An Analytic Study of Molecular Motion in Cell Membranes

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We present a theoretical calculation to describe the confined motion of transmembrane molecules in cell membranes [1]. Understanding the motion of membrane-associated molecules, e.g. various types of receptors, has great modern relevance in cell biology. Our study is divided into two parts. In the first [2], we consider motion in an ordered system and in the second [3], we investigate the effects of disorder. Both are based on Master equations for the probability of the molecules moving as random walkers, and leads to explicit usable solutions including expressions for the molecular mean square displacement and effective diffusion constants. One outcome is a detailed understanding of the dependence of the time variation of the mean square displacement on the initial placement of the molecule within the confined region. How to use the calculations is illustrated by extracting compartment sizes from experimentally reported published observations from single particle tracking experiments on the diffusion of gold-tagged G-protein coupled mu-opioid receptors and by further comparing the analytical results to observations on the diffusion of phospholipids, both in the membranes of normal rat kidney cells [4]. The observations on live cells suggest that there is disorder in both compartment sizes and energetic heights of the barriers that divide adjacent compartments. In order to give an account for the effects of disorder, we make an effective medium approximation and calculate diffusion constants. As a result, the calculations make possible, in principle, the extraction of confinement parameters such as mean compartment sizes and mean intercompartmental transition rates from experimentally reported published observations.

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