Reaction-diffusion approach to prevertebrae formation: Positive role of internal fluctuations

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Pattern formation is a central issue in developmental biology. There is a plethora of examples of periodic structure formation during embryonic growth, from axial segmentation of invertebrates to spine formation in vertebrates. Cells of many tissues differentiate according to concentrations of signaling molecules, the morphogens.
Many approaches, all involving propagation of a wave front, have been proposed to model formation of the prevertebrae called somites. Since observation of temporal oscillations of some morphogens in the undifferentiated tissue, the clock and wavefront model has been the most commonly admitted model of somitogenesis. However, non oscillatory genes have been shown to be essential in this process and the biochemical species involved in the observed time oscillations differ according to the considered vertebrates.

Alternatively, reaction-diffusion models are known to generate spatial periodic structures without recourse to temporal oscillations. Spatial symmetry breaking spontaneously emerges due to the Turing mechanism which leads to a pattern with an intrinsic wavelength. Reaction-diffusion models have been suspected to be unable to mimic experiments in which a local source of morphogen is introduced in the embryo. In addition to clarifying the molecular interactions between biological species, the microscopic foundation of reaction-diffusion models presents the great advantage of making a consistent description of internal fluctuations possible. Using two independent methods, we refute the criticisms about the sensitivity of reaction-diffusion models to noise. We prove robustness of the results in the presence of fluctuations, using a stochastic description [1] and simulations of particle dynamics [2]. Whereas the deterministic properties are often recovered, some interesting fluctuation-induced phenomena, such as the disappearance of a prevertebra, are exhibited (see figure).

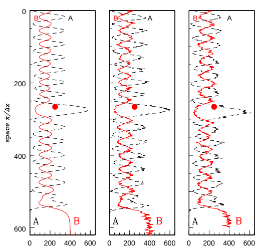

Figure 1: Effect of a local source of B morphogen (red disc): Spatial profiles of morphogen concentrations A (black) and B (red) deduced from the deterministic equations (left), master equation (middle) and simulations of particle dynamics (right). Head of the embryo at the top, tail at the bottom.

1. A. Lemarchand and B. Nowakowski, *EPL*, **94**, 48004 (2011).
2. P. Dziekan, A. Lemarchand and B. Nowakowski, *J. Chem. Phys.*, **137**, 074107 (2012).