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Diffusion of proteins near model biological membranes

Cell membrane separates the interior of the cell from its outside environment and constitute the boundary of the unit of life. It is a specific compartment that harbours essential cell functions. Association of various proteins with the cytoplasmic leaflet of the cell membrane is an important step in a diverse array of cellular processes, from cell signalling to membrane trafficking. The cytoplasmic leaflet of the eukaryotic cell membrane carries a net negative surface charge resulting from the presence of anionic lipids, and recruitment of proteins from the cytoplasm to the membrane is often achieved with the aid of these lipids. There is a significant body of theoretical and experimental work that points to a central role of electrostatics in mediating the association of proteins with membrane surfaces. Another factor important for the protein-membrane association is the geometric confinement of the intracellular space by the cell membrane that introduces an anisotropy in diffusional motions of biomolecules. Moreover, it can be expected that the presence of the membrane will result in a general slowdown of Brownian motions due to hydrodynamic interactions of diffusing biomolecules with the membrane. Among different kinds of interactions governing the dynamics of biomolecules in aqueous solutions, hydrodynamic interactions are somewhat peculiar. They result from the fact that the moving molecule causes a disturbance in the surrounding solvent. As this disturbance propagates through the solvent, motions of other molecules are affected. Hydrodynamic interactions modify also motions of molecules in the presence of fixed obstacles and boundaries such as membranes. Unlike potential forces (arising for example from electrostatic interactions), these long-range, solvent-mediated interactions are only present if molecules are moving. Proteins search membrane-binding spots (or membrane-bound protein receptors) by means of three- (in the cytoplasm) and two-dimensional (near the membrane surface) diffusion and it is expected that this diffusional search (and thus the association kinetics) is affected by hydrodynamic interactions. In the current project we tackle the problem of the proteins' diffusion near the surface of a biological membrane. We investigate to what extent hydrodynamic interactions with biological membranes affect local translational and rotational diffusion of proteins and what is the possible role of these interactions in the association of proteins with membranes. The current project is of purely theoretical/computational nature. It utilises numerical calculations and computer simulations of model protein-membrane systems. Our studies are important for the understanding of the processes of living cells that involve interactions of biomolecules with membranes. Moreover, as effects of hydrodynamic interactions in biological systems are still poorly understood and studies (both computational as well as experimental) on hydrodynamic effects in such systems are rather scarce, our work is also important from the standpoint of the general understanding of fundamental mechanisms of diffusion and molecular processes in biological systems.