Causes and Applications of Enzyme Chemotaxis

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Abstract:

Enzyme chemotaxis is the directional motion of enzyme molecules towards or away from a gradient of their respective substrates and products. The phenomenon has wide-ranging implications for not just modern-day applications, such as drug delivery and disease detection, but also for determining the physiochemical driving force behind the origin of life and its subsequent evolution. We show two factors: 1) kinetic asymmetry, the difference between the unbinding rates of the substrates and the products and 2) diffusion asymmetry, the difference in the diffusivities of the unbound and the bound form of the enzyme, govern the direction of enzyme chemotaxis. Our model captures the non-equilibrium distribution of enzyme molecules while being consistent with the dynamics low Reynold's number regime. Further, we show that enzyme chemotaxis can generate nonreciprocal interactions between complementary enzymes, such as a pair of kinase and phosphatase. Nonreciprocal interactions are common in living systems such as predator-prey interactions, flocking of birds, and swarming of fish. Our work provides a molecular origin for nonreciprocal interactions which may explain the collective motion of enzymes such as metabolon formation and throw light on the origin of life. Finally, we are developing a technology to accelerate drug discovery by leveraging enzyme chemotaxis. The directed motion of enzymes towards small molecules based on binding reaction can assist hit identification. Microfluidics can make this technique high-throughput and cost-effective. We expect that enzyme chemotaxis can be an effective solution to reduce the cost of early-stage drug discovery.