Linear and non-linear instabilities for patterning embryonic tissues

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During the development of animal embryos, regular patterns of gene activation arise within tissues which subsequently direct the differentiation of cells into distinct cell types. These patterns can arise from self-organization dynamics that involve cell-to-cell communication.

We focus herein in one type of short-range spatial communication that enables periodic pattern formation. This communication arises between adjacent cells and is mediated by the Notch signaling pathway. Notch is a receptor at the cell membrane that directs a signal to the cell nucleus after binding to other proteins (Notch ligands) in adjacent cell membranes. It is well known from theoretical grounds that a linear instability can drive periodic patterning through this type of communication [1]. As we have previously shown, this scenario is consistent with patterning of sensory organs in the inner ear of vertebrates [2, 3]. Herein we address an additional aspect of this process. Empirical evidences show that during sensory organ development, cells can have a dual behavior being mostly sensitive to the spatial communication but occasionally insensitive to it [4, 5].

Through a dynamical mathematical model of cell-to-cell interactions that can reproduce these empirical evidences, we propose that whereas patterning is mediated by a linear instability, the occasional insensitivity arises from a non-linear instability. Based on this, our model drives specific predictions, some of which we address experimentally. Taken together, our results provide a novel framework to understand both sensitivity and insensitivity based on linear and non-linear instabilities.

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