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# Editorial: Insights into targeting nanomaterials for drug delivery

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Editorial on the Special Issue
Insights into targeting nanomaterials for drug delivery

Delivering a drug to a specific cell, or to a specific organelle within it, is a central ambition of modern biopharmaceutics. This Special Issue of the British Journal of Biomedical Science was conceived to bring together work on the design and fabrication of nanomaterials for targeted delivery, on cell- and organelle-specific delivery strategies, and on the stability, biological interactions, biocompatibility and toxicity that determine whether a carrier can be translated. The six articles span that range. Two reviews set out the targeting ambition and the materials available to pursue it. Four original research articles then address how carriers are loaded, stabilised, formulated and tested, without which no targeting strategy reaches a patient.

Al Tahan and Al Tahan review porous carriers, particularly mesoporous silica, for mitochondria-targeted therapy. Mitochondria are compelling targets given their roles in energy metabolism, reactive oxygen species generation and the regulation of cell death, but they are difficult to reach. A carrier must survive clearance by the reticuloendothelial system, escape the endosome and cross both the outer and inner mitochondrial membranes. The authors survey molecule-based approaches, such as mitochondria-penetrating peptides and triphenylphosphonium cations, and nanocarrier-based approaches, before focusing on mesoporous silica. Its high surface area and tuneable pores lend themselves to PEGylation to prolong circulation, conjugation of targeting ligands, stimulus-triggered release, and photodynamic strategies that generate reactive oxygen species at the target.

Maan et al. review carbon quantum dots, fluorescent carbon nanoparticles typically below 10 nm, with applications ranging from bioimaging and biosensing to antimicrobial therapy and delivery across the blood–brain barrier. Their central argument is that biological behaviour, including subcellular localisation, is governed less by the carbon core than by precursor choice and synthesis-driven surface chemistry. The review is candid about the obstacles to translation: batch-to-batch variability, incomplete long-term toxicity and biodistribution data, the absence of standardised characterisation, and a regulatory landscape in which such materials are still assessed case by case.

Three original articles then examine mesoporous silica from a formulation perspective. Al Tahan et al. loaded octreotide and bovine serum albumin into a commercial silica microparticle, SYLOID, with a view to oral protein delivery. An oral protein is degraded by gastric acid and intestinal enzymes before it reaches its site of action; silica only protects what is within the pores, rather than adsorbed on the surface. Loading was governed by diffusion and was therefore sensitive to protein size and solvent viscosity. Octreotide, a 1 kDa peptide, reached a recovery of 71% when loaded from methanol and was distributed evenly through

the particle. Albumin, at 68 kDa, reached at most 32% from water, aggregated in alcohols and remained largely at the particle surface.

Al Nuss et al. compared three amorphisation strategies for cefdinir, a poorly soluble and poorly permeable antibiotic: a polymeric solid dispersion, a mesoporous silica system and a co-amorphous formulation with amino acids. For such a drug the first barrier to any targeted effect is getting into solution, and staying that way on the shelf. Hansen solubility parameters and Flory–Huggins theory guided excipient selection. The solid dispersion and co-amorphous systems gave the fastest dissolution and best maintained supersaturation, yet under accelerated humid storage they recrystallised and lost roughly half their drug content within 6 months. The silica formulation dissolved more slowly but retained over 95% of its drug content and remained amorphous under all storage conditions, attributed to confinement of the drug within the pores and the absence of hygroscopic excipients.

Al Tahan et al. confronted a problem rarely reported: mesoporous silica microparticles do not compress well. This matters for targeting a carrier engineered to hold and protect a drug is of little use if tabletting collapses and releases drug prematurely. SYLOID alone fragmented under pressure rather than forming tablets, with mean particle size falling from 117 to 35 μm. As silica content increased, tablet porosity rose but tensile strength fell and disintegration slowed. Adjusting the ratio of microcrystalline cellulose to lactose helped, but only the addition of a binder and a superdisintegrant brought a silica tablet within pharmacopoeial limits for both friability and disintegration. Drug-loaded tablets are the next step.

The final article moves from oral to topical delivery. Marwah et al. formulated withaferin A, a poorly soluble anti-inflammatory steroidal lactone from Withania somnifera, into liposomes of around 120 nm incorporated into hydroxypropyl methylcellulose gels. Withaferin A is of interest as an alternative to topical corticosteroids, whose long-term use thins the skin, but its poor solubility and skin permeability limit topical use. The formulation addresses this in two stages: liposomes, made more deformable with Tween-20, are intended to carry the hydrophobic drug across the stratum corneum, and the gel then retains the liposomes at the site and slows release. The liposomal gel released the drug more slowly than either solution or plain gel. In endothelial cells and dermal fibroblasts stimulated with TNF-α, the formulation reduced IL-6 secretion and intracellular reactive oxygen species, and lowered MMP-9 secretion by fibroblasts. *Ex vivo* permeation and retention studies are the next step.

Together, these papers share a recurring lesson: performance is rarely a property of the carrier alone. It includes design decisions such as surface chemistry, loading solvent, stabilising excipient and diluent ratio, and it almost always involves trade-offs. The cefdinir formulations that dissolved fastest were the least stable. Silica content that raised tablet porosity also weakened the tablet. The most elaborate functionalisation strategies are the hardest to reproduce. Recognising these trade-offs early, and using predictive tools such as solubility parameter modelling to navigate them, may matter as much to translation as any new material.

The collection also shows where the field must go next. The original studies here are *in vitro*, and much of the wider literature is too. Loaded carriers need to be evaluated for release and permeation in biorelevant and *ex vivo* models, and targeting claims confirmed *in vivo*. Long-term safety data are needed, particularly for newer materials. I hope this Special Issue encourages work that treats manufacturability, stability and safety not as afterthoughts but as part of the design of targeted delivery systems from the outset.

## Author contributions

This editorial was written by the Special Issue guest editor, MM.

## Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. Generative AI (Claude Fable 5.1 (Anthropic)) was used to assist with drafting and editing, with all content reviewed and verified by the author.

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