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FELLOWSHIP
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PROJECT

Mathematical Modeling to Reshape Our Understanding of Biological Systems

Understanding how an organism's genetic information translates into specific observable traits poses a significant challenge in biology. This task is particularly difficult due to the intricate interplay between regulatory genes and environmental factors, which collectively give rise to phenotypic traits. The field of Systems Biology has tackled this problem, aiming to understand how and when these traits emerge and function. Central to this endeavor are mechanistic mathematical models, which describe the dynamics of gene regulatory systems employing mathematical functions to represent molecular events.

Undoubtedly, mathematical modeling stands as a powerful tool in biological research, enabling scientists to interrogate the logical consequences of their assumptions, identify gaps in understanding, and design more informative experiments. However, as our ability to make precise measurements of biological systems improves, traditional models struggle to accommodate the observed fluidity and stochastic nature of these systems. Consequently, there is a pressing need for a fresh interpretative framework that can reconcile the complexity of biological systems with our growing understanding.

Based on the available evidence, I am convinced that we stand at the precipice of a paradigmatic shift in the conceptualization of molecular biology. Yet, effecting this transition requires more than mere refinement of mathematical models; it necessitates a fundamental reevaluation of our conceptual approach to biological processes. I assert that this theoretical shift will not only dramatically reshape mathematical models, but also that mathematical models will, in turn, play an essential role driving this new theoretical conceptualization. As such, I aim to explore the pivotal role of mathematical modeling in guiding this conceptual transition, examining both its philosophical implications and practical applications.

Recommended Reading

Chevalier, Michael, Mariana Gómez-Schiavon, Andrew H. Ng, and Hana El-Samad (2019). "Design and Analysis of a Proportional-Integral-Derivative Controller with Biological Molecules." Cell Systems 9: 338–353.e10. https://doi.org/10.1016/j.cels.2019.08.010.

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