

Effects of Lipid Membrane Composition on Gold Nanoparticle Aggregation

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Abstract

Gold nanoparticle or GNP aggregation in liposome membranes presents a design challenge for optimizing hybrid vesicles drug release. Aggregation shifts the resonance frequency of GNP's, limiting control of drug release during irradiation. To study the aggregation phenomenon we designed and analyzed aggregate structure in 2 simulations using the RDF. We observed increased long range ordering in GNP concentration and in lipids with long acyl chains.

Methods

Simulation Set 1: Varying nanoparticle concentration

- POPC membrane

Simulation Set 2: Varying acyl chain length

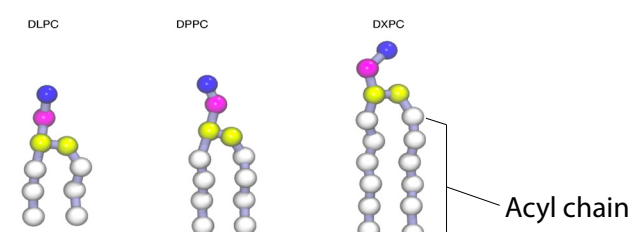
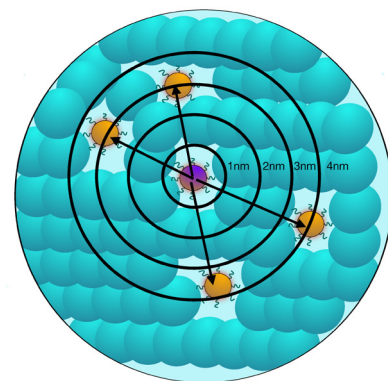


Figure 1. Lipid types for simulation set 2 [1]

- Gromacs 2016.2 Simulation software[2]
- Martini 2.2 force field[1]
- NPT Isothermal-Isobaric ensemble
- Temperature coupling set to 313K

Radial Distribution Function Analysis:

A pairwise distance search between individual nanoparticles



Introduction

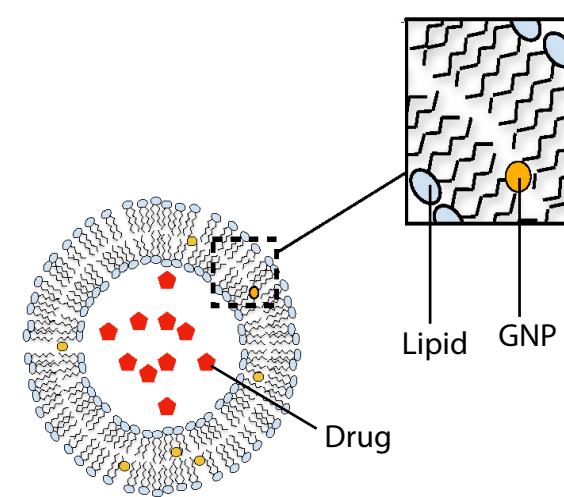


Figure 2. Representation of liposome with drug cargo

① Drugs can have toxic effects at high dosage, like cancer therapeutics

② Liposome-nanoparticle hybrid vesicles improve spatial and temporal control of drug release

③ GNP irradiation at specific resonance frequency causes liposome rupture and poration

④ Hydrophobic GNP's aggregate with varying degrees of order [3], changing the poration properties of the membrane

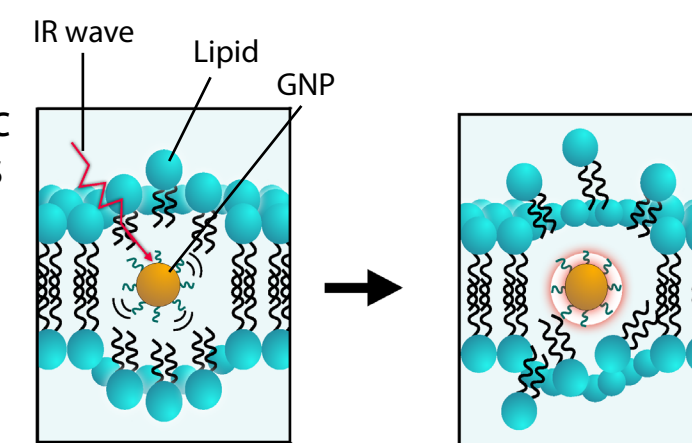


Figure 3. Schematic of membrane disruption by irradiated GNP's

⑤ Reliable vesicle design is necessary for hybrid vesicle use in therapeutics

Research Question

What factors affect aggregate formation and stability in liposomes?

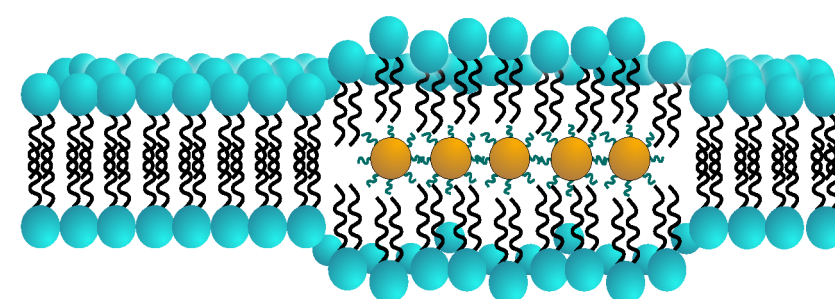


Figure 4. Representation of nanoparticle aggregate in lipid membrane

We hypothesize nanoparticle aggregation will increase with increased nanoparticle concentration and increased acyl chain length.

Results

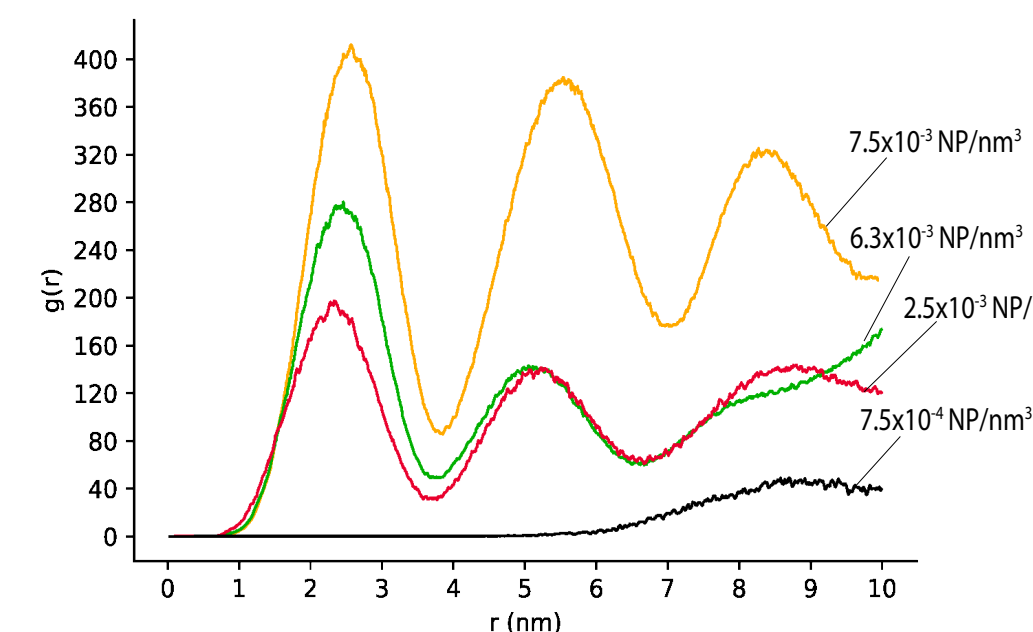


Figure 7: 2D Radial distribution function of GNP-GNP distance at 4 different concentration.

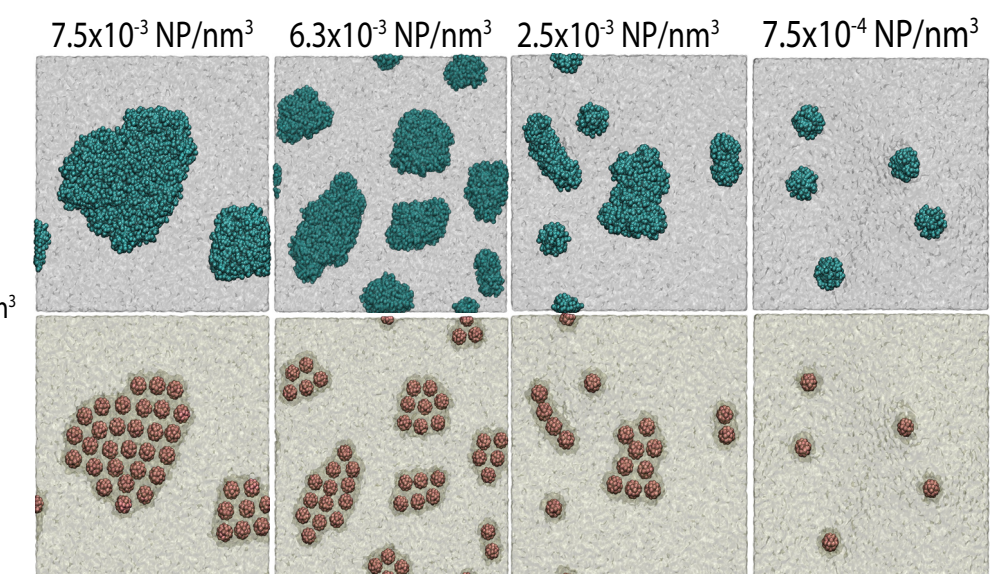


Figure 8: Visualizations of aggregate formation at 4 different concentrations of gold nanoparticles in POPC membrane. Nanoparticles per nanometer cubed (NP/nm³) Top: visualized with hydrophobic coating Bottom: visualized without ligand coating

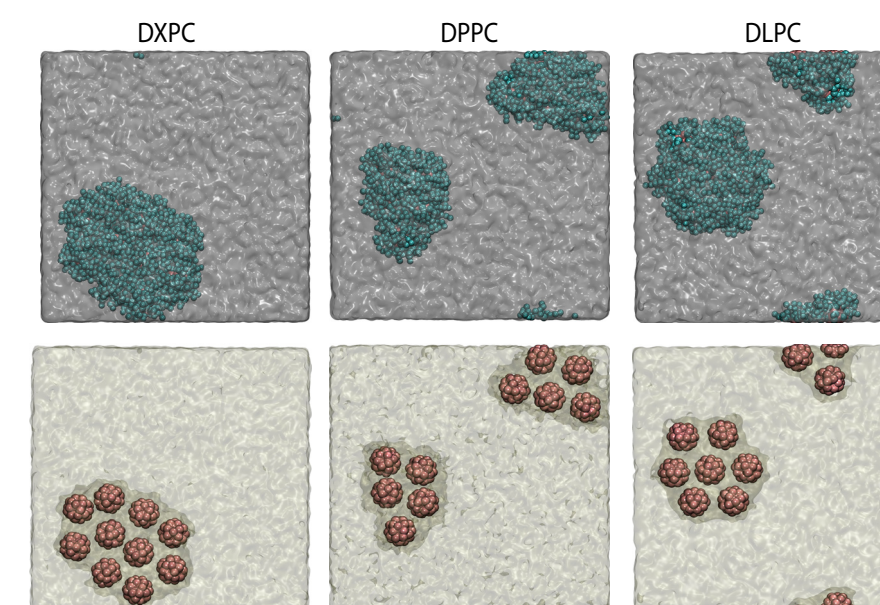


Figure 9: Visualization of aggregations in 3 different lipid lengths. Top: visualized with ligand coating Bottom: visualized without ligand coating

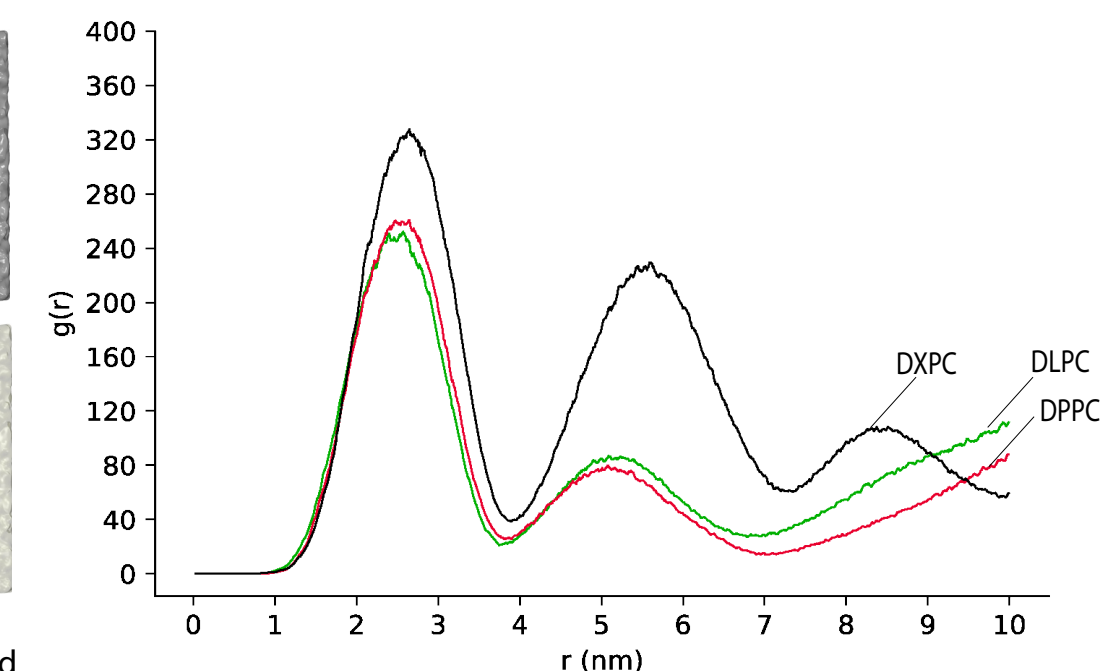


Figure 10: 2D Radial distribution function of GNP-GNP distance in 3 different lipid membranes.

Discussion

- Long range GNP ordering is observed in increased concentration (fig. 7, 8)
- Ordering due to GNP concentration is expected as similar aggregation dynamics are observed in other models[4]
- Differences in DLPC and DPPC ordering are not significant (fig. 9,10) while DXPC lipids show a significant increase in ordering
- Increased GNP ordering in DXPC lipids may be due to GNP's bending the membrane into a favorable curvature

Future Work

- GNP size: Varying GNP size may increase aggregation as nanoparticles induce the membrane's spontaneous curvature
- Ligand chain length: Varying ligand chain length may increase steric hindrance in the ligand chains destabilizing aggregates

References

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