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Molecular Sorting on Fluctuating Membranes

Molecular sorting is a vital process in eukaryotic cells, where proteins and other biomolecules are sorted and encapsulated into lipid vesicles for targeted transport to specific organelles and sub-cellular locations. Recent studies suggest this process is driven by a physical mechanism based on phase separation, in which the formation and growth of sorting domains depends primarily on direct intermolecular interactions. On fluctuating biological membranes, entropic Casimir-like forces also play a significant role in promoting this molecular distillation process, particularly in regimes where direct interactions are weak. Our findings, based on a combination of theoretical analysis and numerical simulations, reveal that Casimir-like forces enhance sorting by reducing the critical radius for the formation of new sorting domains and facilitating the capture of molecules in these domains. The relative rigidity of the membrane and domains are identified as key parameters governing sorting efficiency. These insights provide a deeper understanding of the physical principles shaping molecular organization in biological membranes.

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