Physics, biology, order and disorder

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Key hurdle in modelling biological systems originates from complex interaction between multiple components. Physical models and experiments often reduce the number of components aiming to address the fundamental mechanisms. Nevertheless, in most cases, the inherent heterogeneity is an essential ingredient in the biological context. Utilizing synchrotron and lab-based small-angle X-ray scattering we are now able to explore dynamic and flexible biological materials that lack 3D order. In this talk I will present some of our recent experimental results aiming to address the fundamental relation between order and disorder in functional biological complexes. These results have direct implications on biomedical research though pose new puzzles for the biophysical community.

In the first example, I will present our recent results studying the interactions between neurofilaments. Very much like the skeleton of bridges and towers, the neuronal skeleton contains organized arrays of rigid beams which resist deformations. However, neurons also contain many spaghetti-like flexible proteins, which protrude from the rigid beams and are otherwise free to move in between them. These flexible components naturally do not resist deformations very strongly, which raises the following question: what can nature gain by such architecture?

In the second example, I will show our recent studies on the metastable-to-stable phase transition in lipid bilayers. Such phase transition is usually an uncontrolled spontaneous process, highly sensitive to microscopic details. Using cryogenic TEM and solution x-ray scattering we studied the phase transition dynamics of supercooled lipid-based particles and found unconventional metastable phase transition from liquid-crystalline to stable crystalline state. Here, supercooled recrystallization is delayed by tens of hours in a robust, predetermined and temporally controlled manner. Our results suggest that a non-stochastic physical mechanism is responsible for the delayed recrystallization, involving several rate-affecting processes. A qualitative model will be presented to describe the structural reorganization during the metastable phase transition.