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## Spatially orchestrated reaction kinetics in biological systems

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Catalytic particles are spatially organized in a number of biological systems across different length scales, from enzyme complexes to metabolically coupled cells. Despite operating on different scales, these systems all feature localized reactions involving partially hindered diffusive transport, which is determined by the collective arrangement of the catalysts. We explore how different arrangements affect the interplay between the reaction and transport dynamics, which ultimately determines the flux through the reaction pathway. Two fundamental trade-offs arise, the first between efficient inter-catalyst transport and the depletion of substrate, and the second between steric confinement of intermediate products and the accessibility of catalysts to substrate. We find that the question of optimal catalyst arrangements generalizes the well-known Thomson problem of electrostatics [1]. Furthermore, we map the problem of optimally arranging enzymes to an economic investment problem, which helps to formulate and  understand a possible design principle for synthetic biomolecular systems [2].

[1] F. Hinzpeter, F. Tostevin, A. Buchner, and U. Gerland (2022), Trade-offs and design principles in the spatial organization of catalytic particles,  Nature Phys. 18, 203-211.
[2] G. Giunta, F. Tostevin, S. Tanase-Nicola, and U. Gerland (2022), Optimal spatial allocation of enzymes as an investment problem, Commun. Phys. 5, 319.