are most motile in the posterior PSM while cell densities are largest anteriorly. Using a cell-based model implemented in Chaste, we investigate the interaction between three tightly-coupled processes: embryo elongation, embryo convergence and cell proliferation. Results from the numerical simulations are compared with available experimental data and the model is used to suggest further experimental studies.