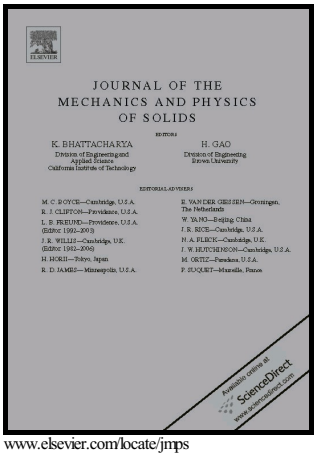

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Krishna Garikipati

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Perspectives on the mathematics of biological patterning and morphogenesis

Krishna Garikipati*

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Abstract

A central question in developmental biology is how size and position are determined. The genetic code carries instructions on how to control these properties in order to regulate the pattern and morphology of structures in the developing organism. Transcription and protein translation mechanisms implement these instructions. However, this cannot happen without some manner of sampling of epigenetic information on the current patterns and morphological forms of structures in the organism. Any rigorous description of space- and time-varying patterns and morphological forms reduces to one among various classes of spatio-temporal partial differential equations. Reaction-transport equations represent one such class. Starting from simple Fickian diffusion, the incorporation of reaction, phase segregation and advection terms can represent many of the patterns seen in the animal and plant kingdoms. Morphological form, requiring the development of three-dimensional structure, also can be represented by these equations of mass transport, albeit to a limited degree. The recognition that physical forces play controlling roles in shaping tissues leads to the conclusion that (nonlinear) elasticity governs the development of morphological form. In this setting, inhomogeneous growth drives the elasticity problem. The combination of reaction-transport equations with those of elasto-growth makes accessible a potentially unlimited spectrum of patterning and morphogenetic phenomena in developmental biology. This perspective communication is a survey of the partial differential equations of mathematical physics that have been proposed to govern patterning and morphogenesis in developmental biology. Several numerical examples are included to illustrate these equations and the corresponding physics, with the intention of providing physical insight wherever possible.

Keywords

Reaction; diffusion; phase segregation; nonlinear elasticity; buckling

*Mechanical Engineering, & Mathematics, University of Michigan, krishna@umich.edu