Development of mesoporous silica nanoparticle-supported lipid bilayer as drug delivery systems

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Background: Mesoporous silica nanoparticles (MSNs) have emerged as promising nanocarriers due to their high surface area, tuneable pore sizes, and cargo-loading capabilities. However, their inorganic nature and rapid clearance pose challenges for the biological interface and regulated drug release. To address these limitations, surface modifications, especially incorporating a supported lipid bilayer (SLBs), form *protocells*- a hybrid nanosystem that combines the structural benefits of MSNs with the biocompatibility and membrane fusion capabilities of liposomes.

Methods: This study explores the synthesis and characterisation of these MSN-SLB assemblies for targeted drug delivery applications. A series of MSNs were synthesised using the sol-gel method and subsequently coated with lipid bilayers formed via thin-film hydration. The structural and physicochemical properties of the nanocarriers were analysed using infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), X-ray diffraction (XRD), nitrogen adsorption–desorption studies (BET), dynamic light scattering (DLS), and scanning electron microscopy (SEM).

Results: The synthesised MSNs exhibited an average diameter ranging across ~30-60 nm, a disordered mesoporous pore order, and a narrow pore size distribution centred around 2.4-2.7 nm. Successful coating with lipid bilayers resulted in the formation of uniform protocells with a narrow size distribution. DLS measurements indicated a hydrodynamic diameter of 90-200 nm for MSNs post-surfactant removal and 60-90nm for the final protocells, suggesting that successful coating with lipid bilayers resulted in the formation of uniform protocells with a narrow size distribution. Importantly, the lipid bilayer coating significantly enhanced the long-term colloidal stability of the MSNs, preventing aggregation and degradation over extended storage compared to uncoated MSNs.

Conclusions: The development of MSN-SLB nanosystems presents a promising platform for targeted drug delivery, integrating the structural versatility of silica nanoparticles with the biocompatibility and targeting efficiency of lipid membranes. Future work will focus on refining synthesis conditions and assessing the loading efficiency, cytotoxicity and in vitro therapeutic performance of these protocell nanosystems to assess their clinical potential.