Institute for Quantitative & Computational Biosciences

Cross Disciplines Seminar
September 10, 2025
10:30 AM

Lecture Hall (00.187) at BioZentrum I, Hanns-Dieter-Hüsch-Weg 15, 55128 Mainz

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A Quantitative Approach to the Emergence of Eukaryotes

The origin of eukaryotes is one of the most significant events in the evolution of life on Earth. Although the endosymbiotic theory is widely accepted, the billions of years since the fusion of an Archaea and a Bacteria have resulted in a lack of known evolutionary intermediates, often referred to as 'the black hole at the heart of biology'. To address this gap, we combined theoretical and observational approaches to quantitatively understand how the genetic architecture of life was transformed to allow such an increase in complexity [1,2,3].

Our analysis revealed that protein coding gene lengths follow lognormal distributions in the different species throughout the tree of life. The evolution of those distributions results from multiplicative stochastic processes, leading to a scale-invariant mechanism of gene growth across the tree of life. We conclude that the eukaryotic cell emerged through a phase transition occurring abruptly at a critical and observable point, analogous to those studied in the physics of magnetic materials, and we argue that the transition was algorithmic. Regardless of whether the phase transition was necessary, it paved the way toward other major transitions that shaped life on our planet as we know it today.

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References

[1] Muro EM, Ballesteros FJ, Luque B, Bascompte J. The emergence of eukaryotes as an evolutionary algorithmic phase transition. Proc Natl Acad Sci U S A. 2025 Apr;122(13):e2422968122. doi: 10.1073/pnas.2422968122. Epub 2025 Mar 27.

[2] Ferrada E. An algorithmic constraint at the transition to complex life. Proc Natl Acad Sci U S A. 2025 Apr 29;122(17):e2505484122. doi: 10.1073/pnas.2505484122. Epub 2025 Apr 21.

[3] Buchanan, M. When life got complex. Nat. Phys. 21, 683 (2025). https://doi.org/10.1038/s41567-025-02905-w

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