Nanoparticle Applications in Lung Cancer Therapy

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Introduction

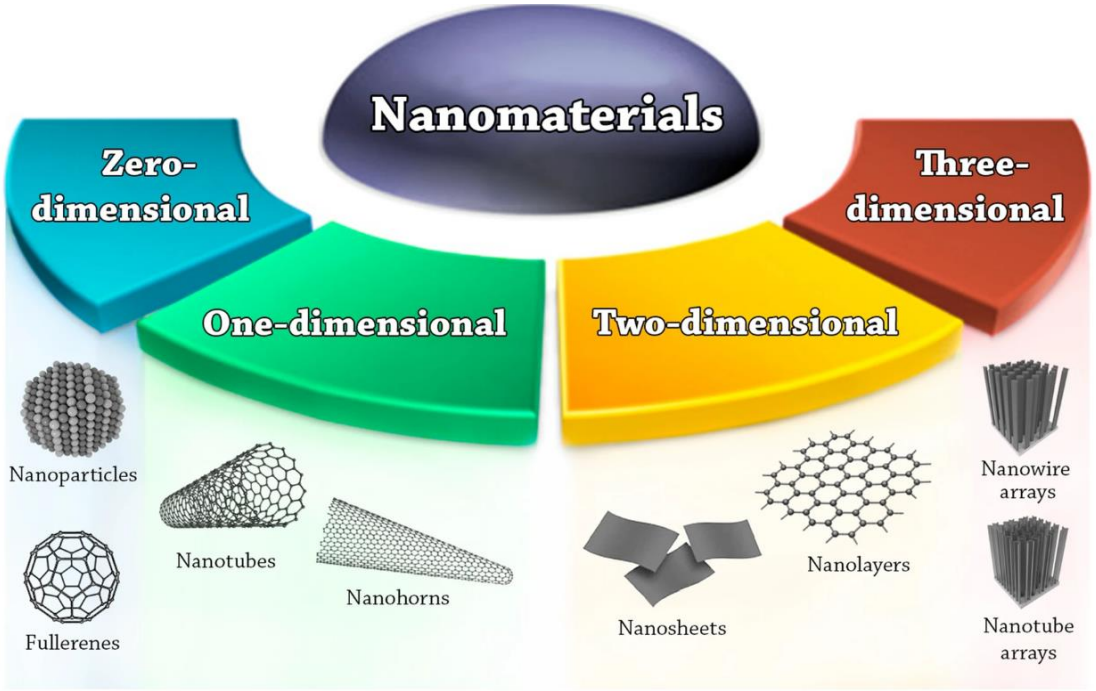
- Nanotechnology: frontier in modern medicine
- Focus: cancer treatment, esp. lung cancer
- Modalities: liposomes, polymeric NPs, gold NPs, extracellular vesicles (EVs)
- Potential: personalized & targeted therapy
- Challenges: toxicity, immune reactions, regulatory hurdles

Overview of Nanotechnology in Medicine

- Nanoparticles = 1–100 nm, unique properties
- Used in drug delivery, imaging, regenerative medicine
- Three classes: Organic, Carbon-based, Inorganic
- Enable new approaches not possible with traditional drugs

Types of Nanoparticles

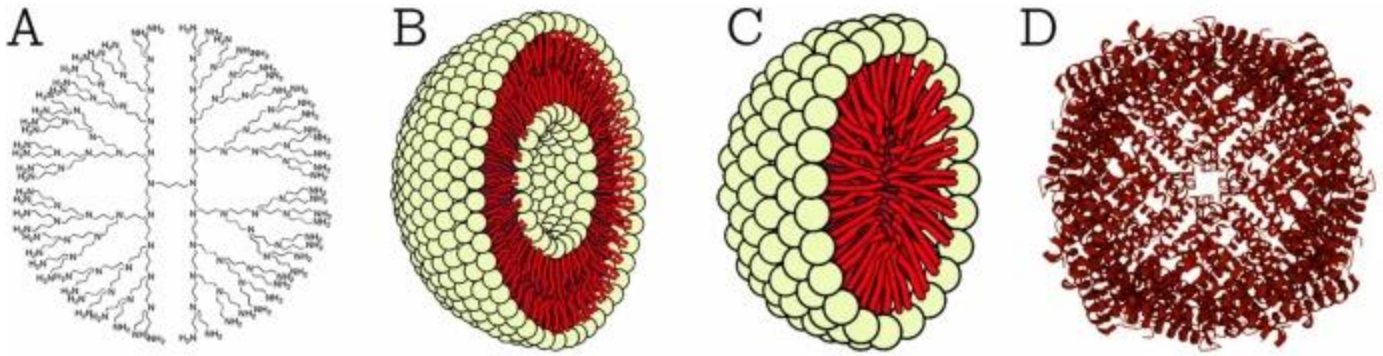
- Organic: liposomes, dendrimers, lipid carriers
- Inorganic: gold nanoparticles
- Polymeric: versatile, controlled-release systems
- Each type has unique advantages and limitations



From: Nanoparticle classification, physicochemical properties, characterization, and applications: a comprehensive review for biologists

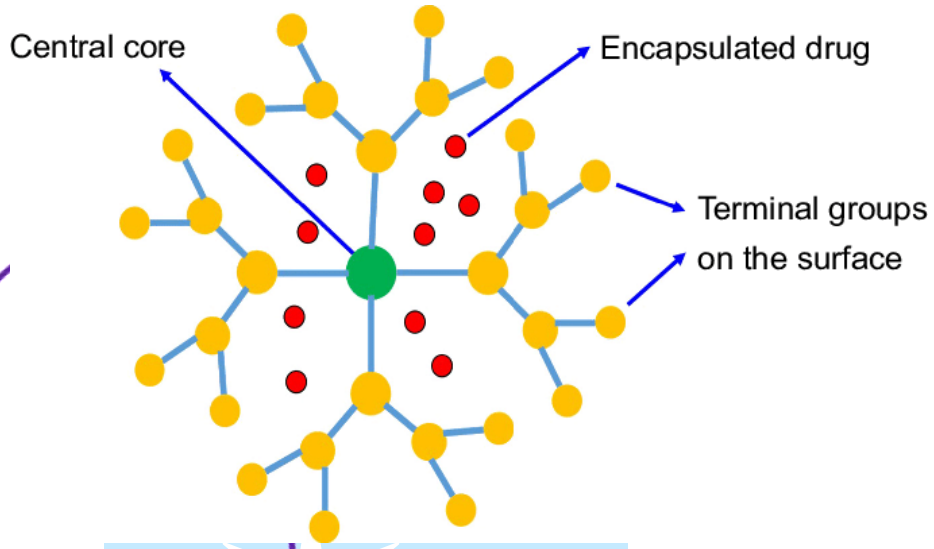
Liposomes & Lipid Nanoparticles

- Lipid bilayer spheres encapsulating drugs
- Enhance drug stability & targeting
- Categories: liposomes, niosomes, transfersomes, SLN, NLC
- FDA-approved example: Doxil (liposomal doxorubicin)
- Limitation: storage stability, dermal delivery barriers



Types of organic NPs. **A** Dendrimers; **B** liposomes; **C** micelles; and **D** ferritin

From: Nanoparticle classification, physicochemical properties, characterization, and applications: a comprehensive review for biologists



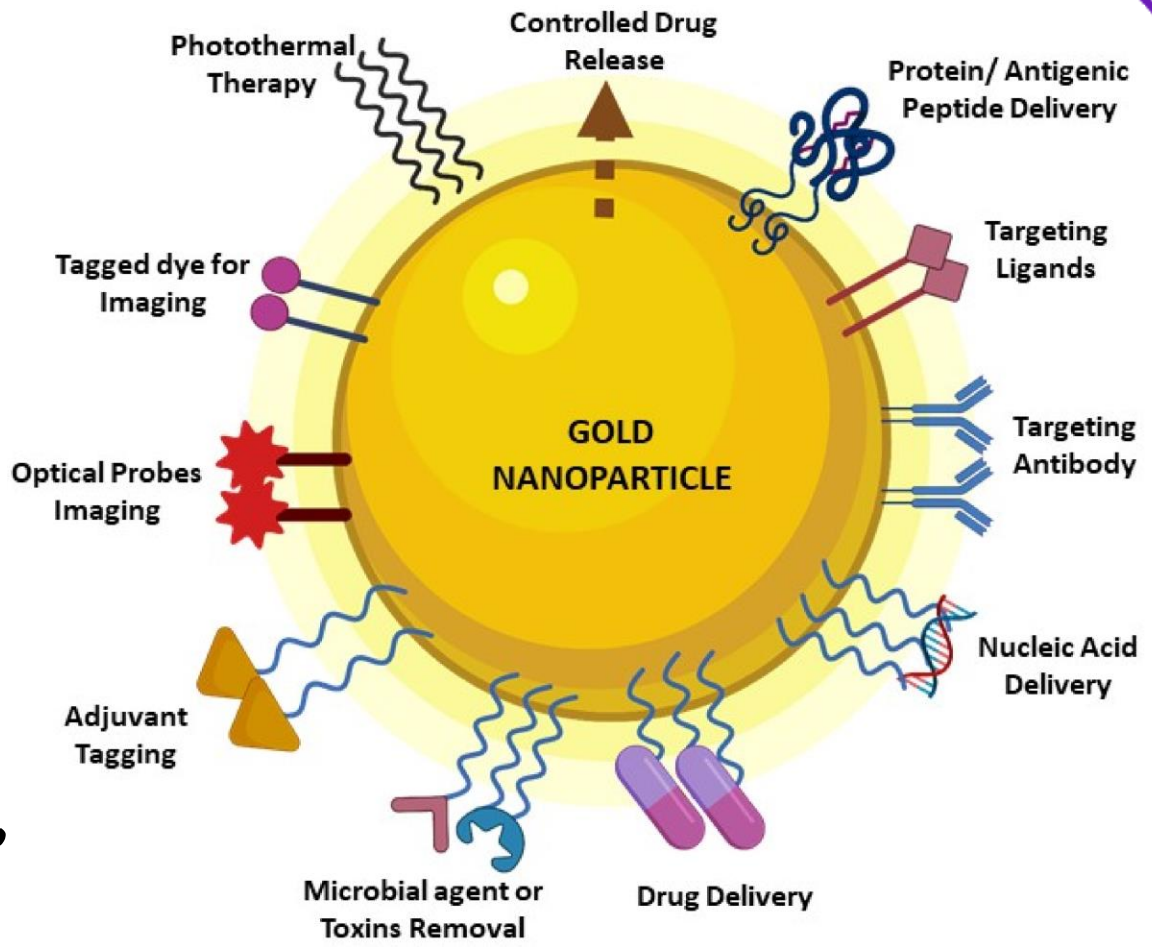
Zeb, Alam & Khan, Fakhar & Aman, Waqar & Qureshi, Omer. (2017). Effective use of nano-carriers as drug delivery systems for the treatment of selected tumors. International Journal of Nanomedicine. 12. 7291–7309.

Dendrimers

- Tree-like, branched structures
- Functional groups allow high drug loading
- Delivery modes:
- Physical encapsulation
- Electrostatic interactions
- Covalent conjugation
- Example: PAMAM dendrimers for anticancer drugs

Gold Nanoparticles

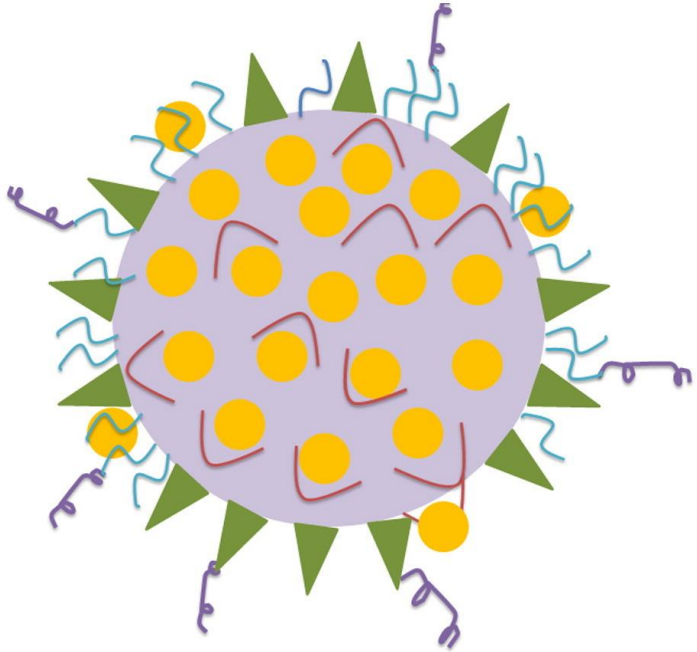
- Small, stable, non-toxic, biocompatible
- Tunable shapes (spheres, rods, shells)
- Surface modifications: citrate, thiols, PEG
- Unique property: surface plasmon resonance (SPR)
- Applications: photothermal therapy, imaging, drug delivery

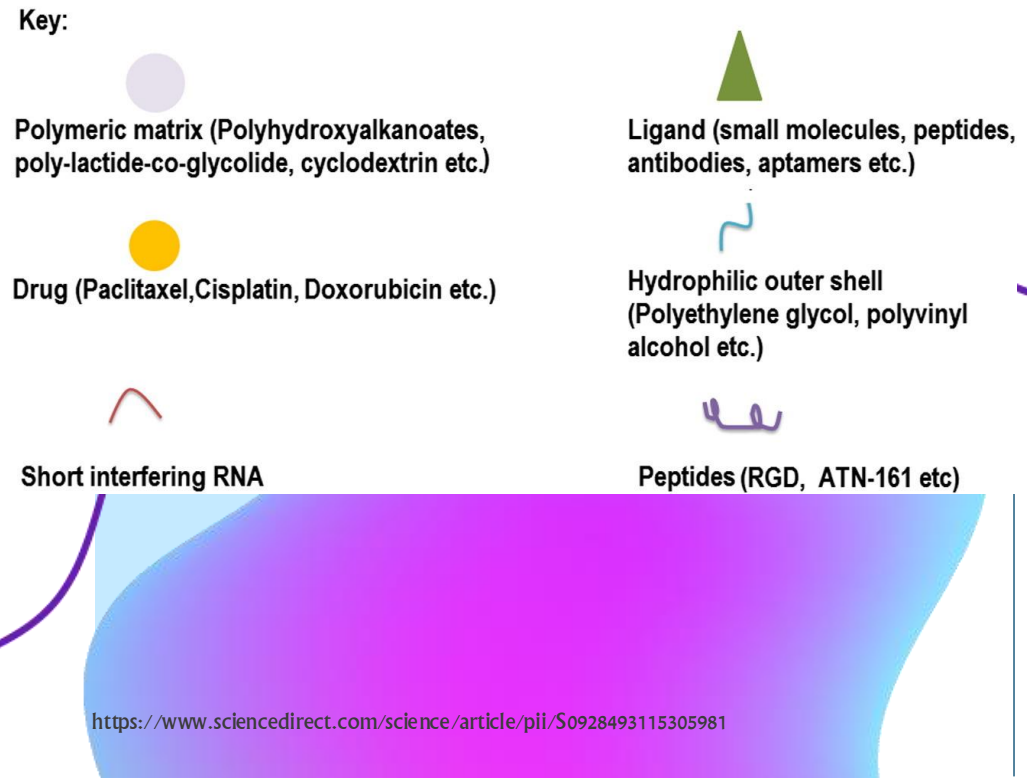


From: **Efficacy and Immune Response Elicited by Gold Nanoparticle- Based Nanovaccines against Infectious Diseases**
https://www.mdpi.com/2076-393X/10/4/505

Polymeric Nanoparticles

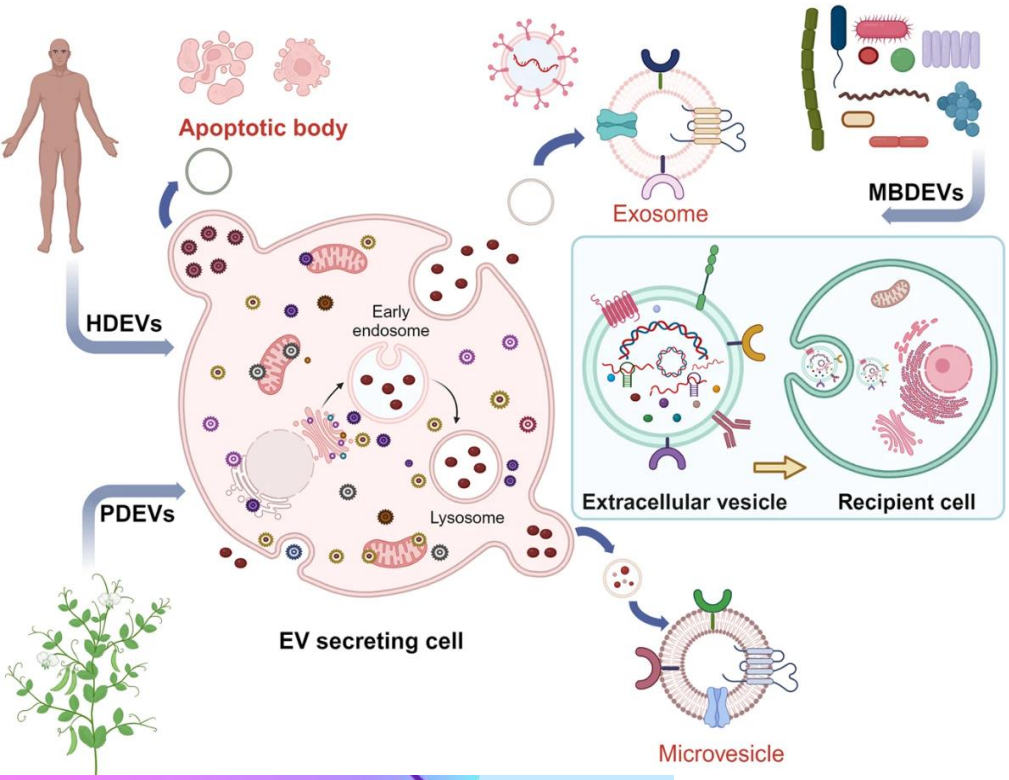
- Controlled drug release systems
- Adaptable for inhalation delivery
- Improve solubility, stability, tumor-specific release
- Barriers: toxicity, scalability, regulatory approval





Advantages of Nanomedicine

- Improved drug bioavailability
- Reduced systemic toxicity
- Targeted delivery via EPR effect & modifications
- Potential for personalized medicine
- Example: EVs as autologous nanomedicine



https://www.nature.com/articles/s41392-024-01735-1

Extracellular Vesicles (EVs) in Cancer

- Nano-sized, lipid-bound particles released by cells
- Subtypes: exosomes, microvesicles, apoptotic bodies
- Functions: intercellular communication, immune modulation
- Clinical uses: liquid biopsies, drug delivery, cancer vaccines
- Challenges: large-scale production & standardization

FDA-Approved Nanomedicines

- **Abraxane**: albumin-bound paclitaxel, better tolerated than solvent-based forms
- **Genexol-PM**: polymeric micelle paclitaxel, improved solubility & dosing
- **Doxil**: liposomal doxorubicin, reduced cardiotoxicity
- Limited approvals compared to systems in research

Challenges in Nanomedicine Development

- Low drug encapsulation efficiency
- Stability issues during circulation/storage
- Immune rejection & clearance
- Long-term safety: organ accumulation, chronic toxicity
- Tumor variability → need for personalized approaches

Clinical Trials in Nanotechnology

- Nanoparticle immunotherapies with ICIs
- Nanobiotix (NBTXR3): radioenhancer in trials
- EV-based liquid biopsies for real-time monitoring
- CRISPR-loaded lipid nanoparticles under evaluation
- Ongoing trials show promise but need long-term safety data

Future Applications

- **Smart nanocarriers:** stimuli-responsive (pH, enzymes, temperature)
- **AI/ML models:** optimize design, size, release profiles
- **CRISPR delivery:** gene editing for cancer mutations
- **Theranostics:** dual therapy + diagnostic systems

Ethical & Regulatory Considerations

- Long-term patient safety: organ accumulation, biodegradation
- Equitable access: high costs & limited availability
- Genetic manipulation risks (CRISPR misuse)
- Regulatory gaps: EVs & multifunctional systems need harmonization

Conclusion

- Nanotechnology shifts lung cancer therapy from broad toxicity → precision targeting
- Modalities: liposomes, dendrimers, gold NPs, polymeric NPs, EVs
- Goal: maximize tumor drug delivery, minimize side effects
- Future: AI-guided design, CRISPR therapies, theranostic tools
- Needs: safety frameworks, global EV standards, equitable access

Thank You

References

(Condensed, 10 key sources)

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