



AIBN Master Projects | Prof. Michael Yu

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Project-1: Virus-mimicking nanoparticles for DNA vaccine

Lead Investigators: Prof. Michael Yu, Dr. Hao Song

DNA vaccine, as the third generation vaccine technology, representing the latest biotechnological breakthrough in vaccine development. Compared to conventional recombinant vaccines usually only stimulating the antibody responses, DNA vaccine show advantages in evoking both cellular and humoral immunity to fulfil the demand in combating chronic infection diseases. Moreover, the cost-effectiveness and fast speed of production make DNA vaccine an ideal strategy to deal with outbreaks such as SARS-COV-2 and H5N1 for the sake of both public and animal healthcare. To enable a successful DNA vaccine technology, it is critical to develop efficient gene vectors to transport and regulate the DNA molecules to be highly expressed in target cells. Mimicking the morphology of virus, this project aims to fabricate a series of virus-like silica nanoparticles with tailored physiochemical features for plasmid DNA delivery, and investigate their gene translation and vaccine performance. The completion of this project will provide fundamental understanding on the impact of designer particle nanostructure/chemistry on the DNA transfection and vaccine immunogenicity.

Contact the project advisor directly to discuss the project and arrange a meeting or AIBN Events (aibn.events@uq.edu.au) to arrange a visit to the AIBN lab.

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Project-2: Developing in situ nanovaccines for Cancer immunotherapy

Lead Investigators: Prof. Michael Yu, Dr. Yannan Yang

In situ vaccines are the next generation of anticancer vaccines that utilize in situ dying cancer cells as the antigens to generate antitumour immunity. This strategy can dramatically simplify the vaccine manufacture procedure and hold great potential for personalized cancer immunotherapy. However, limited immune response generated by in situ vaccines is the major bottleneck. This project aims to develop innovative nanotechnology based in situ vaccines for boosting cancer immunotherapeutic outcome. Nanomaterials with potent reactive oxygen species-generating and glutathione (a major intracellular antioxidant)-depleting activities will be fabricated to maximize the immunogenic cell death of cancer cells. The interactions of nanomaterials with the tumour microenvironment and immune system will be investigated in detail. On completion, this project will provide new knowledge on nanotechnology enabled anticancer strategies with high efficacy and minimized side effects and facilitate the clinical translation of nanoimmunotherapeutics.

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Project-3: Safe battery technologies using aqueous electrolytes and non-metal charge carriers.

Lead Investigators: Prof. Michael Yu, Dr. Xiaodan Huang

Battery technologies are important in electrical energy storage, particularly for portable power supply and renewable energy utilization. Aqueous batteries occupy a distinct space in battery research because of their good safety and low-cost. The charge carriers determine the battery electrochemistry and performance. Metal ions are widely used as charge carriers in conventional batteries, such as lithium-ion batteries, but they are heavy and large in size, leading to low capacity and slow charging. Alternatively, non-metal charge carriers (e.g. H^+ , NH_4^+) can offer many advantages, including high capacity, fast kinetics long lifespan and resource abundance. The development of non-metal ions based battery technologies are still in early stage. Suitable electrode materials and thorough understandings on the electrochemical reactions are both limited so far. This project aims to explore layered van der Waals crystals for high capacity non-metal charge carriers storage and design new battery devices.

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Project-4: Antibiotic-free antibacterial nano-formulations.

Lead Investigators: Prof. Michael Yu, Dr. Jie Tang

The overuse of antibiotics leads to ever-increasing antibiotic resistance, posing a severe threat to human health. Recent advances in nanotechnology provide new opportunities to address the challenges in bacterial infection by killing germs without using antibiotics. This project aims to develop antibiotic-free antibacterial formulations enabled by advanced nanomaterials. Functional nanomaterials with intrinsic or light-mediated bactericidal properties will be fabricated to enable efficient pathogen killing. Meanwhile, porous nanoparticles will also be engineered to serve as vehicles for the delivery of natural antibacterial compounds. On completion of this project, nano-formulations showing potent antibacterial property and good safety will be provided, and their antibacterial mechanisms as well as the structure-performance relationship will be revealed.

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Project-5: Nature-inspired spiky nanomaterials for enhanced intracellular delivery of biomolecules.

Lead Investigators: Prof. Michael Yu, Dr. Hao Song

The intriguing nature systems have inspired remarkable advances in the development of functional nanomaterials for biomedical applications. Nature creations such as pollen grains and virus with spiky topological features at various length scales enable multivalent interactions at bio-interfaces, and typically exhibit intriguing surface adhesive property. This project aims to apply this nature-derived principle to engineer nanoparticles for enhanced intracellular delivery of biomolecules. Nanomaterials with functional compositions and tailored spiky nanostructures will be fabricated. Their cellular internalisation process and biomolecules delivery efficiency will be evaluated. On completion of this

project, a versatile and functional drug delivery platform will be established and in-depth understanding on the spiky nanoparticle-cell interaction will be revealed.

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Project-6: Synthesis of Nanoporous Materials as High-performance Delivery Tools

Lead Investigators: Prof. Michael Yu, Dr. Yue Wang

This project aims to engineer a multifunctional platform of novel nanoporous materials. These nanomaterials can be used for mRNA delivery, or as adjuvants in vaccine formulations. Various synthesis strategies will be used to assemble nanomaterials with adjustable composition, asymmetry and surface chemistry. The nanoparticle-cell interaction and structure-property relationships will be investigated. From this project, students are expected to receive training in materials science (e.g., synthesis of nanoporous materials and their characterisation), cell biology (e.g., cell culture technique, pathway studies) and nanomedicine (e.g., drug delivery performance and in vivo test).

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Project-7: A nanotechnology for long-lasting oral drug delivery.

Lead Investigators: Prof. Michael Yu, Dr. Hao Song

Medication adherence is required for the effectiveness of all pharmacotherapies, especially for long-term treatment of chronic illness and infectious diseases such as malaria, diabetes, and HIV. However, intensive dosage regimens with a high pill burden are associated with a low adherence rate, leading to compromised or even failure of therapies. My project aims to realize the ideal of 'pillbox in a capsule', i.e. taking a single tablet that will provide sustained drug release over several days, by developing a

long-lasting oral drug delivery platform with prolonged gastrointestinal transit time. Inspired by bio-adhesive natural systems, where spiky surfaces enable strong adhesion, this project will engineer silica particles with a spiky morphology as well as their assembled medical devices as oral drug delivery vehicles, and their interactions at the bio-interfaces in gastrointestinal environment will be investigated in detail. On completion, this project will produce guidelines for the rational design of novel oral drug delivery systems, and new potential clinical strategies for simplified oral medications to improve medication adherence and patient outcomes.

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Project-8: A Nano-platform for Affordable and Ultra-sensitive Biomarker Detection

Lead Investigators: Prof. Michael Yu, Dr. Chang Lei

Biomolecules with clinical significance are most often various forms of proteins or peptides at very low concentrations in biological systems. Quantitative analysis of them is a big challenge due to the complexity of bio-samples, but essential for diagnosis and clinical applications. In this project, we focus on developing novel approaches for the sensitive detection of trace amount biomolecules using state-of-the-art nanotechnology.

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