A mathematical model for the morphogen gradient formation and interpretation during the development

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The goal of developmental biology is to understand how a single cell develops into a complex organism. For the proper development, cells should express different sets of genes according to spatial and temporal information. Then, what confer this spatiotemporal information during the development? Extensive studies over last century have established the basic framework of morphogen concept. Morphogen is a diffusible molecule that forms a concentration gradient and provides positional information of cells. Early theoretical works had a great influence on this concept of morphogen and the following experimental works had confirmed the theory. Some of the well known ligands of signaling pathways, such as WNT and TGF-β, are examples of morphogens. Because of their great importance on development, regeneration and cancer, extensive experimental studies have been focused on identifying the components of morphogen signaling pathways. Although experiments have identified many important genes of morphogen signaling pathways, our understanding of morphogen action has not much advanced by them. It is extremely difficult to understand the mechanisms of development just by gathering more detailed information about parts. The difficulties come from the complex and dynamic nature of the developmental process where growth and patterning happens simultaneously. Theoretical and computational methods have a great potential to expand our understanding of many complex biological processes, such as development and complex diseases.

Here, we employ mathematical and computational methods to understand the mechanism by which morphogen information is generated and interpreted. I present a mathematical model and the simulation results of 1) the formation of morphogen profile in a growing two dimensional domain, 2) interpretation of a single morpohgen gradient, and 3) the integration of two perpendicular morphogen signals. The simulation results and experimental observations suggest a novel model for morphogen interpretation and integration.