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Editorial

Scientific advance in biomembranes and biomimetic membranes of biophysical interest

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Abstract: The understanding of the biomembranes structural properties represents a fundamental step in the comprhension of the processes that regulate their functions, within the expecialised tissues of the living cells. More specifically, how lipids and proteins are organized in membranes at the molecular level is one of the most fundamental questions in membrane biophysics. Moreover, biomimetic (model) systems, require advanced methods of preparation as well as appropriately specialized tools for investigation. This special issue provides an opportunity for researchers from different disciplines to share their research results on processes occurring in biological (and model) membranes by means of a broad spectrum of approaches to the topic.

Keywords: biological membranes; biomimetic membranes; lipids self-assembly; lipids nanocarriers

1. Introduction

The biological (cellular) membranes represent protective barriers placed at the interfaces between the internal cytoplasm and the environment of the extracellular fluid of living organisms. They accomplish to the fundamental role of tissues and cells protection from foreign environments. Furthermore, through their bio-active surfaces (that involves the presence of ion channels, enzymes, receptors and signaling molecules), they facilitate the exchange of information between extra- and intra-cellular environments [1,2]. Biological membranes also participate in many fundamental functions of cells such as the signaling, sensing, (selective) transport of bio-active components, recognition and communication processes [3,4]. Due to those special roles in biological systems, the bio-membranes represent then a fundamental substrate of the living systems functioning, while the scientific progress in this topic have great impact at the crossroad of different research fields, including physics, chemistry, biophysics, biochemistry, biotechnology, (bio-)chemical engineering and nanomedicine. For this reason, the investigation of the properties of biological (and biomimetic) membranes has been, and still remain, the object of intensive (experimental/theoretical) research [5–7]. The study of biological and mimetic membranes are also fundamental for the study of their interaction with active components (such as drugs, enzymes, food, and genetic material) and their involved drug delivery phenomena. [8–10]. The investigation of the structure-function relationship of biological membranes requires, in fact, the study of the collective phenomena involving a large number of interacting molecules (including proteins, lipids, carbohydrates, nucleic acids, and other active components), while their detailed structural description requires the simultaneous observation (and simulation) of a large number of factors and parameters [11,12].

For those reasons, the study of the relevant phenomena that take place on model (or cellular) membranes, as well as their interaction with nanocarriers in the physiological (or pathological) situations, is crucial for the development of novel therapeutic potential strategies [5,6], and requires the development of interdisciplinary methods [13,14].

Experiments, Theory and Modeling. The structural (and dynamic) properties of biological membranes, encompasses a large variety of different morphologies and nano-structures, and necessitate then the employment of complementary techniques, in order to elucidate the selfassembly phenomena and the collective molecular processes involved in their biological functions [13–16]. More specifically, how lipids and proteins are organized in biological membranes at the molecular and supramolecular level is one of the most fundamental questions in biomembrane biophysics. Unfortunately, no single experiment (or unique experimental setup) can combine fast processes acquisition and high time-space resolution. Together with the initial analysis of the composition of the biological membranes (very often obtained by using the size-exclusion chromatography technique), the X-rays / Neutron small angle scattering (SAXS / SANS) techniques are certainly among the most important characterization methods usually employed to characterize the main structural properties of biological membranes in complex biological environments [17–19]. Those techniques highlight the formation of various morphologies and nanostructures that help to identify the main molecular biomembranes conformations in a large variety of phenomena.

Complementary information on biological (and mimetic) membranes are provided by using *nuclear magnetic resonance (NMR)*, *dynamic light scattering (DLS)*, and several spectroscopy techniques, including *FT- infrared (FT-IR), ultraviolet (UV), fluorescence correlation spectroscopy (FCS), electron spin resonance (ESR), electron paramagnetic resonance (EPR), circular dichroism, differential scanning and isothermal titration calorimetry (DSC and ITC), (cryo-) transmission electron microscopy (TEM), atomic force microscopy (AFM)* and *optical far-field* microscopy *(OFFM)* [13–15].

On the theoretical side, (model) biomembrane systems require advanced methods as well as appropriate theoretical background for investigation [1,3]. In this respect, a large variety of computational techniques and analytical approaches (based on the of the *statistical physics* and *thermodynamic* concepts) have demonstrated a significant potential in the description of the complex properties of real (and mimetic) biomembranes [20,21]. Moreover, the *molecular dynamics* (MD) simulations approaches furnish the opportunity to investigate (in high time-space resolution) the study of cooperative dynamic of complex multi-component systems, for a large variety of biophysical processes [22,23].

Finally, it is worth pointing that, each experimental (or theoretical) approach alone is not sufficient to completely describe the *structure* and *function* relation of biological membranes, while a suitable combination of them represents an important stage to integrate the insights coming from different approaches.

Lipidomic and system biology. The structural and dynamical processes of biological membranes depend on a large variety of interactions in multicomponent systems that favourites the selfassembly of nanostructures at different molecular (and supramolecular) levels of complexity. As the lipids represent crucial components of the biomembranes, the *lipidomics* approach emerged as a relevant sub-topic of *system biology* approach for the study of biological membranes [24]. According to this method, the complex functioning and interactions of the biomembranes at various levels of the living organisms (and cells) can be studied by inferring the pathways (and networks) that regulate a large variety of bio-processes. This method rely in a (large-scale) mapping of the lipid profile in a large variety of bio-systems (such as a tissue, cell or organism), with the aim to identify the relevant associated biomarkers. The method helps to elucidate the main modifications of the biomembranes (physiological/pathological) configuration, that are at the basis of several diseases [24]. The synergistic organization of interconnected research fields allow to identify the role of the investigation of biological membranes within an interdisciplinary organization of subfields (so called *"-omics"* technologies) at the crossroad between chemistry, physics, mathematics, informatics, biology and (nano-)medicine [24].

Future directions and perspectives in biophysics. The biological membranes can be considered among the most (multi-)functional and (multi-)performing cellular nanostructures. Their study require, then, the description of the complex cooperative phenomena involving of numerous interacting (macro-)molecules, and the simultaneous calculation (and simulation) of a large number of parameters of the system. For this reason the investigation of the events occurring on cell membranes, (at the molecular or supramolecular level, and in physiological or pathological situations), requests an interdisciplinary effort in many different field of science, and represents then a fundamental topic at the crossroad of different disciplines, including physics, chemistry, biochemistry, biotechnology and nano-medicine [25].

In conclusion, the future efforts in the study of the biological and mimetic membranes must focus on an integration of the various research methods into a common program. To obtain this integration, the structural and dynamic characterization methods (with improved time-space resolution), should be combined with an improvement of the theoretical models and computational methods, with the aim to integrate them into a multi-scale description of the complex biological systems. Moreover, as the main techniques and approaches employed require the high performance characterization methods capable to cover a large range of the space-time domains, the collaboration, and integration among the researchers with complementary expertise or working in complementary sub-fields will have a fundamental role in future research. All those resources should contribute in a synergistic way to the development of a common background which results in the effective integration of several sub-disciplines in (interconnected) multi- and interdisciplinary programs.

Conflict of interest

The authors declare no conflict of interest.

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