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Gene Therapy and Diagnosis for Next Generation Health Care-Opportunities for Micro-/Nano-Scale Engineering

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Abstract

Along with AI and quantum computing, genetic engineering is considered one of the three major technologies that will shape the future of our lives. Gene therapy is emerging as one of the most promising solutions for addressing many unmet medical needs, and genetic information has become a critical tool in disease diagnosis. In the field of gene therapy, I will introduce a new technology platform—nanochannel electroporation (NEP)—and explore its potential in both regenerative medicine and cancer therapy. Applications include anti-aging, rare diseases and high-mortality cancers such as brain tumors and pancreatic cancer. Regarding gene-based disease diagnosis, I will introduce liquid biopsy as a minimally invasive detection method with the potential to reduce mortality rates for major diseases like cancer and viral infections. Examples include early cancer screening, prognosis monitoring, surveillance of cancer treatments, and rapid COVID-19 detection. To realize the full potential of gene therapy and diagnosis for next-generation healthcare, advanced micro- and nano-scale engineering is essential, offering numerous opportunities in the field of engineering.

Relevant Recent Publications

Y. Tian, et.al., L.J. Lee, et.al. and A.S. Lee, "Skeletal Muscle–Targeted Non-Viral Delivery of Full-length Dystrophin mRNA for Duchenne Muscular Dystrophy", **Nature Biomedical Engineering**, under revision.

H. Li, et.al. and L.J Lee, "Extracellular Vesicular Delta-Like Ligand 3 and Subtype Transcription Factors for Small Cell Lung Cancer Diagnosis", **Advanced Science**, accepted (2025).

Y. You, et.al., L.J. Lee, et.al., "Extracellular Vesicle-Mediated VEGF-A mRNA Delivery Rescues Ischemic Injury with Low Immunogenicity", **European Heart Journal**, 10.1093/eurheartj/ehae883 (2025).

K.T. Nguyen, et.al., L.J. Lee and E. Reátegui, "Integrated Antigenic and Nucleic Acid Detection in Single Virions and Extracellular Vesicles with Viral Content', **Advanced Healthcare Materials**, 2400622 (2024)**.**

Y. You, et.al., L.J. Lee, et.al, "Intradermally Delivered mRNA-encapsulating Extracellular Vesicles for Collagen-replacement Therapy', **Nature Biomedical Engineering**, 7, 887-900 (2023).

C-L Chiang, et.al and L.J. Lee, "Dual Targeted Extracellular Vesicles Regulate Oncogenic Genes in Advanced Pancreatic Cancer", **Nature Communications**, 14, 6692 (2023).

S. Dong, et.al., L.J. Lee, et.al, "Adaptive Design of mRNA-loaded Extracellular Vesicles for Targeted Immunotherapy of Cancer", **Nature Communications**, 14, 6610 (2023).

H. Li, et.al. and L.J. Lee, "Extracellular Vesicular Analysis of Glypican 1 mRNA and Protein for

Pancreatic Cancer Diagnosis and Prognosis", **Advanced Science**, 2306373 (2023).
Z. Yang, et.al. and L.J. Lee, "Large-Scale Generation of Functional mRNA Containing Exosomes via Cellular Nanoporation", **Nature Biomedical Engineerin**g, 4, 69-83 (2020).
D. Gallego-Perez, et.al., L.J. Lee and C.K. Sen, "Topical Tissue Nano-transfection Mediates Non-viral Stroma Reprogramming and Rescue", **Nature Nanotechnology**, :10.1038/nnano.2017.134 (2017).
J. Hu, et.al. and L.J. Lee, "A Signal-amplifiable Biochip Quantifies Extracellular RNAs for Early Cancer Detection", **Nature Communication**, 8(1), 1683 (2017).
L.J. Lee, et.al., "Extracellular mRNA Detected by Tethered Lipoplex Nanoparticle Biochip for Biomarker Development in Lung Cancer", **American Journal of Respiratory and Critical Care Medicine**, 193(12), 1431-1433 (2016).

About the Speaker

Dr. Lee is the Emeritus Helen C. Kurtz Professor of Chemical and Biomolecular Engineering at The Ohio State University (OSU) and a Yushan Scholar at National Yang Ming Chiao Tung University (NYCU) . He founded and served as the Director of the NSF Nanoscale Science and Engineering Center for Affordable Nanoengineering of Polymer Biomedical Devices (CANPBD) at OSU. Dr. Lee holds a BS degree in chemical engineering from National Taiwan University and a Ph.D. in chemical engineering from the University of Minnesota. His research interests include polymer processing and nanobiotechnology. He has authored over 460 refereed journal publications with more than 25,000 citations and an h-index of 82, in addition to more than 40 patents and patent applications, and 14 book chapters. Dr. Lee was elected a Fellow of the Society of Plastics Engineers and the American Institute for Medical and Biological Engineering. He received the 2008 Malcolm E. Pruitt Award from the Council of Chemical Research, the 2010 International Award from the Society of Plastics Engineers, and the 2016 Lifetime Achievement Award from the Society of Advanced Molding Technology. In 2024, he was honored as a Distinguished Alumnus in the Department of Chemical Engineering at National Taiwan University.