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Bimolecular reactions in the cell membrane exhibit switch-like behaviour with respect to diffusivity and molecular reach

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Many T cell receptors have long, unstructured cytoplasmic tails that contain tyrosine sites. These sites can serve as regulators of receptor activation when phosphorylated or dephosphorylated, while also serving as docking sites for cytosolic enzymes. We coarse-grain the effective interaction between two tails, and develop a mesoscopic particle-based stochastic reaction-diffusion model to study the combined diffusion of individual receptors within the cell membrane, and chemical reactions between proteins bound to receptor tails. The model suggests a switch-like behaviour in the dependence of the fraction of activated receptors on both receptor diffusivity, and on the molecular reach at which two receptor tails can interact. A simplified, analytically solvable model is developed to approximate the more complicated multi-particle system, and used to illustrate how the switch-like behaviour appears.

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