

The Effect of Temperature on the Structure of Charged Membranes

*Pablo Szekely^{1,2}, Tom Dvir^{1,2}, Roi Asor¹, Roi Resh^{1,2}, Ariel Steiner¹, Or Szekely¹, Avi
Ginsburg^{1,3}, Jonathan Mosenkis¹, Vicky Guralnick¹, Yoav Dan¹, Tamar Wolf¹, Carmen
Tamburu¹ and Uri Raviv¹ **

1. The Institute of Chemistry, 2. The Racah Institute of Physics, 3. School of Pharmacy, The Hebrew University of Jerusalem, Edmond J. Safra Campus, Givat Ram, 91904 Jerusalem, Israel.

Supplementary Information

* Correspondence should be addressed to U.R. (raviv@chem.ch.huji.ac.il).

Section 1: Equilibrium time

To find the time required for reaching equilibrium after a temperature change of few degrees Celsius, we measured the lamellar repeat distance, D , as function of the time elapsed after a temperature change, at two concentrations of DLPS (Figure S1). After 30 minutes D was stable within the measurement error. Radiation damage was not observed. To make sure that the system reached equilibrium before each set of measurements, we waited 90 minutes before measuring the repeat distance at each temperature.

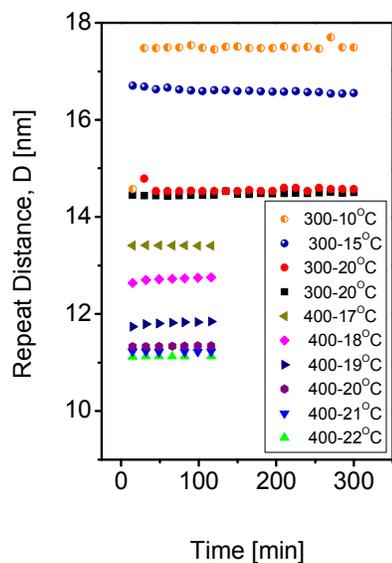


Figure S1. The repeat distance, D , as a function of the time elapsed after the temperature was changed by a few degrees Celsius for DLPS at different temperatures, as indicated in the figure. The 300 or 400 in the legend represent the lipid concentration in mg/(ml of water). The second number is the temperature.

Section 2: DLPS phase transition

We studied in greater detail the gel to liquid phase transition of DLPS around 18 ± 1 °C (Figure S2).

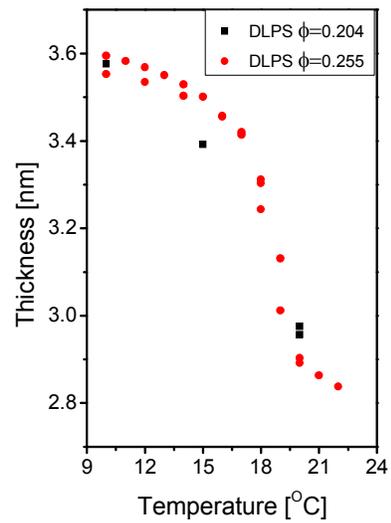
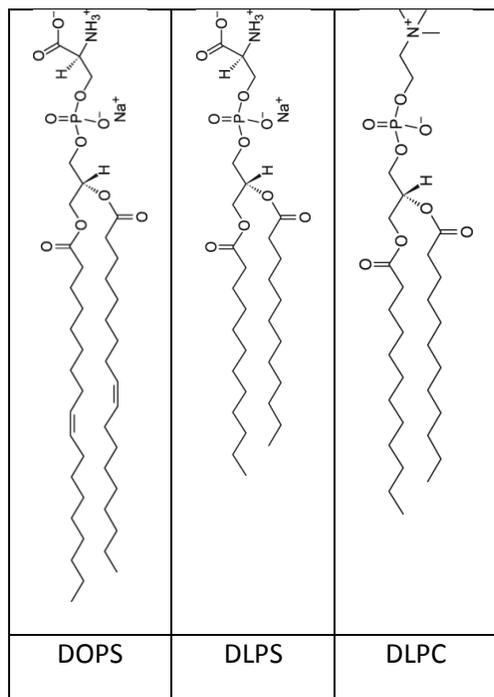


Figure S2. The variation of the volumetric membrane thickness of DLPS as a function of temperature, about the gel to liquid phase transition. The steepest slope is around 18 °C.

Section 3: lipid structure

We present the chemical structure of the phospholipids used in this study (Sketch S1).



Sketch S1. Chemical structure of DOPS, DLPS and DLPC, taken from the website of Avanti-Polar Lipids (<http://avantilipids.com/index.php>), from whom we purchased those synthetic lipids.

Section 4: The ratio between the volumetric membrane thickness and the head-to-head distance

The ratio between the volumetric thickness, δ , and the head-to-head distance, δ_{hh} , decreases slightly with temperature as long as the lipids remain in the liquid phase. This fact implies a change in the packaging of the lipids in the membranes throughout the range of studied temperatures. This ratio does not change dramatically between two charged lipids and remains roughly constant at 0.8 - 0.9 (Figure).

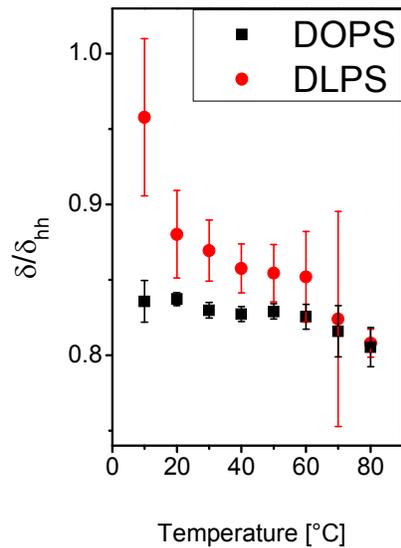


Figure S3. The temperature dependence of the ratio between the volumetric thickness, δ , and the head-to-head distance, δ_{hh} , as a function of temperature.

Section 5: Raw data and analysis

Figure S4 shows examples of 2D images measured, using our in-house setup.

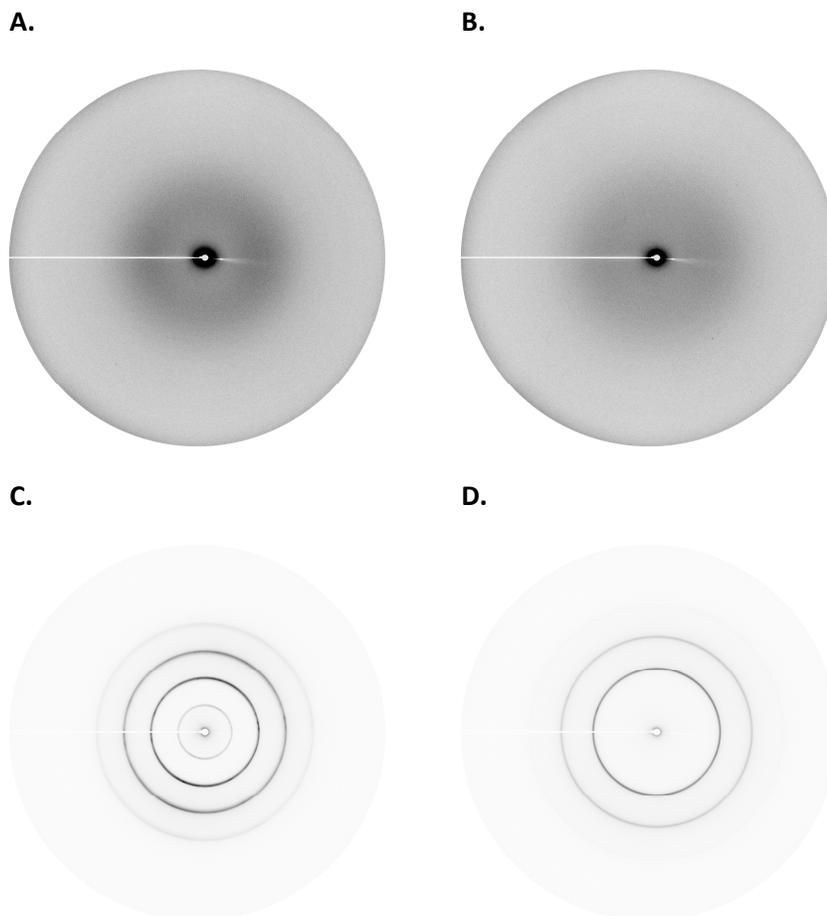


Figure S4. Representative 2D raw scattering images, taken at our in-house setup. A. 100(mg/ml of water) DOPS at 20 °C. B. 100(mg/ml of water) DOPS at 60 °C. C. 400 (mg/ml of water) DLPS at 20 °C. D. 400(mg/ml of water) DLPS at 60 °C.

The raw 2D data is radially integrated into 1D plots of intensity vs. the magnitude of the momentum transfer vector, q (Figures S5 and S6). The data analysis includes peak indexing (Figure S5) and form-factor analysis (Figure S6).

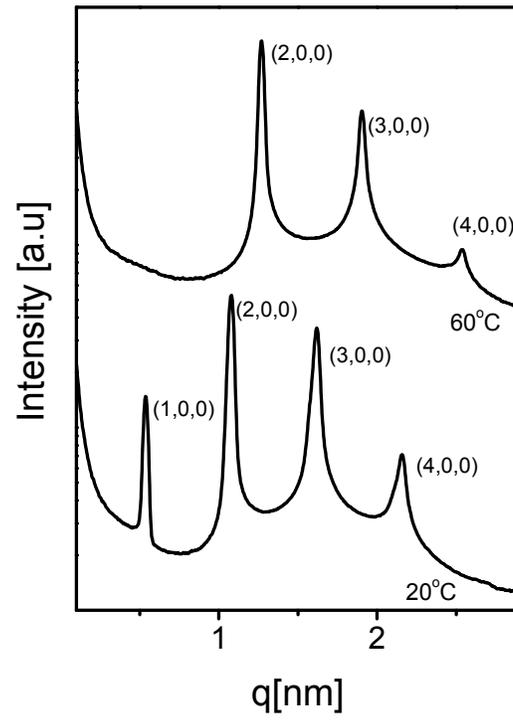


Figure S5. Radially integrated scattering data from Figure S4C & S4D - 400mg/(ml of water) DLPS at 20 and 60 °C, as indicated. Peak indexes are also shown.

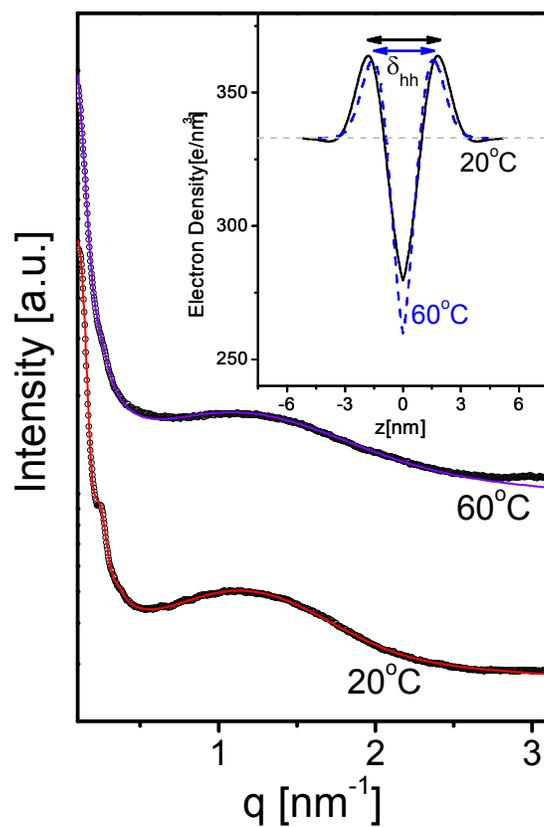


Figure S6: Radially integrated scattering data from Figure S4A & S4B - 100 mg/(ml of water) DOPS at 20 and 60 °C (open symbols), as indicated. The scattering data were fit to models of a stack of infinite flat slabs having a Gaussian electron density profile along the z direction that is normal to the membrane plane (red and blue solid lines). The inset shows the electron density profiles used in each model (black solid curve and broken blue curve).