Lipid nanoparticle technology for mRNA delivery: bridging vaccine applications with fundamental insights into nano-bio interactions

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Propositions accompanying the thesis

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1. The worldwide success of mRNA-lipid nanoparticle (LNP) vaccines against COVID-19 has spurred out efforts to translate these delivery platforms into therapies for treating non-infectious diseases, yet safety and efficacy remain uncertain. *Chapter 1, this thesis.*

2. Advancing LNP-mRNA therapeutics demands mechanistic insight into the factors that drive clinical success versus failure. *Chapter 2 & 4, this thesis*.

3. Understanding how LNP features shape pK_a tuning, mesophase behavior, and endosomal escape requires standardized materials and methods—standards the field still lacks.

4. Endosomal escape is no longer a bottleneck for LNP-mRNA delivery.

5. Heterologous prime-boost vaccination regimen combining antigen-encoding mRNA-LNPs with costimulatory agonist-based boosters drives potent antigen-specific cellular immune responses, providing a safer and more precise alternative to systemic CD40 agonist antibodies. *Chapter 3, this thesis.*

6. Expanding a molecule to reveal previously unresolvable details exposes an underlying nanoscale world that lies beyond the reach of conventional imaging. *Chapter 5, this thesis.*

7. The advancement of nanomedicine depends fundamentally on interdisciplinary collaboration.

8. Chemistry trains us in the suffering of serenity; molecules react according to activation energy, not to our plans.

9. In science, "never is enough" reflects the reality that every answer generates new questions, making research inherently endless.

10. Science advances faster when there are no borders.

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