



Advances in Neutron Scattering from Biomembranes

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- Fluid Biomembranes
- Lipid Rafts in Model Membranes
- Location of Cholesterol
- Role of Vitamin E





Biomimetic Systems



- Active functions are mainly provided by proteins
- Functionality depends strongly on the structure of a lipid matrix
- Lipid matrix is a 2D liquid, where lipids and proteins diffuse almost freely

Biological membranes deliver

- Protection (separate cells)
- Signaling (transport of information)
- Selective permeability (transport of matter)



G.Pabst, N.Kučerka, M.-P.Nieh, M.Rheinstädter, J.Katsaras, Chemistry and Physics of Lipids 163 (2010)





Lipid Rafts by Neutron Scattering

Neutron scattering (via selective deuteration) is sensitive to nanometer-sized domains, previously not accessible by other methods.





The study of complex membrane models, including functional domains, I A C S

helps to further our understanding of how the cell may regulate critical biological process via the composition of lipid bilayers.



РНСИ-КС 2014 р.4

Heberle, Petruzielo, Pan, Drazba, Kučerka, Standaert, Feigenson, Katsaras, JACS 135 (2013) 6853-6859





Label Distribution







РНСИ-КС 2014 р.5









Biomimetic Systems with Cholesterol



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Findings

- cholesterol inserts as a spacer into the bilayer hydrophobic core, where it increases the order of lipid's hydrocarbon chains
- the hydrocarbon ordering effect of cholesterol dominates over its ability to reduce the hydrophobic mismatch between itself and the lipid chain
- cholesterol can be made to change its orientation in model membranes by changing the ratio of PUFA to saturated chain lipids.

РНСИ-КС 2014 р.6

10

N.Kučerka, D.Marguardt, T.A.Harroun, M.-P.Nieh, S.R.Wassall, J.Katsaras, JACS 131 (2009) 16358-16359





Domains driven by Lipids





In addition to demonstrating cholesterol's aversion to the disordered PUFA chains,

Neutron Diffraction suggested also that DMPC avoid interacting with PUFA chains and form domains,

i.e., domain formation is driven by the aversion that certain lipids have for each other.

РНСИ-КС 2014 р.7

Kučerka, Marquardt, Harroun, Nieh, Wassall, de Jong, Schafer, Marrink, Katsaras, Biochemistry 49 (2010)





Cholesterol in Biomembranes

Cholesterol - Bad ?



Cholesterol is essential to life.

- modifies the fluidity of biological membrane
- is important in the development of memory
- is necessary for the uptake of hormones in the brain
- is the main organic molecule in the brain, making up half the dry weight of the brain
- functions as a powerful antioxidant, protecting us against cancer and aging
- is a precursor to Vitamin D
- is a precursor to hormones that regulate blood sugar levels
- is a precursor to the sex hormones
- is a precursor to the bile salts

РНСИ-КС 2014 р.8





Water Distribution



РНСИ-КС 2014 р.9



methyl) is well above the hydrophobichydrophilic interface among the lipid choline headgroups.

methyl) is closer to the lipid's glycerol backbone.

РНСИ-КС 2014 р.10

D.Marguardt, J.A.Williams, N.Kučerka, J.Atkinson, S.R.Wassall, J.Katsaras, T.A.Harroun, JACS 135 (2013)





A New Perspective on the Antioxidant Vitamin E



Findings

- termination of lipid radicals can occur when slightly deeper located αToc intercepts acyl chains that snorkle to the membrane's surface
- αToc is best able to protect against waterborne reactive oxygen species (ROS) when situated higher in the membrane
- DMPC is a remarkable exception to αToc's membrane presence

Conclusions • αToc's location is directly related to its antioxidation role in membrane
• importance of lipid diversity in controlling the function of biomembranes

РНСИ-КС 2014 р.11

Marquardt, Williams, Kinnun, Kučerka, Atkinson, Wassall, Katsaras, Harroun, JACS 136 (2014)







- Neutron Scattering is able to support bio-relevant studies with data not accessible to other techniques
- Specific deuteration and contrast variation enhances neutron scattering by revealing subtle details
- Structural studies help to further our understanding of critical biological process taking place in biomembranes





Collaborators

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Thank You!