BIOCHEMICAL NETWORKS

⟷ Pieter Rein ten Wolde

Biochemical networks are the information processing devices of life. We use concepts from information theory and recent advances from non-equilibrium thermodynamics to quantify what the resource requirements are for cellular information transmission, in terms of protein copy numbers, time, and energy. In addition, we aim to elucidate the design principles that govern cellular rhythms, ranging from the bacterial cell cycle to circadian clocks. Lastly, we use techniques from statistical mechanics to describe cellular force generation.

Highlights

- We have shown that biochemical networks can come surprisingly close to the Landauer bound on the thermodynamic cost of computational copying ([1,2].

- We have demonstrated that the combination of active forces, dimensionality, and membrane bending free energy creates a plethora of novel shape transitions in active vesicles [3].

- We have developed a theory for the optimal cellular sensing of time-varying signals [4].

- We have developed the first mechanistic model of how the bacterium E. coli controls the initiation of DNA replication [5].

Plans

Living cells can enhance their fitness by anticipating environmental change. In the coming years, we aim to extend our work on cellular information transmission to address not only the question how reliably living cells can predict future signals, but also how the accuracy of prediction limits behavioral tasks like navigation. Moreover, we plan to investigate how cells can learn, and hence adapt to changes in, the statistics of time-varying signals. Lastly, we aim to elucidate the role of mechanics, and its interplay with chemistry, in organoid development.

Key research items

1. T.E. Ouldridge, C.C. Govern and P.R. ten Wolde, *Thermodynamics of Computational Copying in Biochemical Systems*, Physical Review X 7, 021004 (2017)

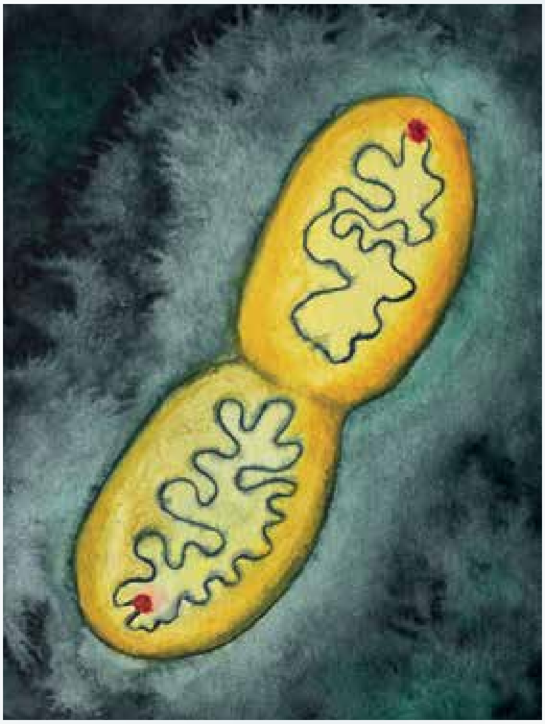
2. T.E. Ouldridge and P.R. ten Wolde, *Fundamental Costs in the Production and Destruction of Persistent Polymer Copies,* Physical Review Letters 118, 158103 (2017)

3. Y. Li and P.R. ten Wolde, *Shape Transformations of Vesciles Induced by Swim Pressure,* Physical Review Letters 123, 148003 (2019)

4. G. Malaguti and P.R. ten Wolde, *Theory for the Optimal Detection of Time-Varying Signals in Cellular Sensing Systems,* eLife 10, e62574 (2021)

5. M. Berger and P.R. ten Wolde, *Robust Replication from Coupled Homeostatic Mechanisms,* Nature Communications 13, 6556 (2022)

Artist impression of a dividing bacterial cell with its circular chromosome.



Credits: Mareike Berger