Chemotaxis of porated liposomes with encapsulated enzymes

Barbara Borges Fernandes[1,2,3], Subhadip Ghosh[1,3], Ian Williams[1,4], Joe Forth[5,6], Lorena Ruiz Perez[1,3,5], Giuseppe Battaglia[1,3,5,7]

1. Institute for Bioengineering of Catalonia (IBEC), The Barcelona Institute of Science and Technology (BIST), Barcelona, Spain.
2. Department of Physics, University of Barcelona, Barcelona, Spain.
3. Biomedical Research Networking Center in Bioengineering, Biomaterials, and Nanomedicine (CIBER-BBN), Barcelona, Spain.
4. Department of Physics, University of Surrey, Guildford, UK.
5. Department of Chemistry, University College London, London, UK.
6. Department of Chemistry, University of Liverpool, Liverpool, UK.
7. Catalan Institution for Research and Advanced Studies (ICREA), Barcelona, Spain.

gbattaglia@ibecbarcelona.eu

Active systems have gained significant interest across various scientific disciplines. Active motion is an important phenomenon in nature, particularly when related to concentration gradients, a behavior known as chemotaxis. Examples include the directed movement exhibited by bacteria and neutrophils, orchestrated through intricate signaling pathways. In synthetic systems, active and chemotactic behavior has been demonstrated in Janus particles and colloidal structures such as polymersomes and liposomes.

This study investigates a novel active system composed of liposomes with encapsulated enzymes. Asymmetry is introduced by incorporating the pore protein alpha-hemolysin, accelerating the diffusion of substrate and products across the vesicle membrane. The resulting asymmetric distribution of species creates a slip velocity on the liposome's surface, resulting in self-propulsion. Experimental exploration of this motion was conducted within a microfluidic channel.

The nature of the substrate proves to be a critical factor influencing the direction and velocity of the drift. Phenomena such as diffusioosmosis and diffusioosmophoresis emerge as inherent components of the motion. Specifically, amine-modified polystyrene beads exhibit distinctive drift behaviors in a gradient of urea and glucose, attributed to interactions between the substrate with the channel walls and the surface of the beads. These phenomena are also present in the movement of porated liposomes. In addition to them, a chemotaxis component is also observed for the liposomes that have pores. The direction and velocity of the drift is a result of all these events and depend on the enzyme/ substrate pair.

This research sheds light on some fundamental principles governing liposome chemotaxis with encapsulated enzymes. This system can offer insights into the active behavior of some natural vesicles, like exosomes or synaptic vesicles. Also, it could have potential applications in diverse fields, including drug delivery. The interplay between substrate properties, surface interactions, enzyme reactions, and asymmetry opens new horizons for further exploration of chemotaxis in biochemical systems.

Figure

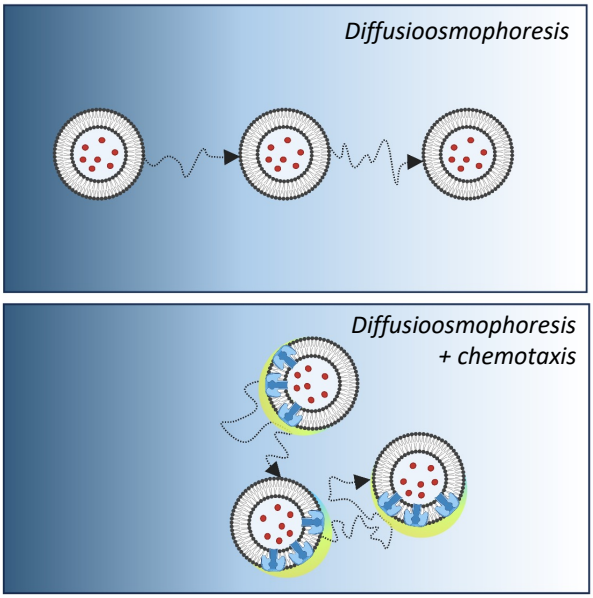

Figure 1. Liposomes with encapsulated enzymes and no pores present a drift due to diffusioosmophoresis. In liposomes with pores, a chemotactic component results in a total drift aligned with the substrate concentration gradient. In both cases, the direction and velocity of the drift depend on the enzyme and substrate.