纳米农药的未来展望：设计、功效、机制与环境管理视角

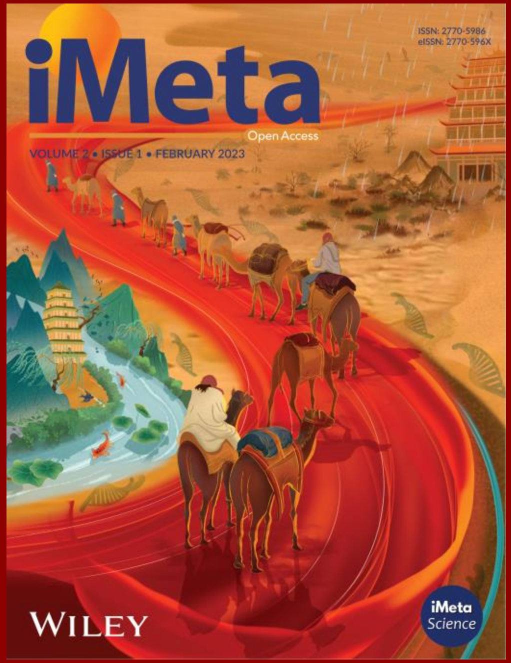
邓希乐[1,2]，朱菲莹[1]，乔恒[3]，上官文杰[4]，余勤[5]，
Sandeep Sharma[6,7]，Vijayakumar Shanmugam[6]，邓亚男[1]，吴雨丹[1]，
赵鹏跃[4]，Ullah Farman[8]，曹立冬[4]，闫硕[3]，董智超[9]，柏连阳[1,2]

[1]湖南省农业科学院 [2]湖南大学隆平农学院

[3]中国农业大学植物保护学院 [4]中国农业科学院植物保护研究所

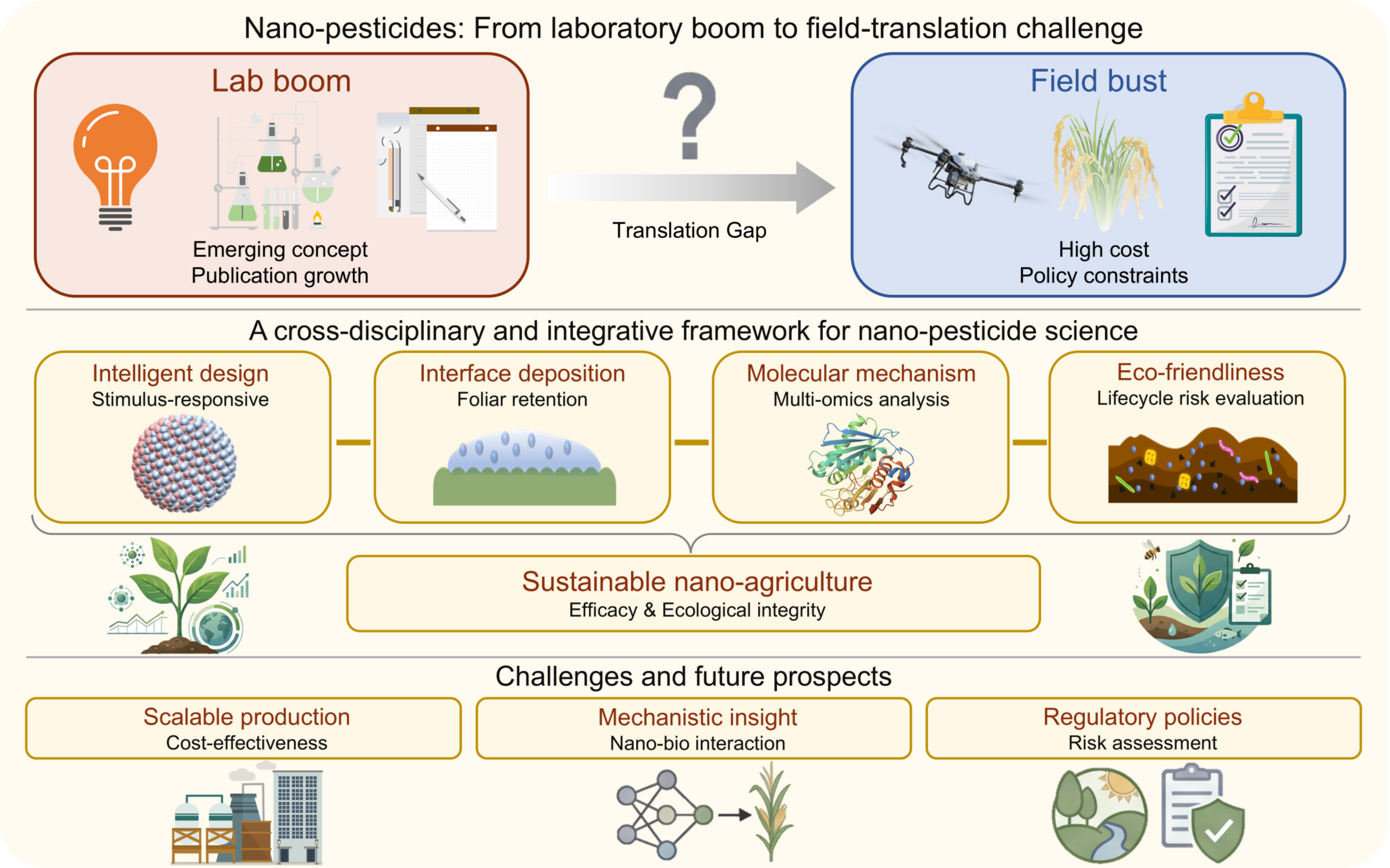
[5]西澳大学 [6]印度纳米科学与技术研究所

[7]加州大学河滨分校 [8]湘湖实验室 [9]中国科学院理化技术研究所



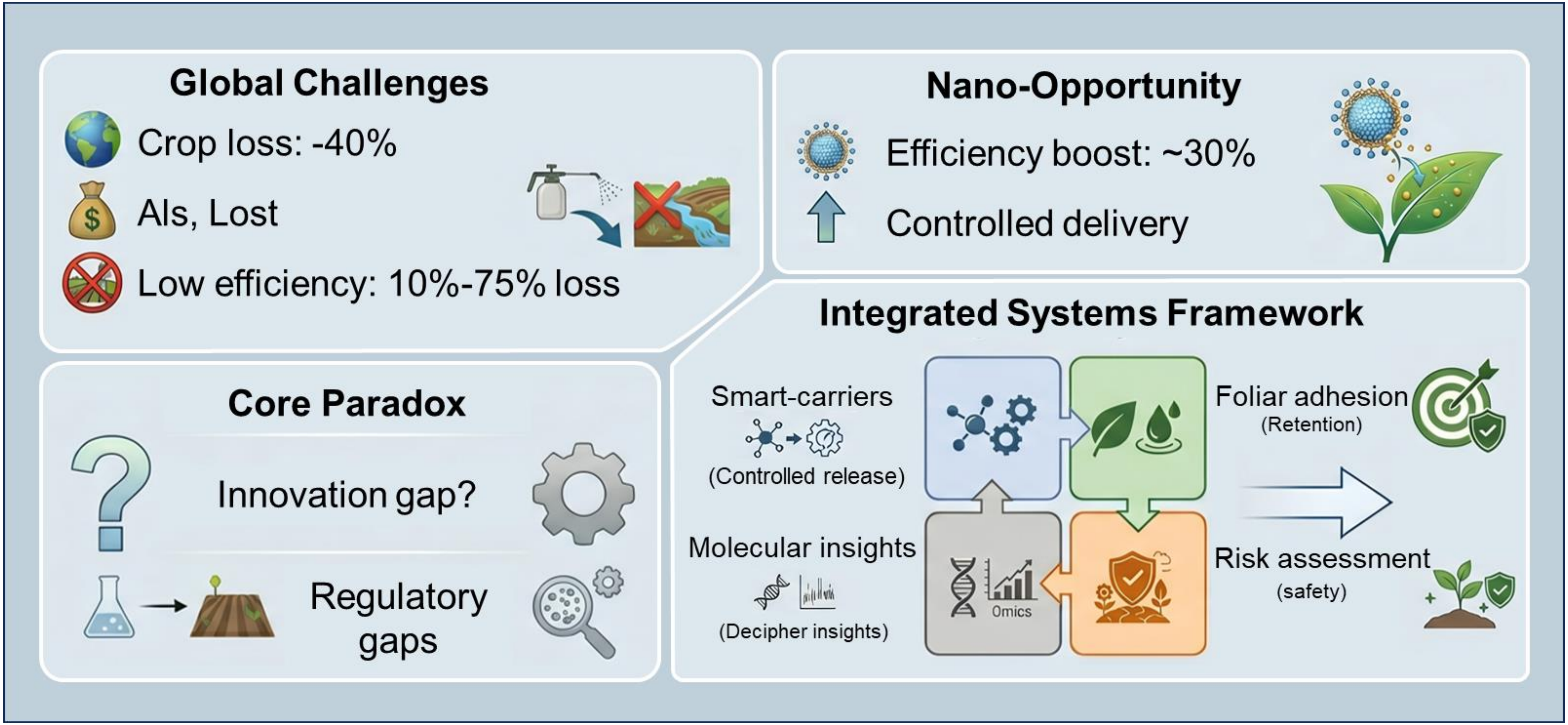
Xile Deng, Feiying Zhu, Heng Qiao, Wenjie Shangguan, Qin Yu, Sandeep Sharma, Vijayakumar Shanmugam, et al. 2026. Navigating the future of nano-pesticides: A perspective on design, efficacy, mechanisms, and environmental stewardship. ***iMeta*** 5: e70129. https://doi.org/10.1002/imt2.70129

亮点



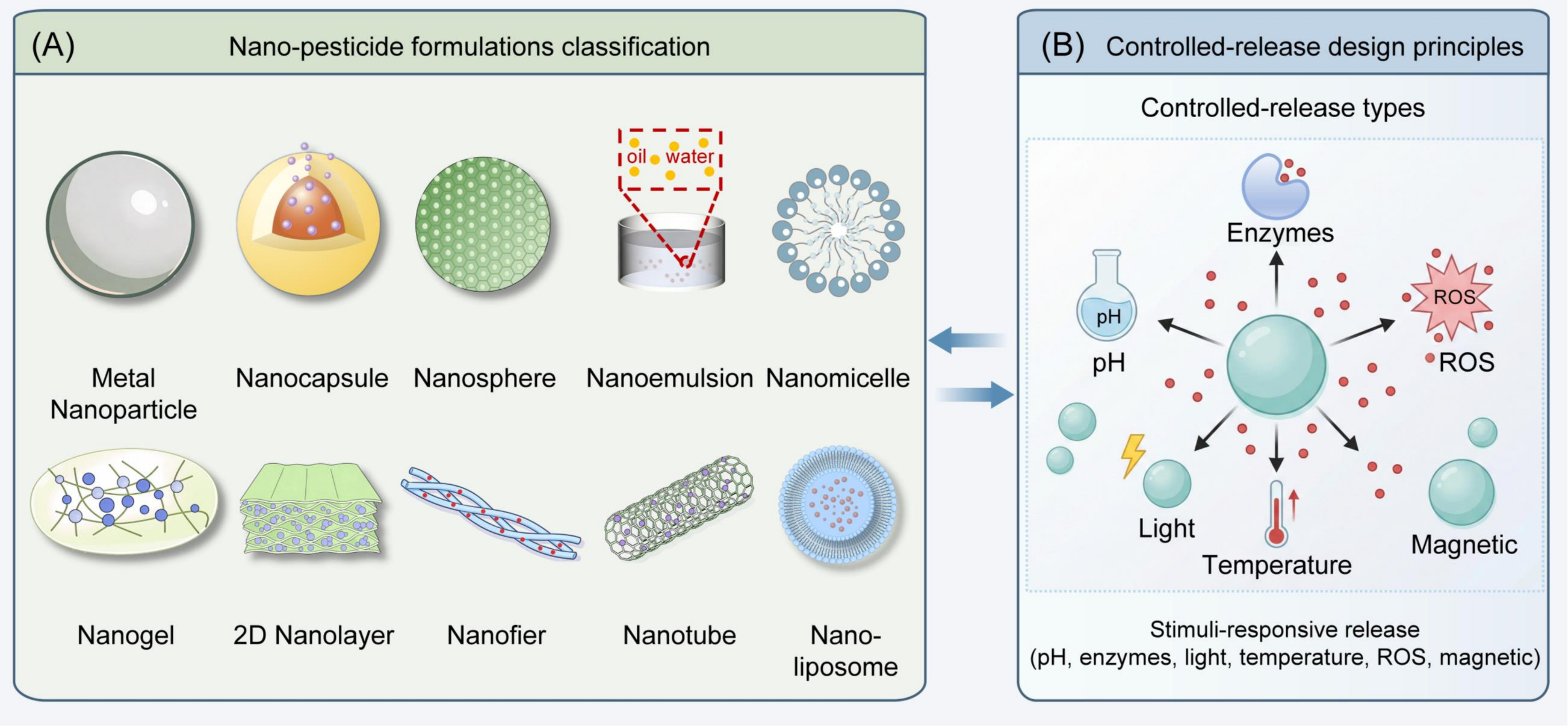
Nano-pesticides: From laboratory boom to field-translation challenge
Lab boom
Emerging concept
Publication growth
?
Translation Gap
Field bust
High cost
Policy constraints
A cross-disciplinary and integrative framework for nano-pesticide science
Intelligent design
Stimulus-responsive
Interface deposition
Foliar retention
Molecular mechanism
Multi-omics analysis
Eco-friendliness
Lifecycle risk evaluation
Sustainable nano-agriculture
Efficacy & Ecological integrity
Challenges and future prospects
Scalable production
Cost-effectiveness
Mechanistic insight
Nano-bio interaction
Regulatory policies
Risk assessment

前言

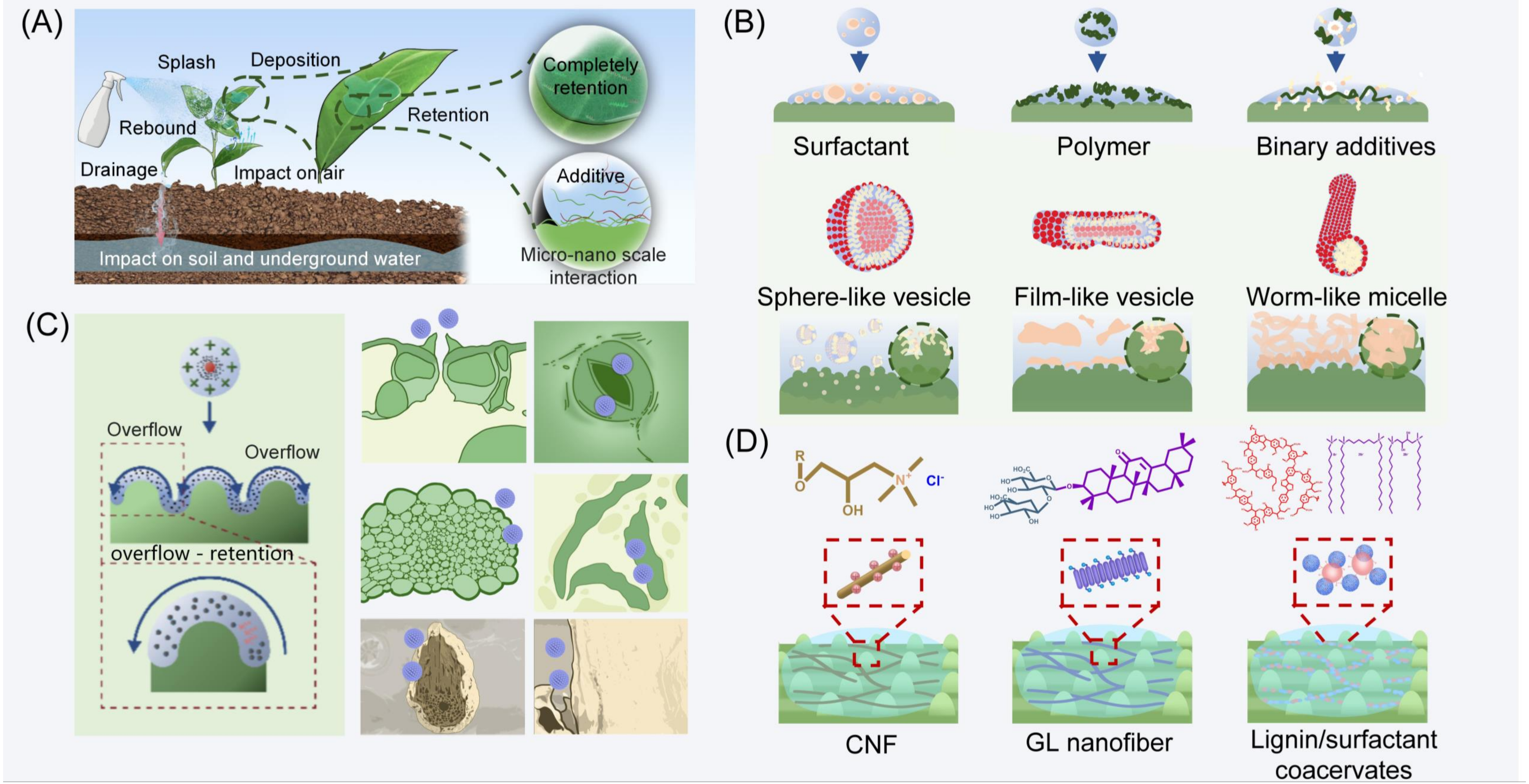


Global Challenges
Crop loss: -40%
AIs, Lost
Low efficiency: 10%-75% loss
Nano-Opportunity
Efficiency boost: ~30%
Controlled delivery
Core Paradox
Innovation gap?
Regulatory gaps
Integrated Systems Framework
Smart-carriers
(Controlled release)
Molecular insights
(Decipher insights)
Omics
Foliar adhesion
(Retention)
Risk assessment
(safety)

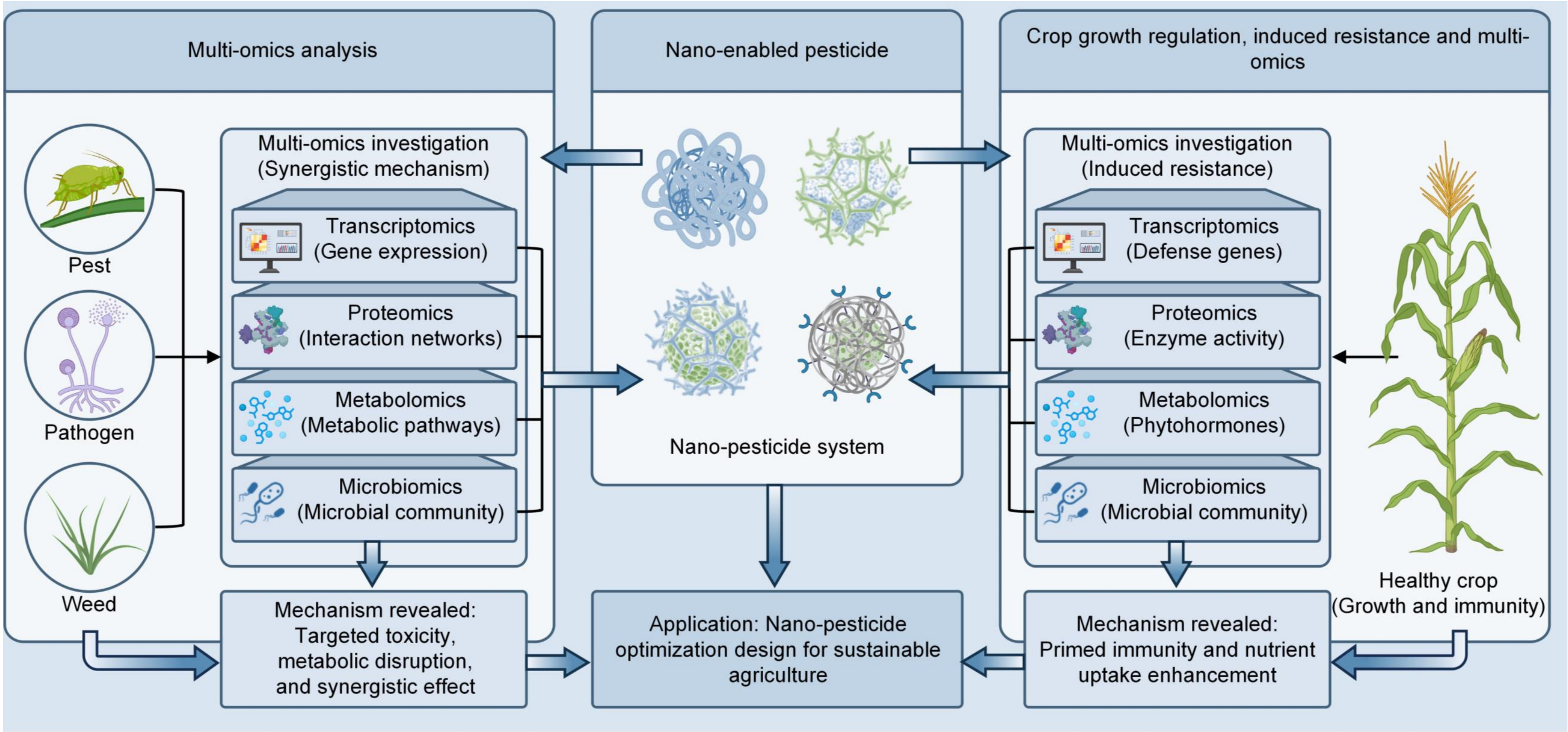
第一部分 纳米农药剂型的分类与可控释放



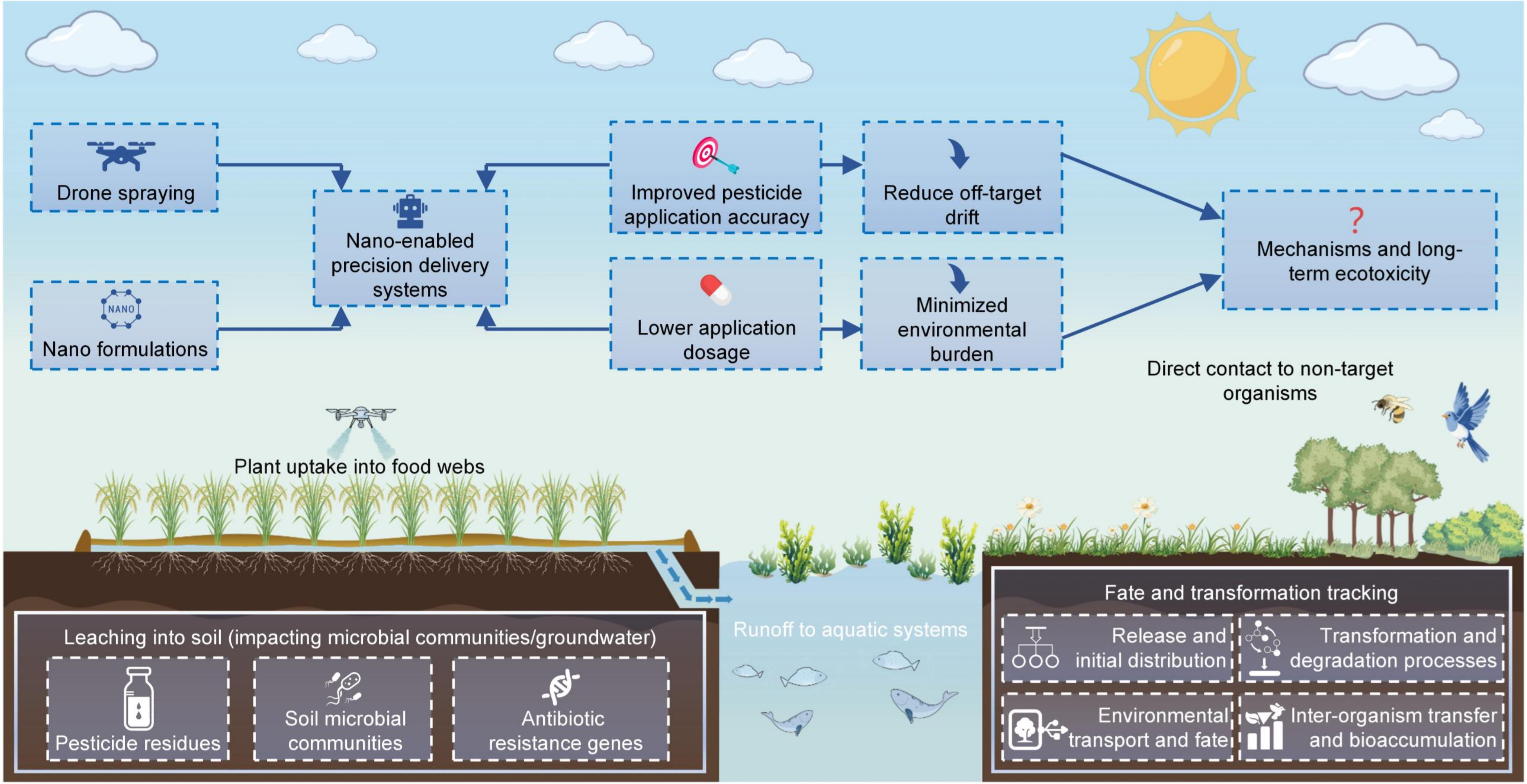
第二部分 纳米农药的界面行为与沉积机制



第三部分 纳米赋能农药的作用机制：基于多组学的视角



第四部分 纳米农药的生态风险评估



前景与挑战

- 纳米农药的广泛应用目前仍受限于高生产成本、规模化制造瓶颈以及对载体材料安全性的担忧;
- 克服这些障碍需要综合性解决方案，包括开发低成本环保载体、建立可扩展的生产平台，并利用机器学习进行理性设计;
- 未来的研究需优先关注三大前沿：优化叶面液滴行为、阐明进入生物体后的内在反应机制，以及推进载体材料的毒理学与环境归宿研究;
- 必须建立一个强大且具有适应性的监管框架，并呼吁成立国际联盟，以协同制定标准、共享数据、引领其负责任的发展。

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