The Open-Access Journal for the Basic Principles of Diffusion Theory, Experiment and Application

Diffusivity of Water in a Biological Model Membrane: an NMR Study

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1. Introduction

The structure and dynamics of biological membranes are the base for understanding some main functions of living cells. Since a biomembrane is a very complicated system for research by physical methods the development of an adequate model is a very important aspect of this problem. Oriented lipid bilayers are conventionally accepted to be one of the simplest models that describe some physical properties of biological membranes like water permeability, bending rigidity, surface tension, and membrane fluidity. Furthermore, artificial lipid membranes are well-defined systems and are readily prepared. Thus the model lipid bilayers provide a unique opportunity to investigate certain physiological functions and processes in biological membranes, particularly, molecular transport. The main mechanism for that is diffusion.

Investigation of model lipid bilayers by NMR techniques provides a unique opportunity in studying of main dynamic and structural characteristics of biological membranes. Oriented lipid bilayers are one of several convenient objects for studying molecular mobility of the membrane components by NMR PFG technique. Investigations of macroscopically aligned bilayers oriented at an angle of 54.7^0 (magic angle) with respect to the magnetic field allows to remove residual proton dipolar interactions in lipid molecules and to observe the lipid diffusion coefficient directly [1]. This technique is also promising for the investigation of water mobility along and across lipid bilayers. A number of fascinating studies of lipid diffusion were made, but water diffusion measurements are rare and not completely interpreted [2,3]. Water diffusion along the lipid bilayers was mainly studied, whereas transmembrane water diffusion (the passive water transport) wasn't measured directly because of several reasons including the relative small value of the diffusion coefficient [2,3] and the presence of non-bilayer diffusion pathways conditioned by cracks [4].

2. Diffusivity of water in model lipid bilayers

Our studies showed that diffusion decays for transbilayer diffusion are complicated. That provides difficulties for adequate interpretation of these data in the light of a relevant conception of interbilayer water behaviour and requires more detailed investigations. We analysed diffusion decays in dimiristoylphosphatidylcholine bilayers at room temperature in a broad range of diffusion times and obtained the component which reliably can be related to the transbilayer diffusion of water molecules [4]. Our subsequent experiments include the study of water diffusion under the conditions of multiphase structure of the bilayers induced by temperature, hydration, and sterols content. Special attention was paid to the system behaviour at phase transitions: gel -

liquid crystal and liquid ordered – liquid disordered. Also were estimated the coefficient of permeability of one-component (phospholipid/water system), two-component (unsaturated chain phospholipid/sterol/water system) and three-component (saturated chain phospholipid/unsaturated chain phospholipid/ cholesterol or "raft" system) oriented model membranes using the model of semi-permeable plane membranes [5]. The coefficient of permeability increases in the presence of small concentrations (~10% mol) of sterols (cholesterol and ergosterol) and it decreases in the presence of essential concentrations (~30% mol) of sterols (cholesterol and ergosterol) that was in agrement with reference studies [1]. Particularly, the permeability coefficient for the "raft"-system has the maximum value.

3. Conclusion

Investigation of oriented model membranes by NMR techniques provides a unique opportunity in studying the transport of water molecules across lipid bilayers. This approach leads to an estimate of the influence on the "fluidity" and on the permeability of model biomembranes in the component (phospholipid/water bilayers), two-component (unsaturated chain phospholipid/sterol/water bilayers) and three-component (saturated chain phospholipid/unsaturated chain phospholipid/cholesterol bilayers) systems.

4. Acknowledgements

This work is supported by US Civilian Research and Development Foundation grant BRHE (REC 007), RFBR (grant #04-03-32861), RFBR (grant #05-04-48370), UR (grant #01.01.076).

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