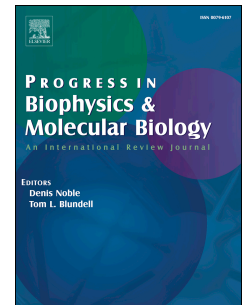


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Bioelectrical control of positional information in development and regeneration: a review of conceptual and computational advances

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Abstract

Positional information describes pre-patterns of morphogenetic substances that alter spatio-temporal gene expression to instruct development of growth and form. A wealth of recent data indicate bioelectrical properties, such as the transmembrane potential (V_{mem}), are involved as instructive signals in the spatiotemporal regulation of morphogenesis. However, the mechanistic relationships between V_{mem} and molecular positional information are only beginning to be understood. Recent advances in computational modeling are assisting in the development of comprehensive frameworks for mechanistically understanding how endogenous bioelectricity can guide anatomy in a broad range of systems. V_{mem} represents an extraordinarily strong electric field ($\sim 1.0 \times 10^6$ V/m) active over the thin expanse of the plasma membrane, with the capacity to influence a variety of downstream molecular signaling cascades. Moreover, in multicellular networks, intercellular coupling facilitated by gap junction channels may induce directed, electrodiffusive transport of charged molecules between cells of the network to generate new positional information patterning possibilities and characteristics. Given the demonstrated role of V_{mem} in morphogenesis, here we review current understanding of how V_{mem} can integrate with molecular regulatory networks to control single cell state, and the unique properties bioelectricity adds to transport phenomena in gap junction-coupled cell networks to facilitate self-assembly of morphogen gradients and other patterns. Understanding how V_{mem} integrates with biochemical regulatory networks at the level of a single cell, and mechanisms through which V_{mem} shapes molecular positional information in multicellular networks, are essential for a deep understanding of body plan control in development, regeneration and disease.

1 Introduction

A deep understanding of morphogenesis is essential for the identification and application of strategies that will mitigate birth defects and restore damaged and diseased tissues, organs, and anatomy

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