Composition Fluctuations and Microdomains in Three-component Model Biomembrane Systems - The Effects of Temperature, Pressure and Lipid Composition

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The lateral organization of the constituents of biological membranes poses one of the major current problems in membrane biophysics. A particular question is related to the existence of lipid domains on the nm and micrometer length scale. Substantial evidence has also accumulated that points to the presence of distinct liquid-ordered lipid regions termed "rafts" in cell membranes. They are rich in sphingomyelin and cholesterol and are thought to be important for cellular functions, such as signal transduction and the transport of lipids and proteins. We studied the structure and lateral organization of several ternary lipid mixtures without and with incorporated peptides using small-neutron scattering (SANS) in combination with the H/D contrast variation technique and two-photon excitation fluorescence microscopy. The ternary mixtures DOPC / sphingomyelin / cholesterol (10-33 mol%) exhibit a power-law behavior of their SANS intensity with an exponent of 3.0 over an extended temperature range, indicating the existence of composition fluctuations, which correspond to space-filling droplets with a broad size-distribution ranging from about 20 to 200 nm. The heterogeneous membrane structure observed in this system thus contrasts with the characteristic shapes of gel-fluid type lipid domains, and can rather be described by coexisting liquid-ordered/liquid-disordered domains. Fluorescence microscopy was used for direct visualization of the lateral lipid organization and domain shapes including information on the lipid phase state in the micrometer range. By adding peptides (gramicidin, short lipidated peptides), drastic changes of the lateral organization of the membrane occur and, by a molecular sorting mechanism, new lateral structures may be induced. Moreover, pressure dependent FT-IR spectroscopy, SAXS and fluorescence microscopy experiments were carried out to reveal pressure dependent conformational and phase changes in these systems and to construct their corresponding temperature-pressure phase diagrams.