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Born in 1984 in Mexico City
Studied Biology at the National Autonomous University of Mexico (UNAM) and Systems and Synthetic Biology and Bioengineering at Imperial College London

FELLOWSHIP
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ARBEITSVORHABEN

Towards a Mathematical Description of Health: from Phenotypical Stability to Ecological Resilience

A key feature of healthy biological systems is their ability to adapt and respond to environmental and genetic fluctuations while simultaneously maintaining their stability, homeostasis, and resilience. Understanding how this balance between robustness and plasticity is maintained in health and lost in disease is one of the most pressing questions in biology.

In my research, I tackle this question from a systems biology perspective. Specifically, I construct and analyse mechanistic mathematical models of complex biological systems and ask under which conditions health emerges from the system's interactions. Qualitative transitions between healthy and disease states can be interpreted as catastrophic shifts, or bifurcations, of the mathematical model. Using this approach, it has been possible to contribute to understand, prevent, diagnose, and reverse health-to-disease transitions in complex biological systems ranging from individual cells to whole ecosystems.

The time is ripe to critically think about the features of these models from a theoretical perspective. Questions to be addressed include:

(1) What are the shared structural properties of the regulatory networks that maintain homeostasis in biological systems operating at different scales?

(2) Can we define the health of complex biological systems as a trade-off between robustness and plasticity in response to perturbations?

(3) What are the methodological scopes, limitations, and implications of using catastrophe theory to study the health of complex biological systems?

In this project, I will tackle these questions by constructing, validating, analysing, and comparing a set of minimal mathematical models that represent critical bifurcations of complex biological systems operating at three different scales: (1) Cellular-level phenotypical stability; (2) Physiological homeostasis, and (3) the Integrity of an ecological community.

This project will contribute to an integrative and systems-level understanding of health in complex biological systems across different scales and to improve the strategies for the prevention, early detection, and reversal of unwanted cata-strophic transitions.

Recommended Reading

Domínguez-Hüttinger, Elisa, Panayiotis Christodoulides, Kosuke Miyauchi, Alan D. Irvine, Mariko Okada-Hatakeyama, Masato Kubo, and Reiko J. Tanaka (2017). "Mathematical Modeling of Atopic Dermatitis Reveals 'Double-Switch' Mechanisms Underlying Four Common Disease Phenotypes." Journal of Allergy and Clinical Immunology 139, no. 6: 1861-1872.e7. https://doi.org/10.1016/j.jaci.2016.10.026.

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Álvarez-Buylla Roces, Maria Elena, Juan Carlos Martínez-García, José Dávila-Velderrain, Elisa Domínguez-Hüttinger, and Mariana Esther Martínez-Sánchez (2018). Modeling Methods for Medical Systems Biology: Regulatory Dynamics Underlying the Emergence of Disease Processes. Cham: Springer.

Untangling the Wires that Maintain Health

Healthy physiological systems are simultaneously plastic and robust. This is, they dynamically respond to changing environments without large or long-lasting deviations from a homeostatic set point. This fine balance is achieved through exquisitely connected networks of regulatory interactions between biological players such as molecules, cells, and tissues. What are the key structural features of these intricate feedback control structures maintaining homeostasis? In my research, I tackle this question from a dynamical systems biology perspective. This means that I study the interactions of biological networks through the mathematical framework of dynamical systems theory. With this, I aim to move from a descriptive to a predictive understanding of the mechanisms through which health is maintained and lost. In this endeavour, my main object of study has been the epithelium, which is the main tissue that separates us (and any other animal – even sponges!) from the outside. Now, I am zooming in and out of my comfort zone, focusing also on cellular-level decision-making processes of a developing fungus and on ecological-level interactions in a closed community. By assembling and comparing such a multi-level collection of systems, my dream is to distil the essential regulatory features into an abstract mathematical model – a so-called network motif – to propose a richer and yet more mathematically formal definition of health.

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Predicting dynamic trajectories of a protected plant community under contrasting conservation regimes : insights from data-based modelling

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Mathematical model of the immunopathological progression of Tuberculosis

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Bifurcation analysis of a mathematical model of atopic dermatitis to determine patient-specific effects of treatments on dynamic phenotypes

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Modeling Methods for Medical Systems Biology : Regulatory Dynamics Underlying the Emergence of Disease Processes

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Modeling methods for medical systems biology : regulatory dynamics underlying the emergence of disease processes

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Mathematical modeling os Streptococcus pneumoniae : colonization, invasive infection and treatment

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Mathematical modeling of atopic dermatitis reveals “double-switch” mechanisms underlying 4 common disease phenotypes

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Domínguez-Hüttinger, Elisa (London,2017)

Gene regulatory network underlying the immortalization of epithelial cells

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Domínguez-Hüttinger, Elisa (London,2017)

Computational design of treatment strategies for proactive therapy on atopic dermatitis using optimal control theory

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