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Lipid vesicles in pulsed electric fields: fundamental principles of the membrane response and its biomedical applications

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Abstract

The present review focuses on the effects of pulsed electric fields on lipid vesicles ranging from giant unilamellar vesicles (GUVs) to small unilamellar vesicles (SUVs), from both fundamental and applicative perspectives. Lipid vesicles are the most popular model membrane systems for studying biophysical and biological processes in living cells. Furthermore, as vesicles are made from biocompatible and biodegradable materials, they provide a strategy to create safe and functionalized drug delivery systems in health-care applications. Exposure of lipid vesicles to pulsed electric fields is a common physical method to transiently increase the permeability of the lipid membrane. This method, termed electroporation, has shown many advantages for delivering exogenous molecules including drugs and genetic material into vesicles and living cells. In addition, electroporation can be applied to induce fusion between vesicles and/or cells. First, we discuss in detail how research on cell-size GUVs as model cell systems has provided novel insight into the basic mechanisms of cell electroporation and associated phenomena. Afterwards, we continue with a thorough overview how electroporation and electrofusion have been used as versatile methods to manipulate vesicles of all sizes in different biomedical applications. We conclude by summarizing the open questions in the field of electroporation and possible future directions for vesicles in the biomedical field.

Keywords

lipid vesicle, electroporation, electrofusion, artificial cell, microreactor, drug delivery vehicle

Abbreviations

AC, alternating current; CARS, Coherent Anti-Stokes Raman Scattering; DC, direct current; DIC, differential interference contrast; DOPC, dioleoyl-phosphatidylcholine; DOPG, dioleoyl-phospatidylglycerol; DPhPC, diphytanoyl-phosphatidylcholine; DPPC, dipalmitoyl-phosphatidylcholine; EDTA, ethylenediaminetetraacetic acid disodium salt dehydrate; Egg PC, L-α-phosphatidylcholine from egg yolk; EV, extracellular vesicle; GUV, giant unilamellar vesicle; LUV, large unilamellar vesicle; MD, molecular dynamics; MLV, multilamellar vesicle; MNP, magnetic nanoparticle; PDMS, polydimethylsiloxane; PEG, polyethylene glycol; PC, phosphatidylcholine; PE, phosphatidylethanolamine; PG, phospatidylglycerol; POPC, palmitoyl-oleoyl-phosphatidylcholine; POPE, palmitoyl-oleoyl-phosphatidylethanolamine; SUV, small unilamellar vesicle.