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Topologically Active Soft Materials for Cellular Delivery

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Lyotropic lipid liquid crystalline materials having nanostructures that deviate from the conventional flat bilayer arrangement such as 2D hexagonally packed lipid tubes and bicontinuous cubic phases have been increasingly recognized as relevant materials for the applications of gene and drug delivery as well as linked to the functionality of cellular organelles comprising lipid-membranes. The simple argument that non-bilayer phases such as bicontinuous cubic having 3D nanostructured intertwined channels have a higher surface-to-volume ratio enabling more point contacts with cell surfaces while having a larger encapsulation power to host drug/gene molecules might be insufficient to completely describe the experimental findings. In this work we will show our recent efforts in stabilizing topologically rich lipid-based materials incorporating drugs or nucleic acids in diverse morphologies such as: i) bulk, ii) dispersed in an aqueous solution, iii) as well as thin film coatings. We utilize a combinatorial technical approach including Small/Wide Transmission/Grazing Incidence X-ray Scattering structural characterization and Cell Culture methods to demonstrate that a judicious choice of lipid materials allows an incredibly rich phase behavior in bulk, solution, and thin film platforms. Furthermore, the systems can be tailored to be adaptive in response to a number of environmental cues. The general finding is that lipid-based materials comprising negative Gaussian curvature membranes are able to most efficiently deliver their cargo across cell membranes by lowering the energy cost of forming a membrane pore. These new materials have great potential in the particular field of responsive and self-healing materials for surface-based and systemic drug/gene delivery devices as well as bioadhesive drug delivery.