Enzyme-driven chemotactic synthetic vesicles

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The movement of organisms toward (or away from)[1] specific chemicals in their environment is possibly one of the most important evolutionary milestones for many living systems to secure a superior position over non motile competitors. In particular, chemotaxis is a very important biological process used by many unicellular organisms to gather food and/or escape danger[2] as well as by multicellular system to control tissue development[3], immune response[4] and cancer metastasis[5]. From a physical point of view, chemotaxis is possibly the longest ranged form of chemical targeting extending over several orders of magnitude larger than the motile organism itself.[6] Here we report for the first time an example of nanoscopic chemotactic system fully driven by enzymatic conversion of small water soluble molecules. We demonstrate this by encapsulating enzymes into nanometer sized synthetic polymeric vesicles also called polymersomes. These polymersomes are formed by double-layered membranes that are topologically designed to contain permeable domains within an impermeable matrix. The asymmetric distribution of these permeable domains enables to direct and focus the discharged enzymatic reaction products generating thrust. This in turn allows propulsion with direction controlled by the substrate concentration. The combination of membrane topology and enzyme encapsulation is a new approach, which produce chemotaxis without the need of chemical modification. We demonstrate this by using physiologically-relevant hydrogen peroxide and glucose coupled with catalase, glucose peroxidase and their combination loaded within asymmetric polymersomes. This can be potentially applied into several biomedical applications spanning from targeted delivery to biochemical sensing. Finally, we propose a new mechanism of advanced diffusion controlled by the vesicle membrane topology suggesting the role of selective permeability as potential new way to produce nanoscale locomotion.

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