UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL ATOMIC ENERGY AGENCY
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
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SMR.961 - 3

WORKSHOP ON:
PROTEINS, MEMBRANES and their INTERACTIONS

22 JULY - 2 AUGUST 1996

"Lipid polymorphism and Membrane Structure and Function"

PART II

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SW7 2AY London
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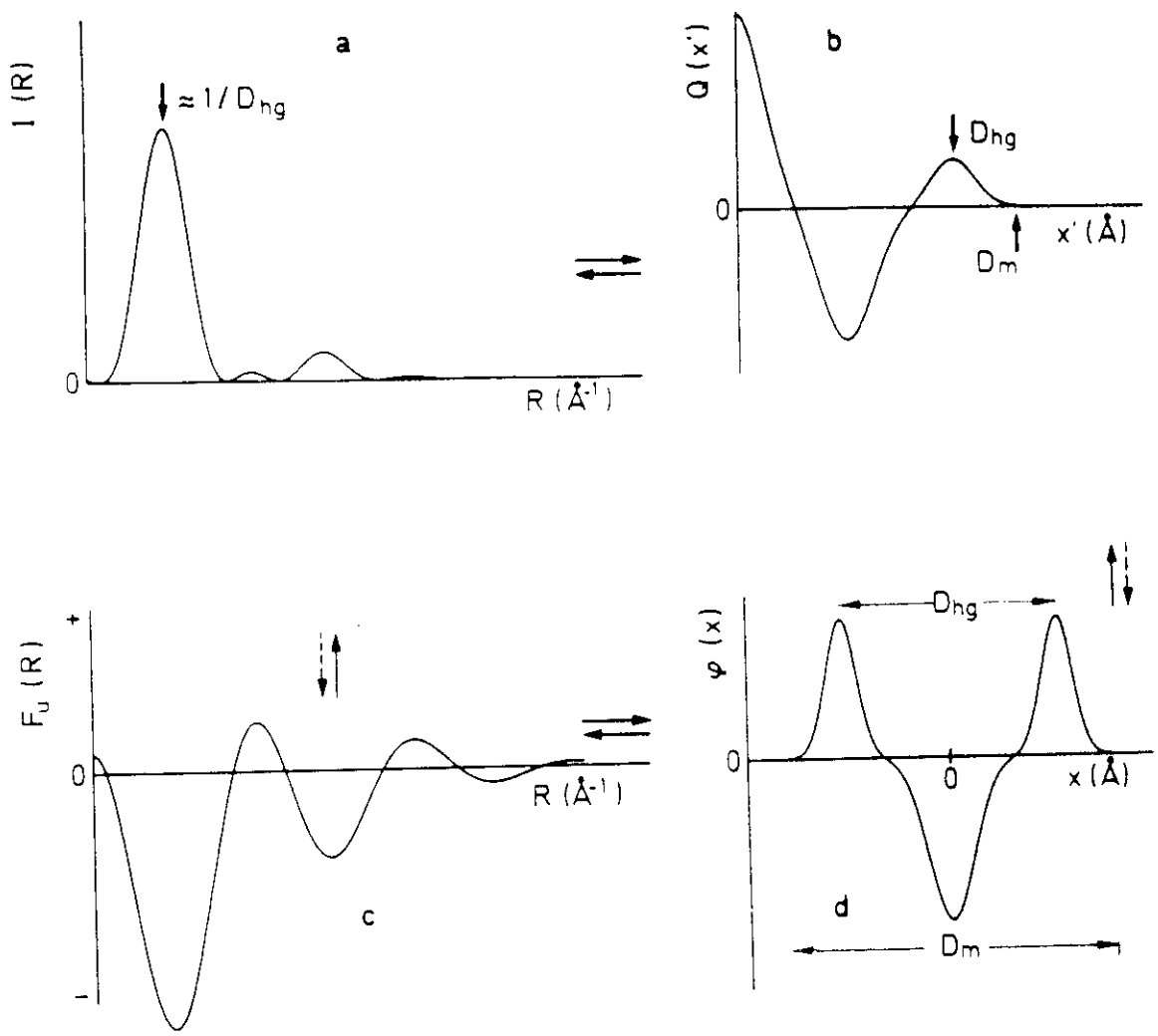
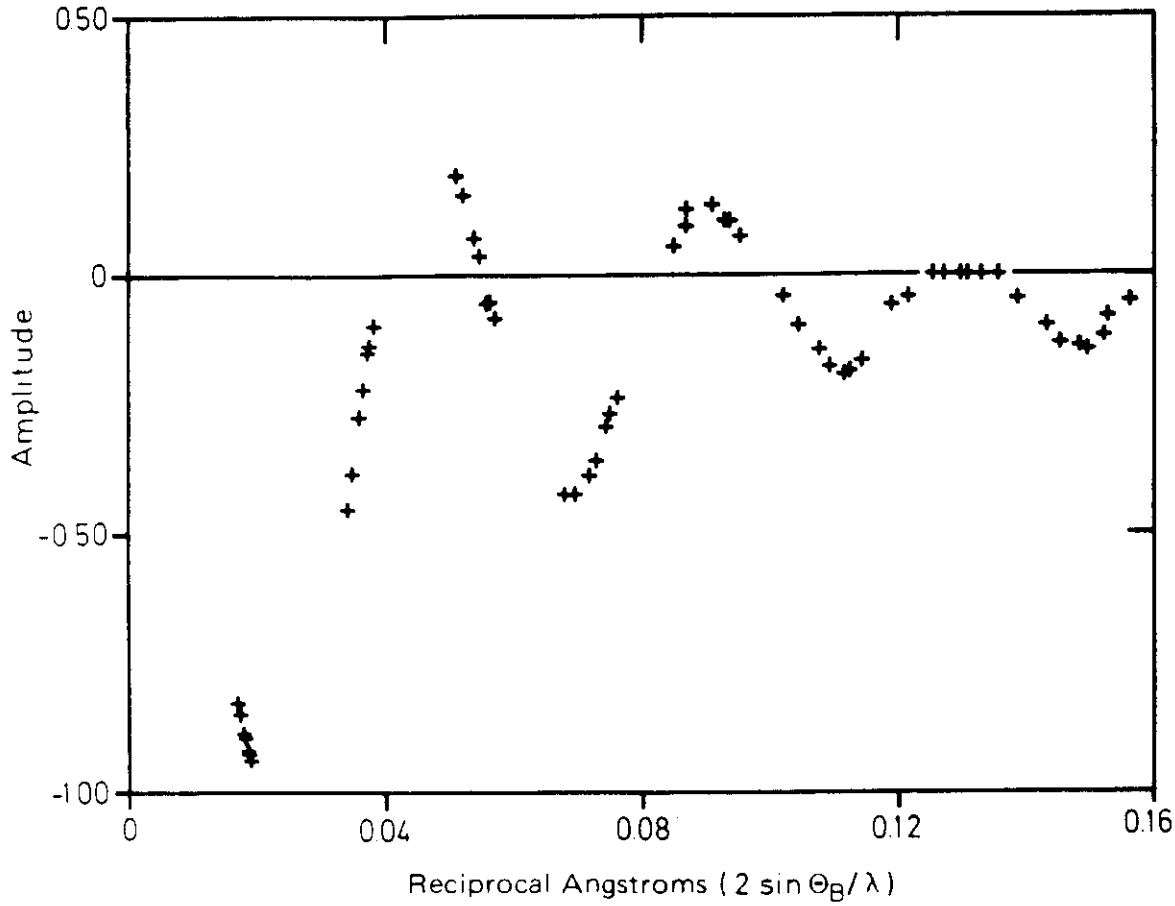
Single bilayer diffraction



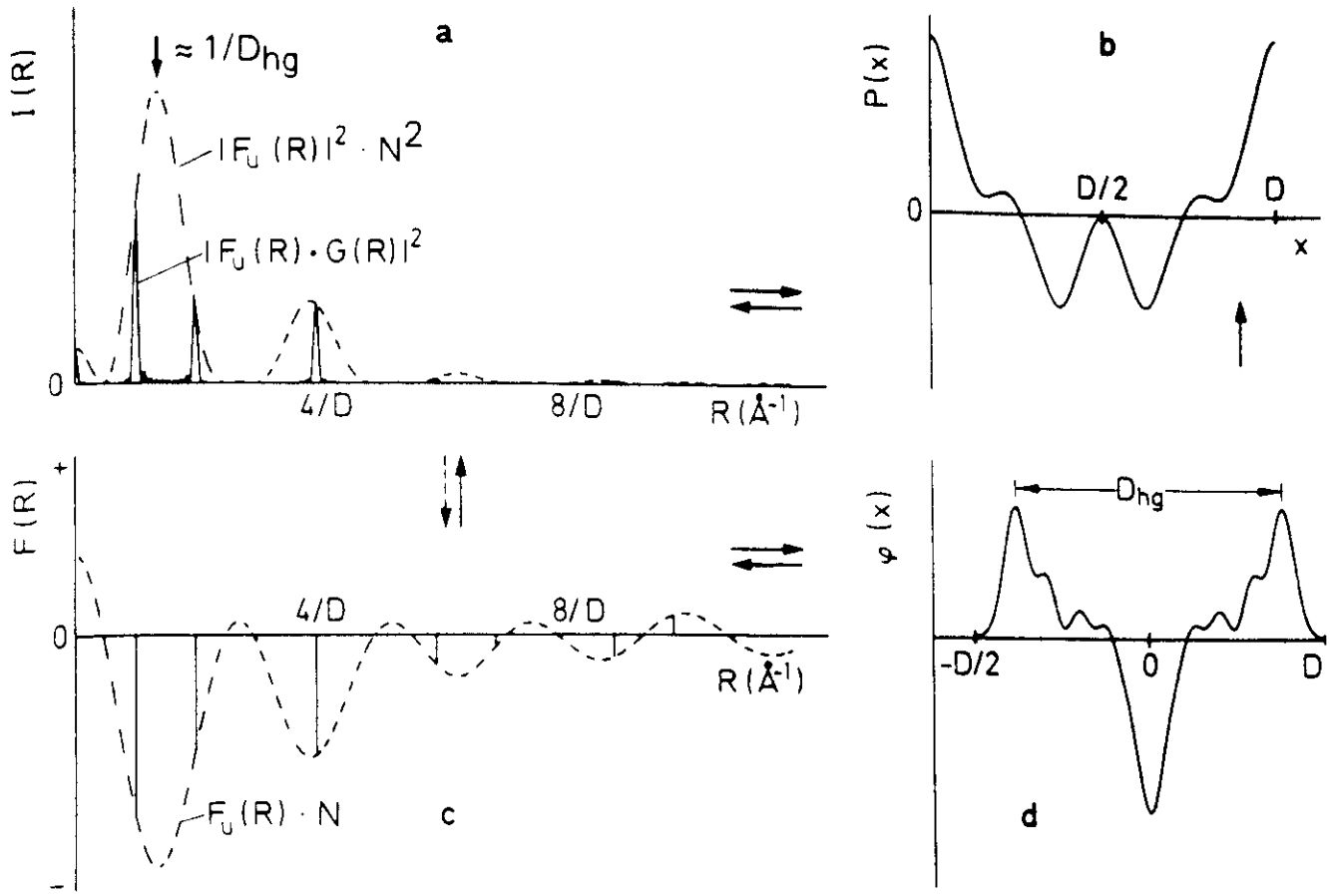
From: N. P. Franks and Y. Levine, in: Membrane Spectroscopy (E. Grell, Ed.), 1981, Springer Verlag, Berlin.

Lamellar swelling series



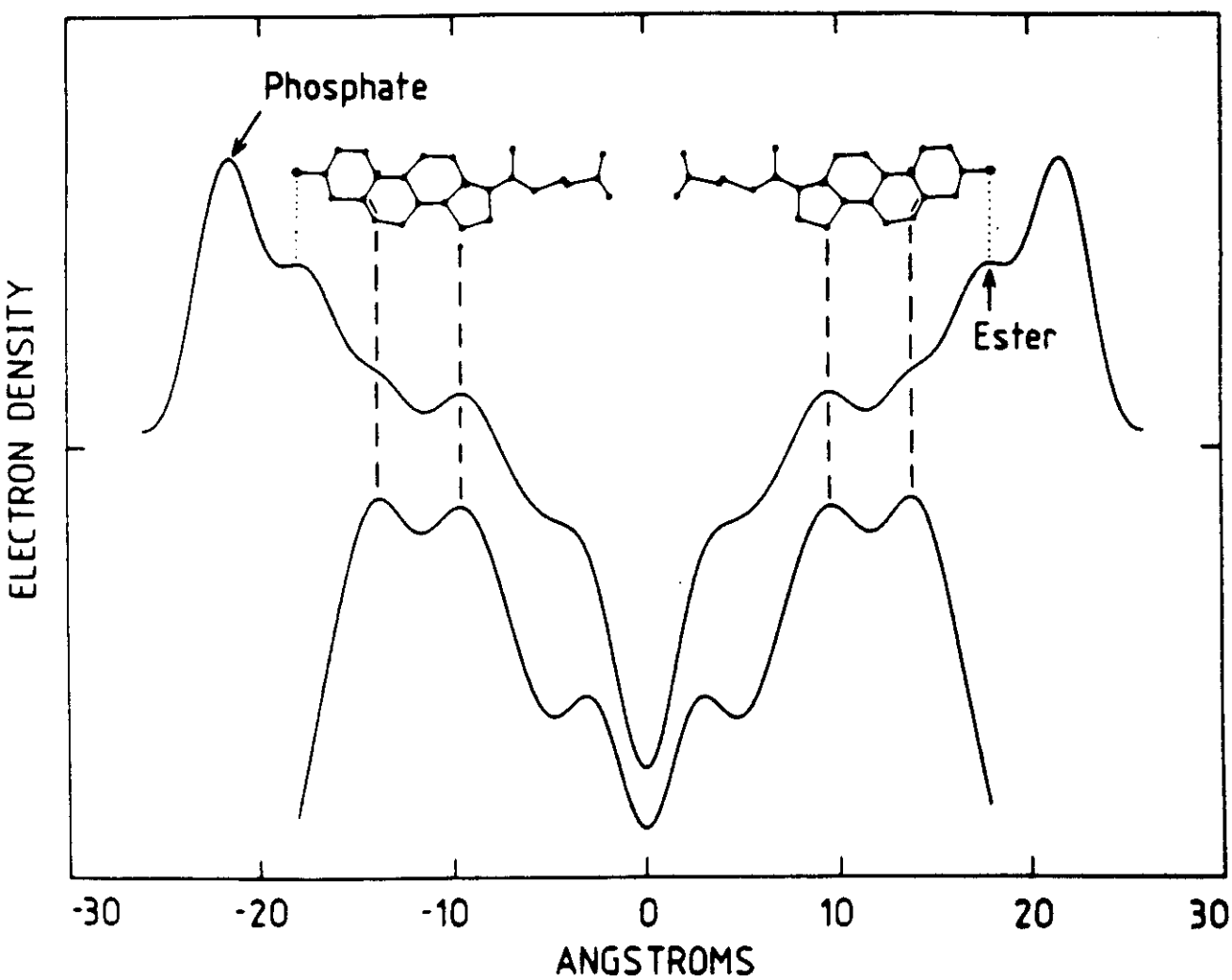
From: N. P. Franks and Y. Levine, in: Membrane Spectroscopy (E. Grell, Ed.), 1981, Springer Verlag, Berlin.

Lamellar phase diffraction



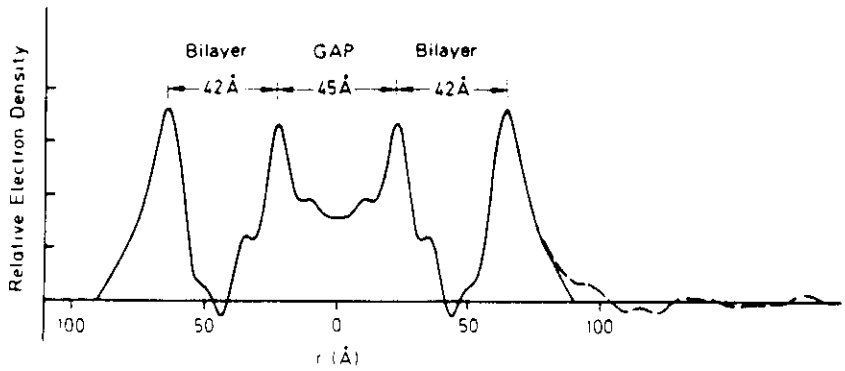
From: N. P. Franks and Y. Levine, in: Membrane Spectroscopy (E. Grell, Ed.), 1981, Springer Verlag, Berlin.

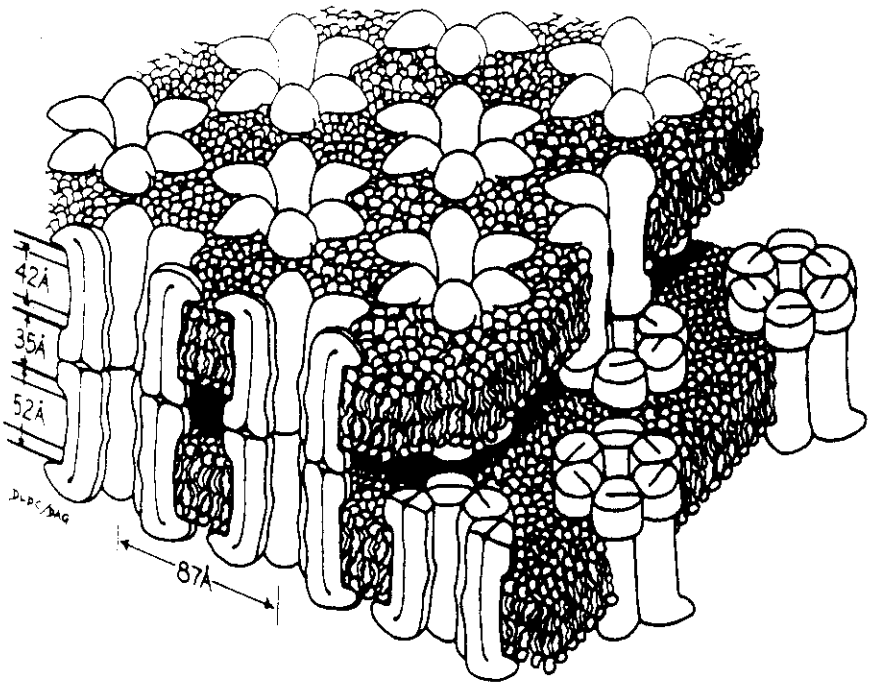
Cholesterol / DMPC bilayers: electron density profile



From: N. P. Franks and Y. Levine, in: Membrane Spectroscopy (E. Grell, Ed.), 1981, Springer Verlag, Berlin.

Gap junction profile

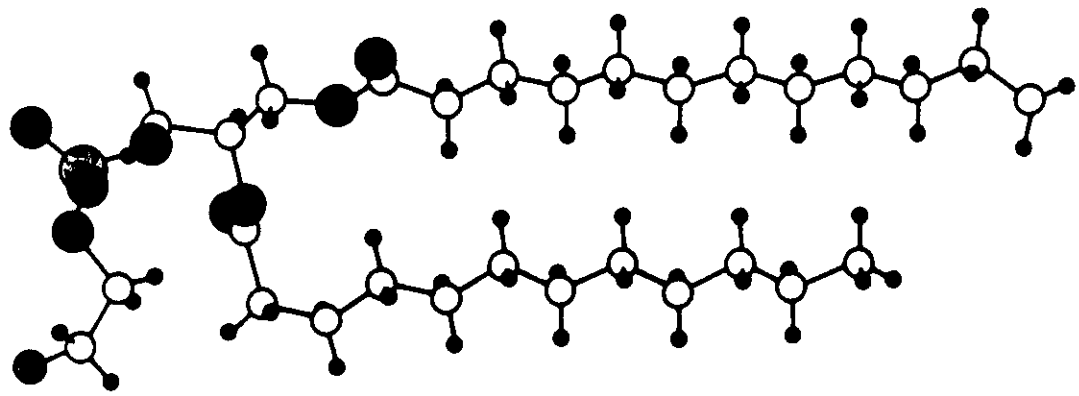




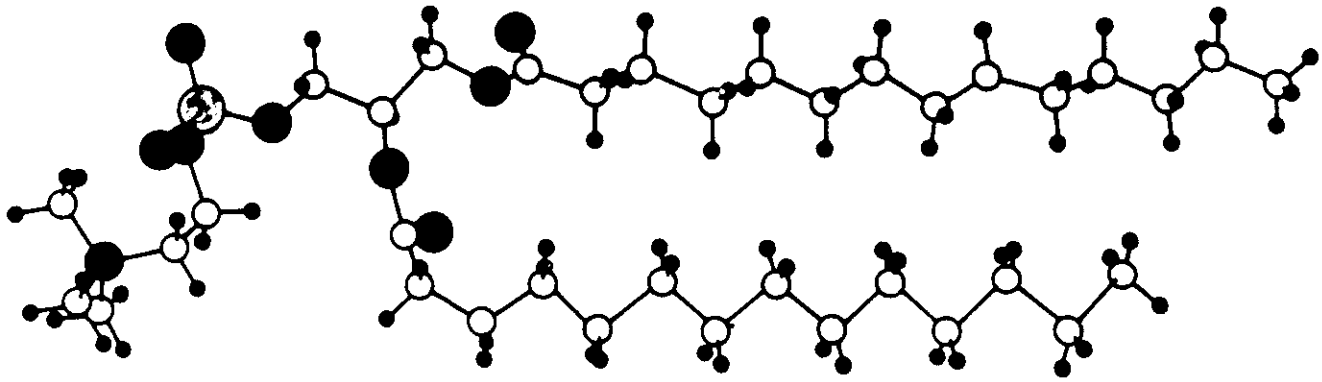
From: L. Makowski et al., 1977, J. Cell Biol. 74, 629-645.

Molecular conformations of crystalline phospholipids

DLPE



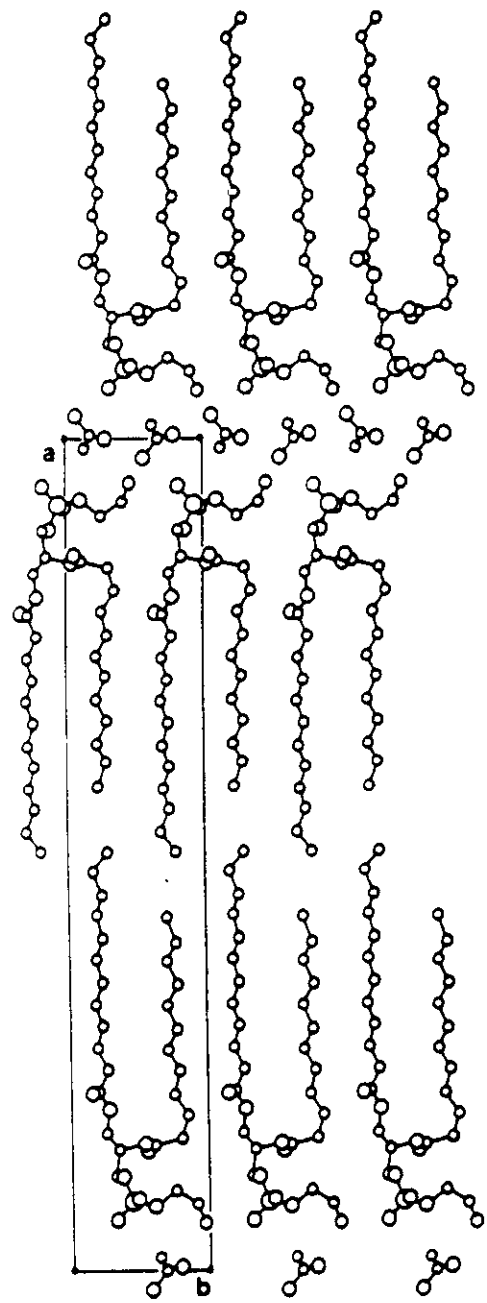
DMPC



From: I. Pascher et al., Biochim. Biophys. Acta, 1992, 1113, 339-373

Packing: crystalline bilayers

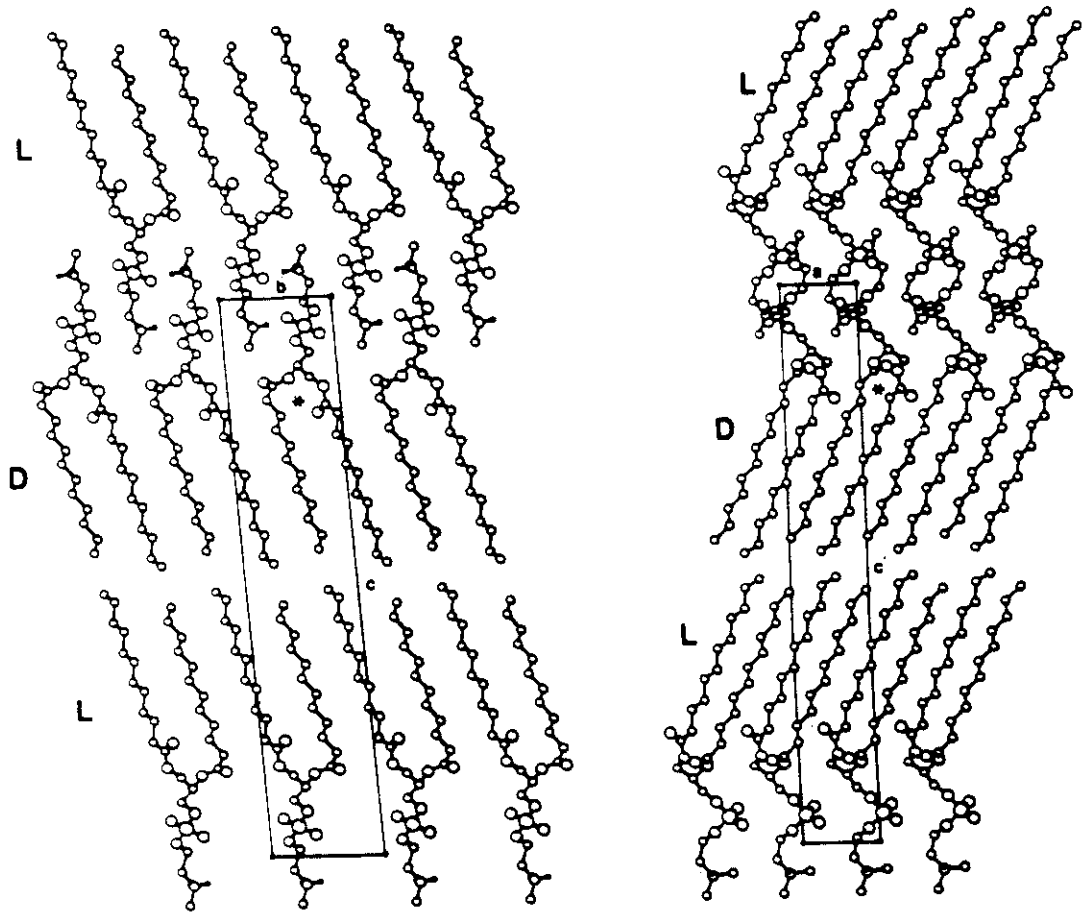
DLPE



From: I. Pascher et al., Biochim. Biophys. Acta, 1992, 1113, 339-373

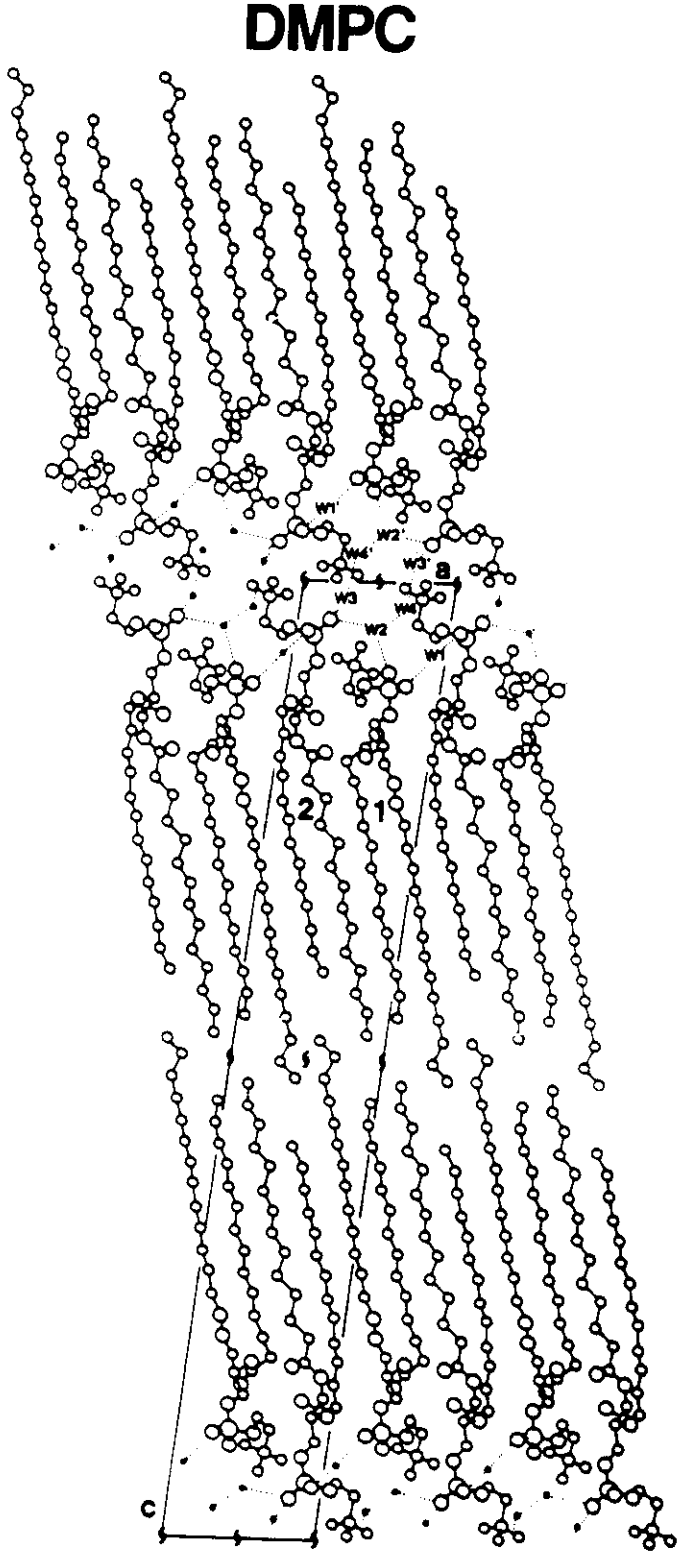
Packing: crystalline bilayers

Dimethyl-DLPE



From: I. Pascher et al., Biochim. Biophys. Acta, 1992, 1113, 339-373

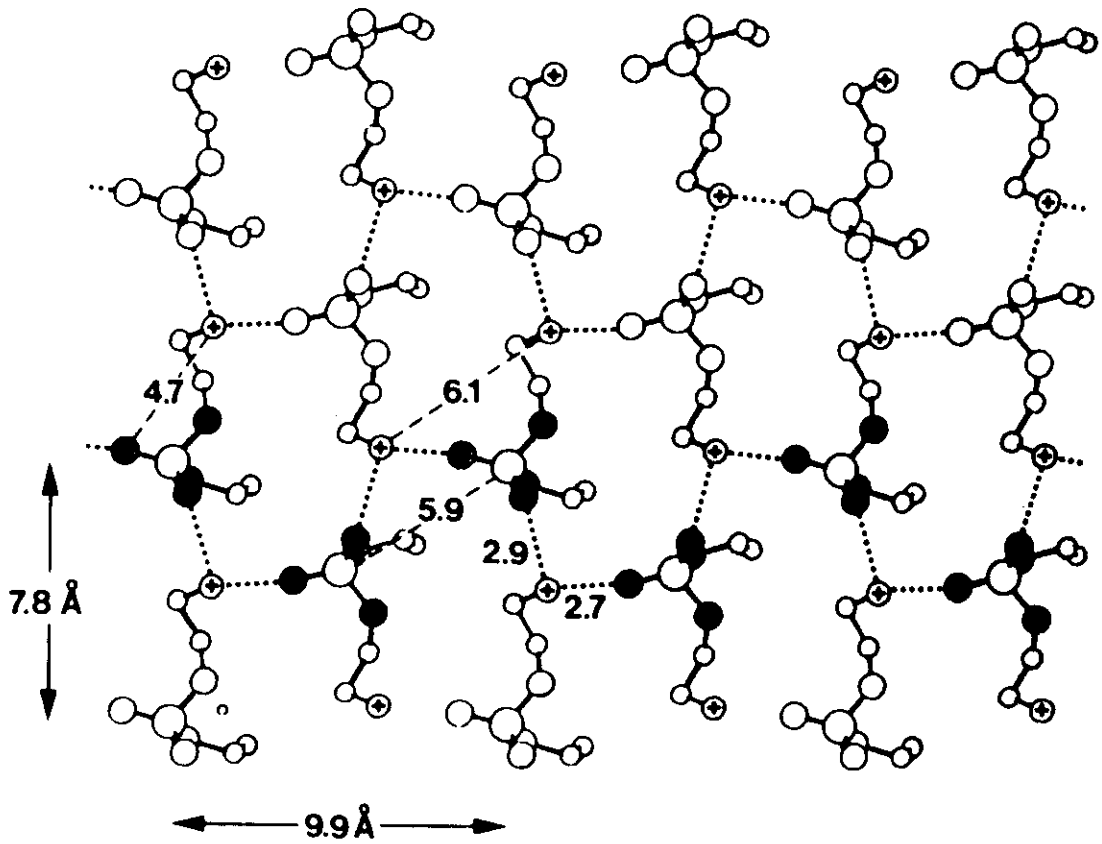
Packing: crystalline bilayers



From: I. Pascher et al., Biochim. Biophys. Acta, 1992, 1113, 339-373

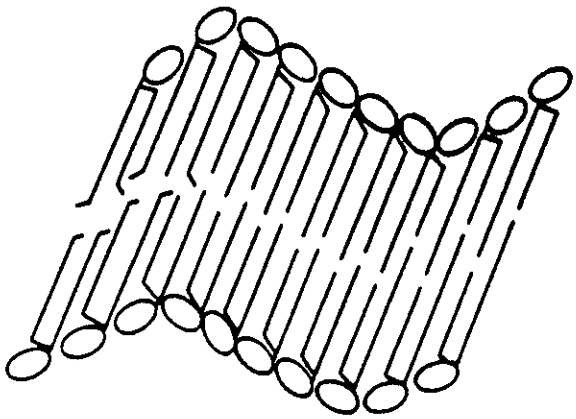
Headgroup lateral packing: crystalline bilayers

DLPE

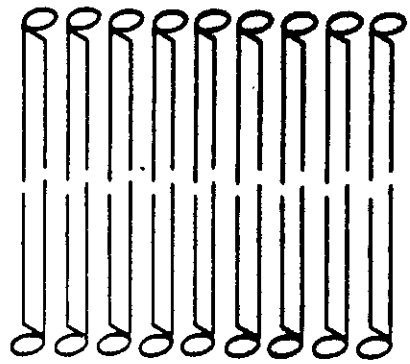


From: I. Pascher et al., Biochim. Biophys. Acta, 1992, 1113, 339-373

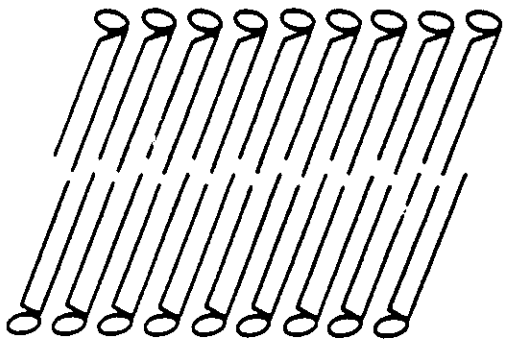
a) $P_{\beta'}$



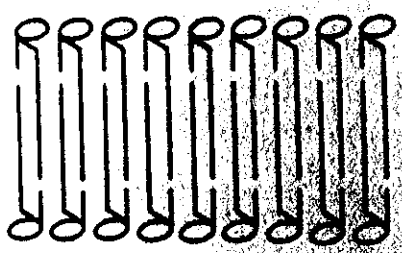
b) L_{β}



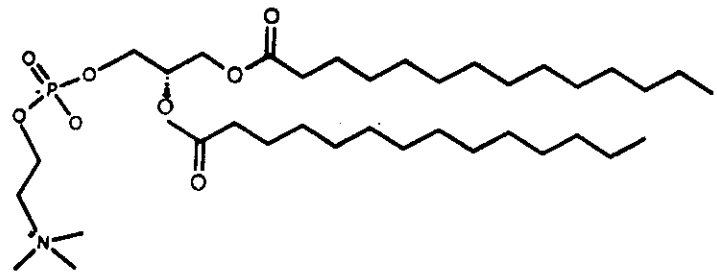
c) $L_{\beta'}$

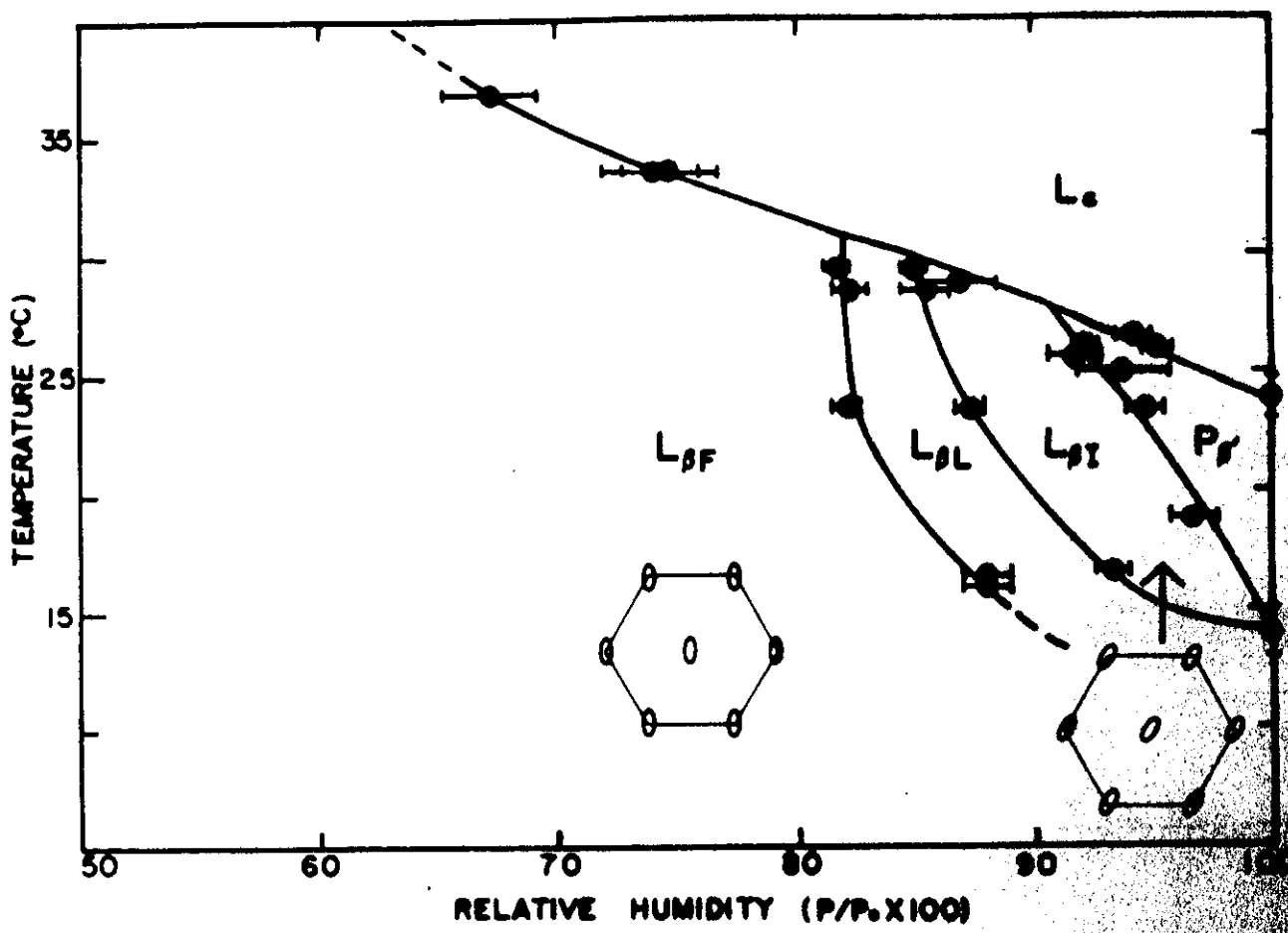


d) $L_{\beta I}$



Dimyristoyl phosphatidylcholine / water

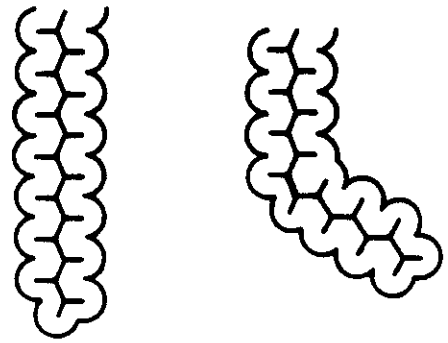




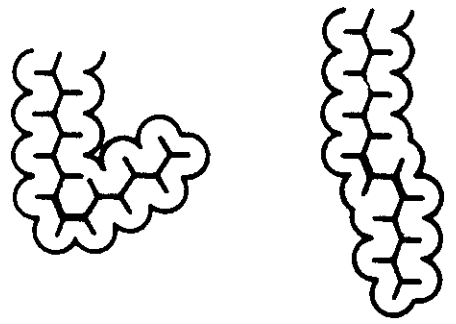
From: G. S. Smith et al. (1990) J. Chem. Phys. 92, 4519.

Gel-fluid transition

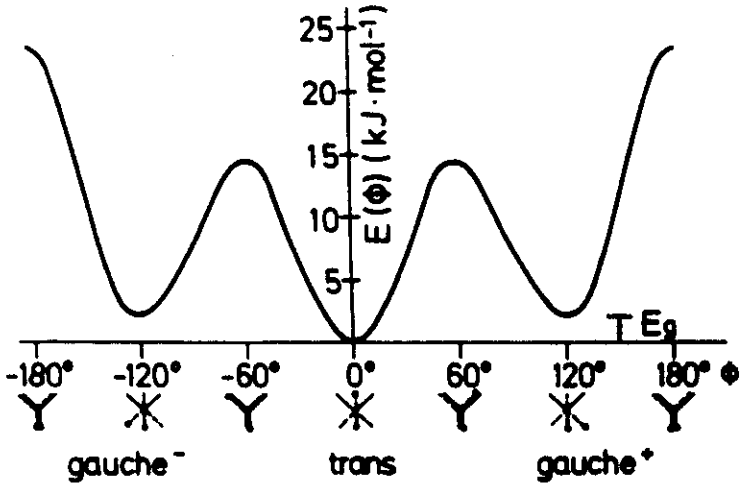
Chain rotational isomerism



all-*trans* *gauche* (g)

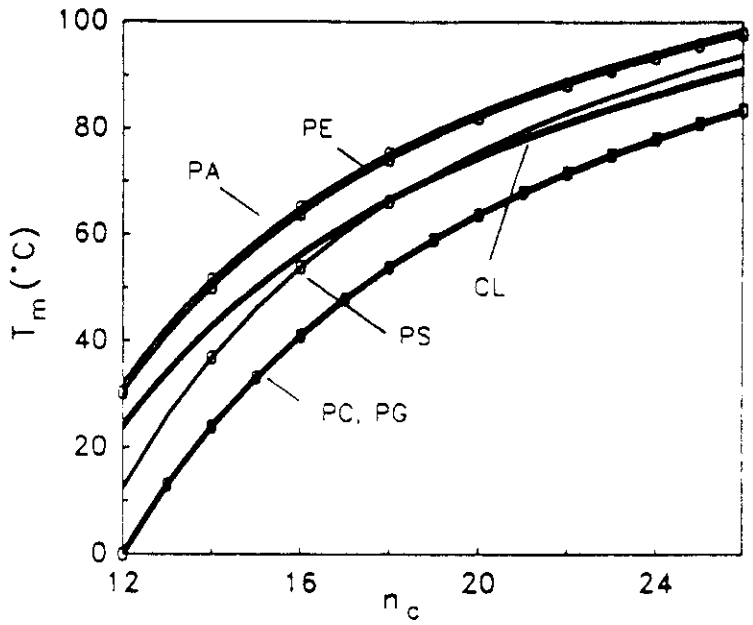


$g^{\pm}g^{\mp}$ $g^{\pm}tg^{\mp}$



From: G. Cevc and D. Marsh, Phospholipid Bilayers, 1987, John Wiley, N[illegible]

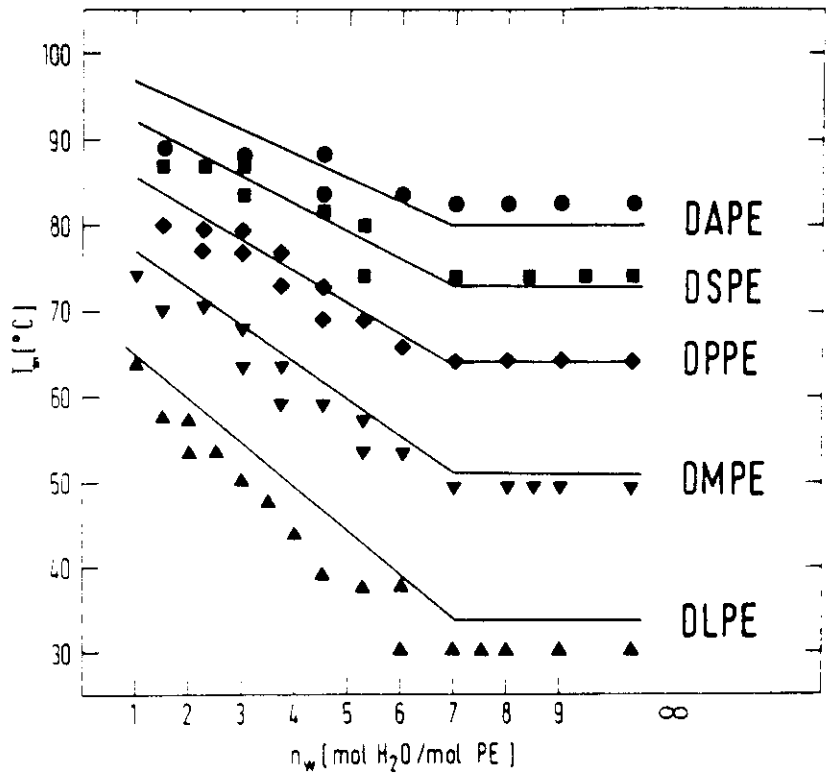
Chainlength-dependence of T_m



PA: Phosphatidic acid
PE: Phosphatidylethanolamine
PC: Phosphatidylcholine
PG: Phosphatidylglycerol
PS: Phosphatidylserine
CL: Cardiolipin

From: J. M. Seddon and G. Cevc, in Phospholipids Handbook (G. Cevc, Ed.), 1993, Marcel Dekker, New York.

Hydration-dependence of T_m

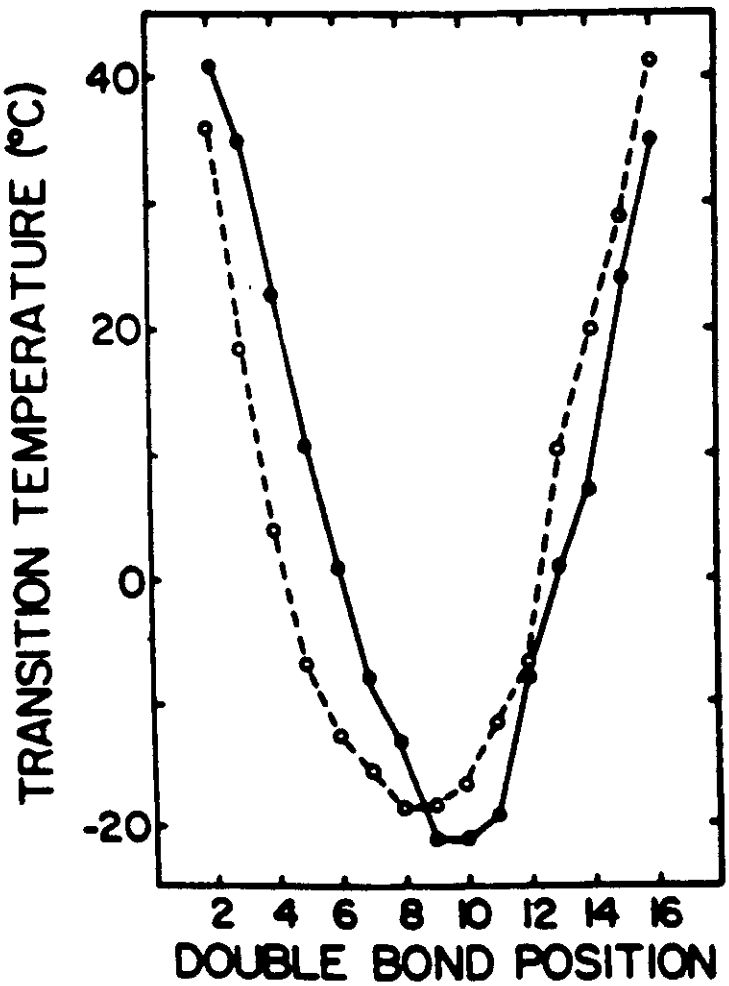


DLPE:	**di-C12**	**Phosphatidylethanolamine**
DMPE:	**di-C14**	"
DPPE:	**di-C16**	"
DSPE:	**di-C18**	"
DAPE:	**di-C20**	"

From: J. M. Seddon and G. Cevc, in Phospholipids Handbook (G. Cevc, Ed.), 1993, Marcel Dekker, New York.

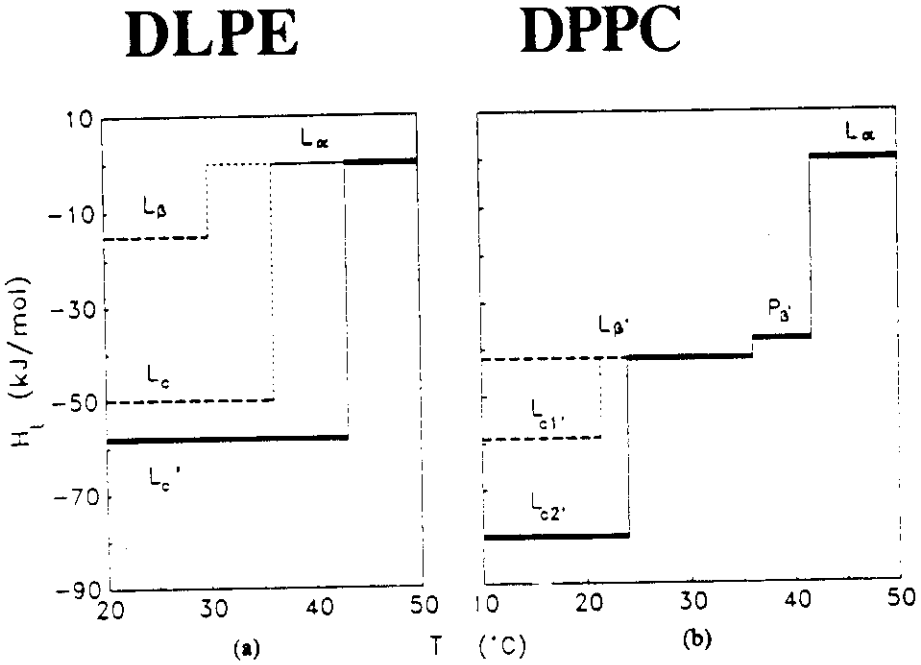
Effect of double bond position on T_m

cis-unsaturated PC / H_2O



From: C. B. Berde et al., 1983, Biochemistry, 19, 4279-4293.

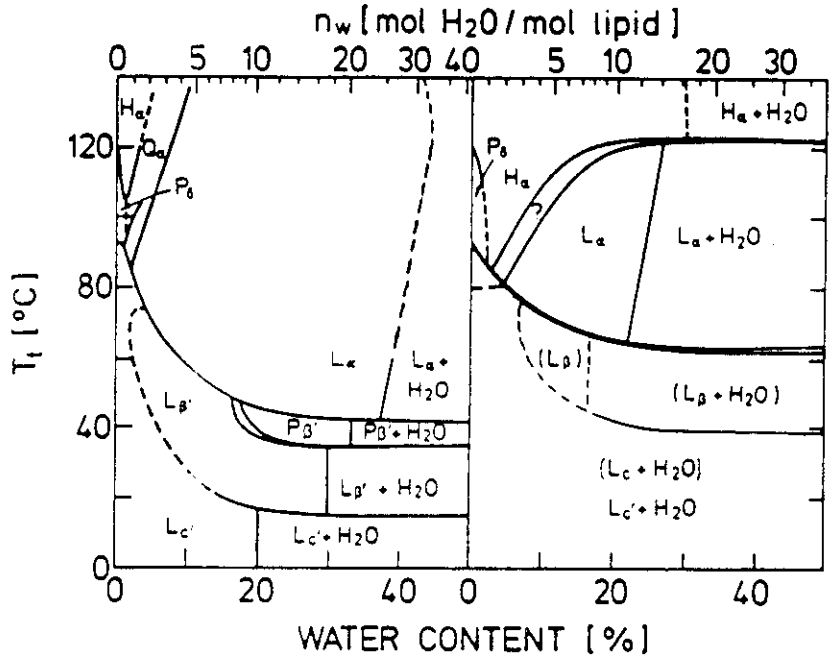
Lipid bilayer metastability



From: J. M. Seddon and G. Cevc, in Phospholipids Handbook (G. Cevc, Ed.), 1993, Marcel Dekker, New York.

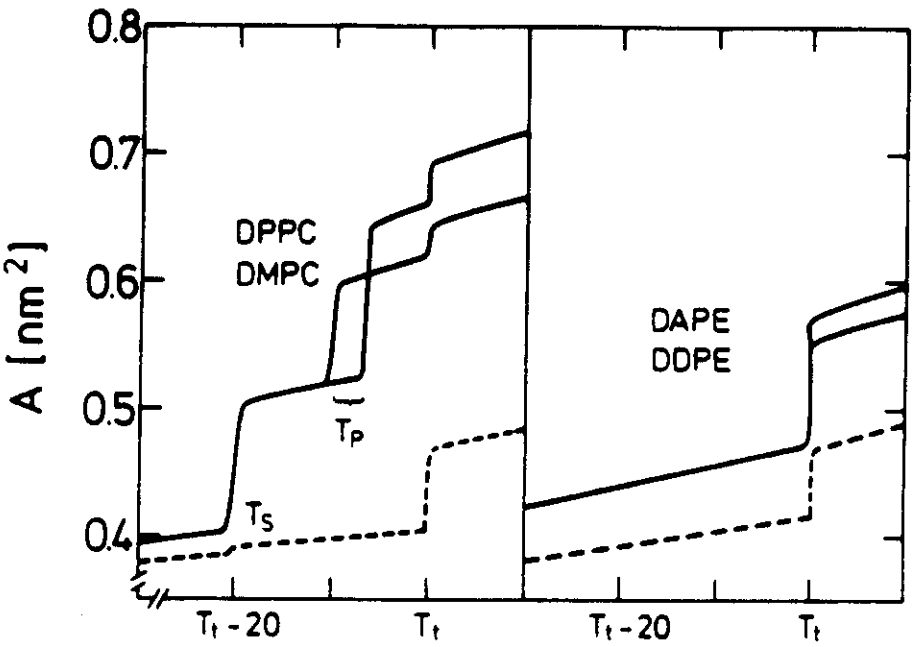
Phospholipid / H_2O phase diagrams

DPPC DPPE

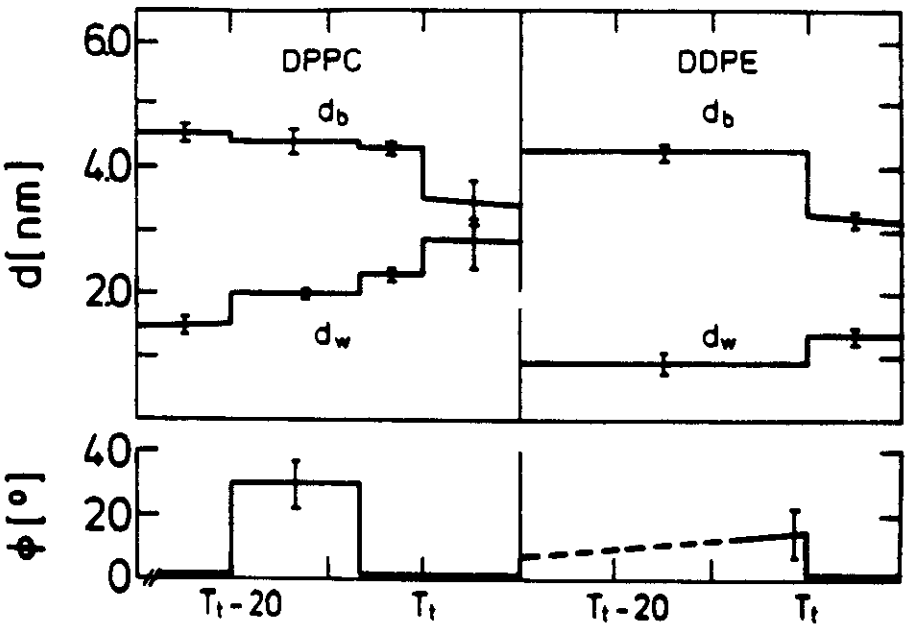


From: J. M. Seddon and G. Cevc, in Phospholipids Handbook (G. Cevc, Ed.), 1993, Marcel Dekker, New York.

Temperature-dependence of lipid molecular area for PC and PE



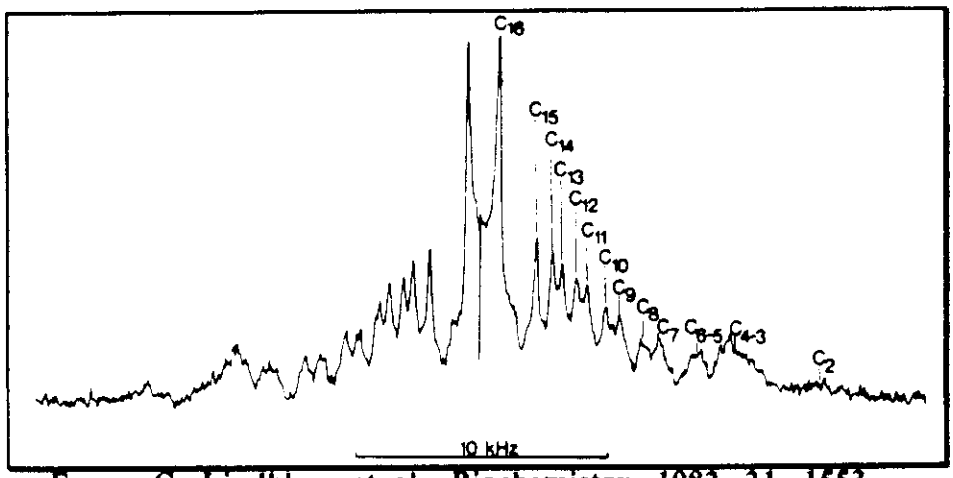
Temperature-dependence of lipid and water layer thickness for PC and PE



From: G. Cevc and D. Marsh, Phospholipid Bilayers, 1987, John Wiley, New York

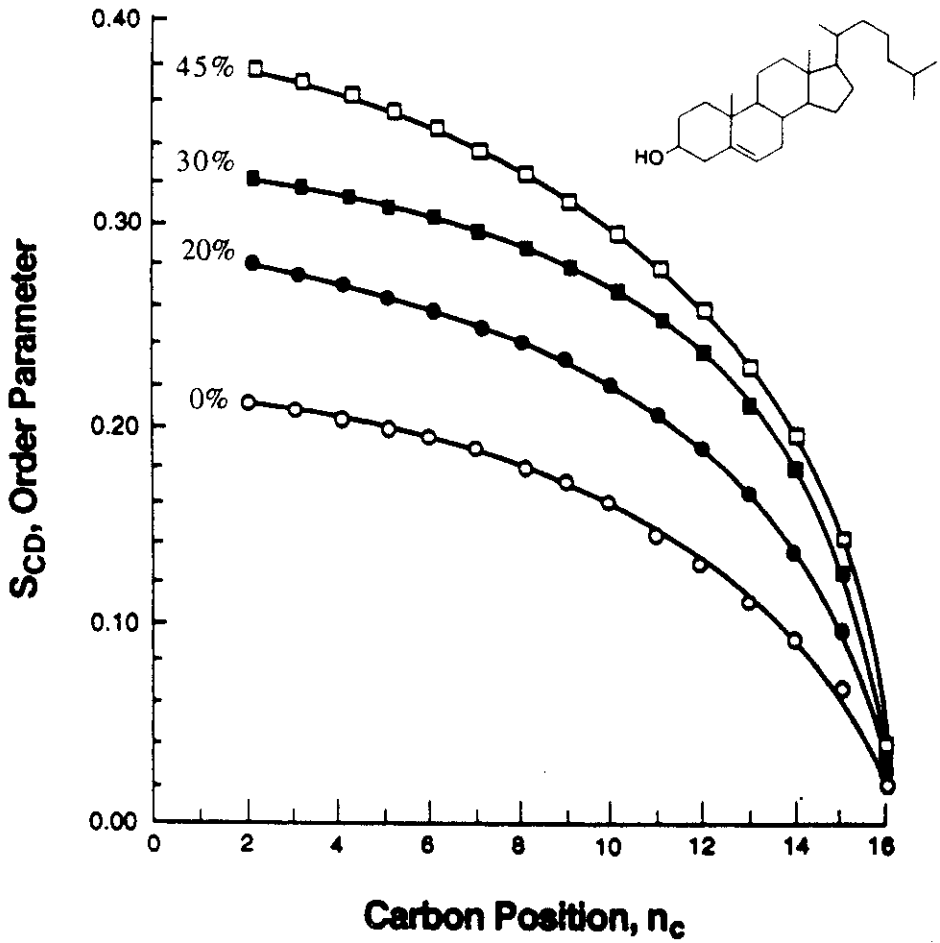
Order parameter profile of bilayer

^{2}H-NMR: POPC/cholate/water



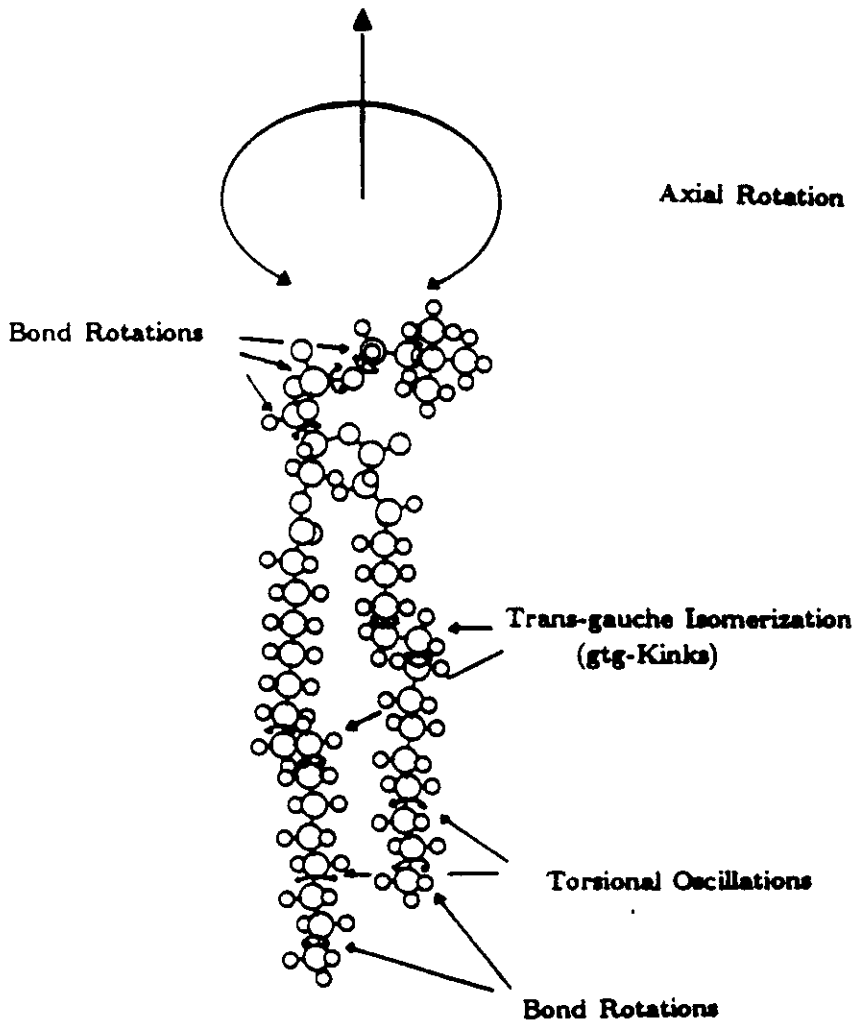
From: G. Lindblom et al., Biochemistry, 1982, 21, 1553

Addition Of Cholesterol To POPC



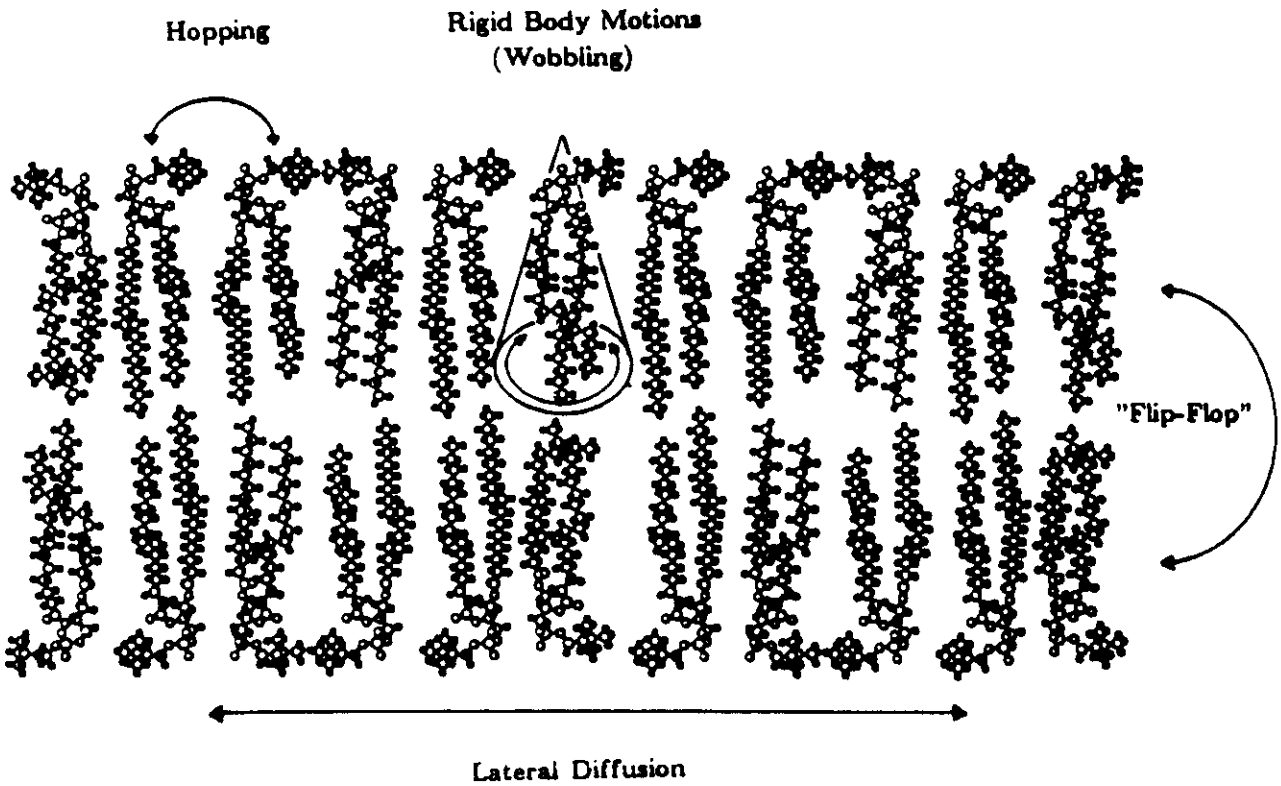
From: G. Lafleur et al., Eur. Biophys. J., 1990, 19, 55

Motions of lipids in membranes



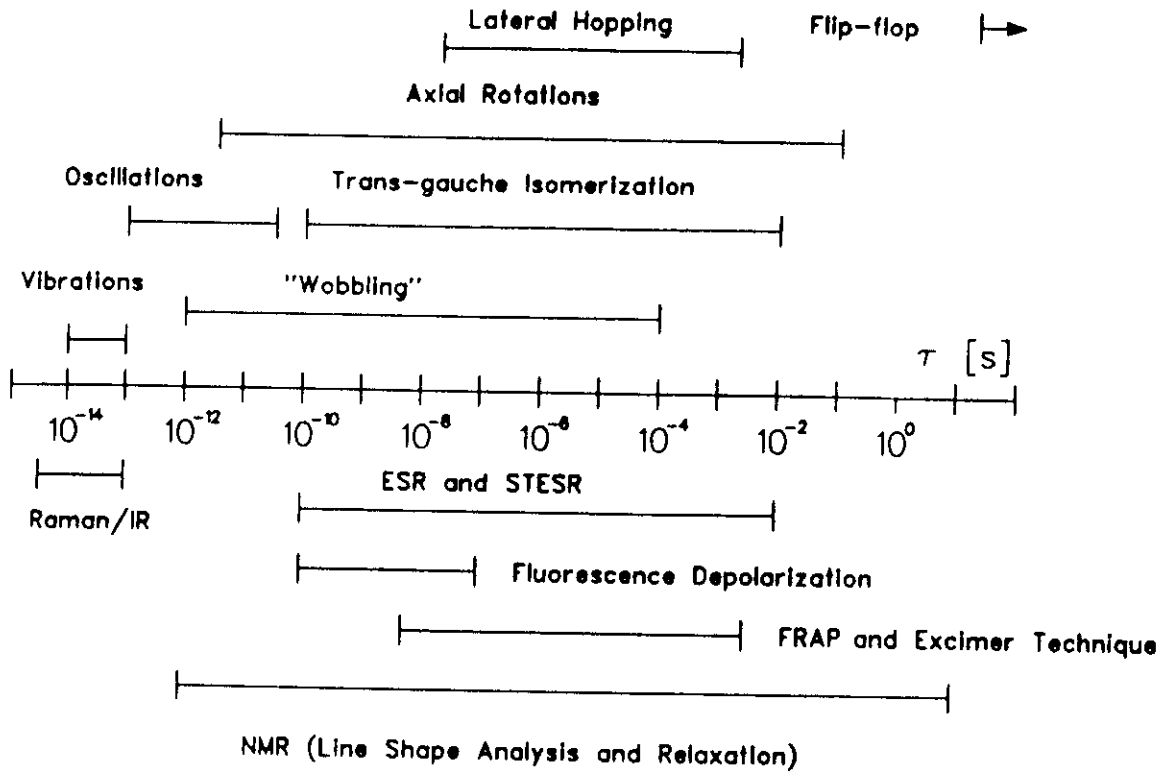
From: A. Blume, in Phospholipids Handbook (G. Cevc, Ed.), 1993, Marcel Dekker, New York.

Molecular motions in membranes



From: A. Blume, in Phospholipids Handbook (G. Cevc, Ed.), 1993, Marcel Dekker, New York.

Molecular motions in membranes: correlation times and time ranges



From: A. Blume, in Phospholipids Handbook (G. Cevc, Ed.), 1993, Marcel Dekker, New York.

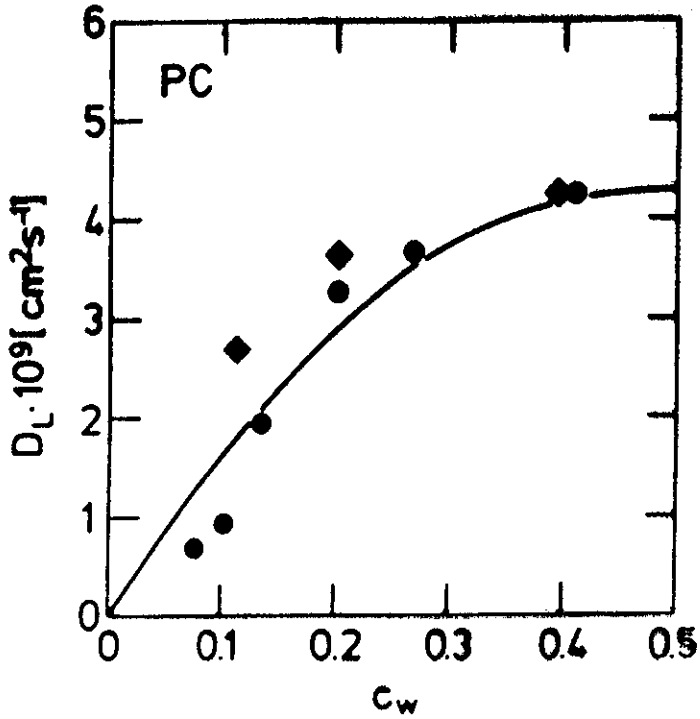
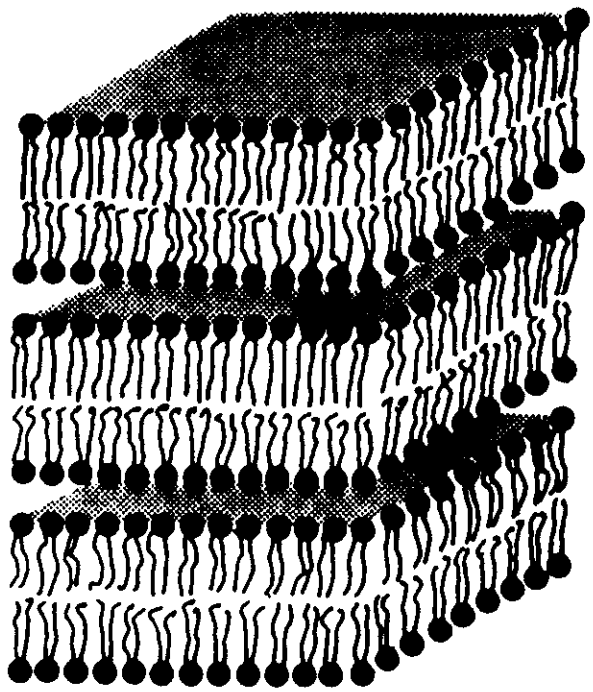


Figure 3.14. The lipid lateral diffusion constant in phosphatidylcholine bil
the water concentration. Experimental points are deduced from the da
(1978) and McCown et al. (1981), and the curves are from Eq. (3.41), w
given in the text. [From Cevc and Seddon (1985), courtesy Plenum P

Fluid Lamellar L_α Phase



Typical values for phospholipids:

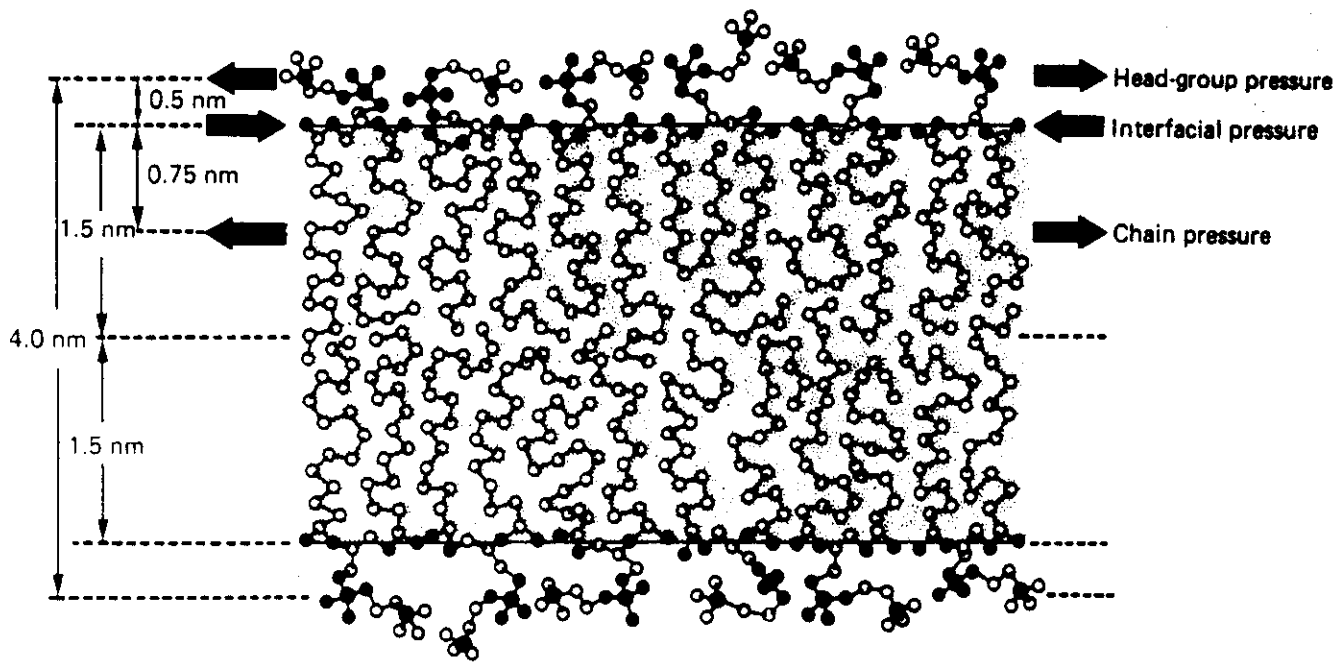
Area compressibility modulus: 0.1 - 1 Nm^{-1}

Bending modulus: 4 x 10^{-20} J (10 kT)

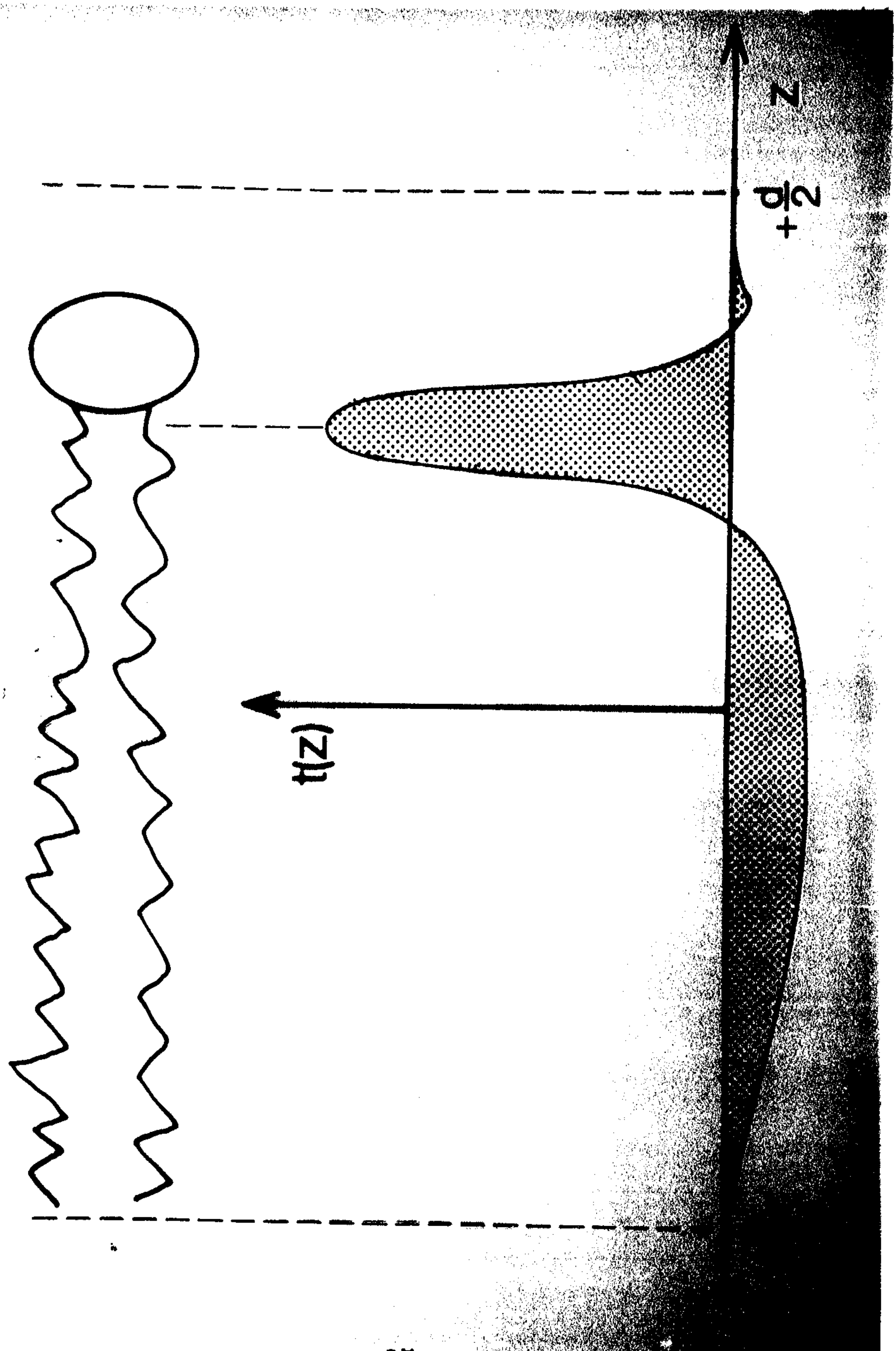
Lateral diffusion constant: 10^{-11} - 10^{-12} m^2s^{-1}

Rotational correlation time: 10^{-9} - 10^{-8} s

Balance of forces in fluid lipid bilayers

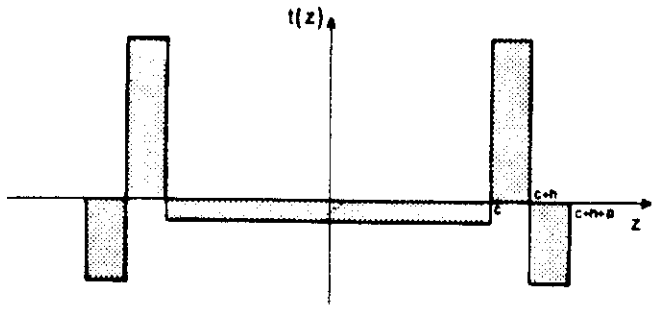


From: J. Israelachvili, 1991, *Intermolecular and Surface Forces*, Academic [illegible] London.

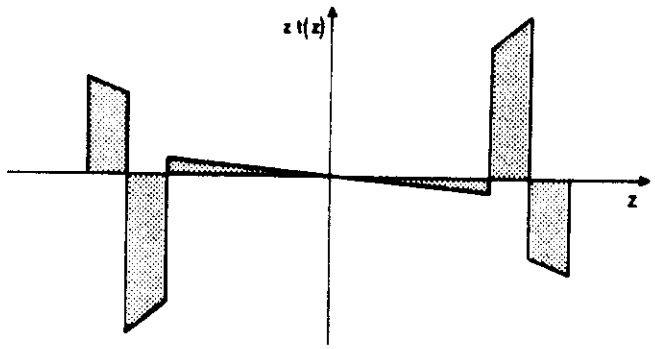

z
+d/2
t(z)

Bilayer curvature elasticity

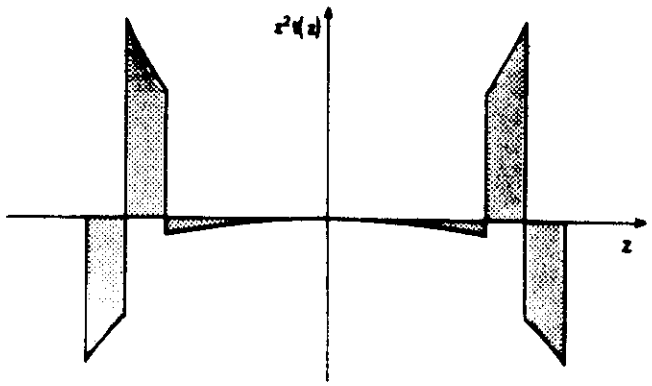
$$g = 1/2\ \kappa_M\ (c_1 + c_2 - c_0)^2 + \kappa_G\ c_1 c_2$$



$$\sigma = \int t(z)\ dz = 0$$



$$\tau = -\kappa_M\ c_0 = \int t(z) z dz = 0$$



$$\kappa_G = \int t(z) z^2 dz > 0$$

INTERFACIAL CURVATURE

Mean curvature

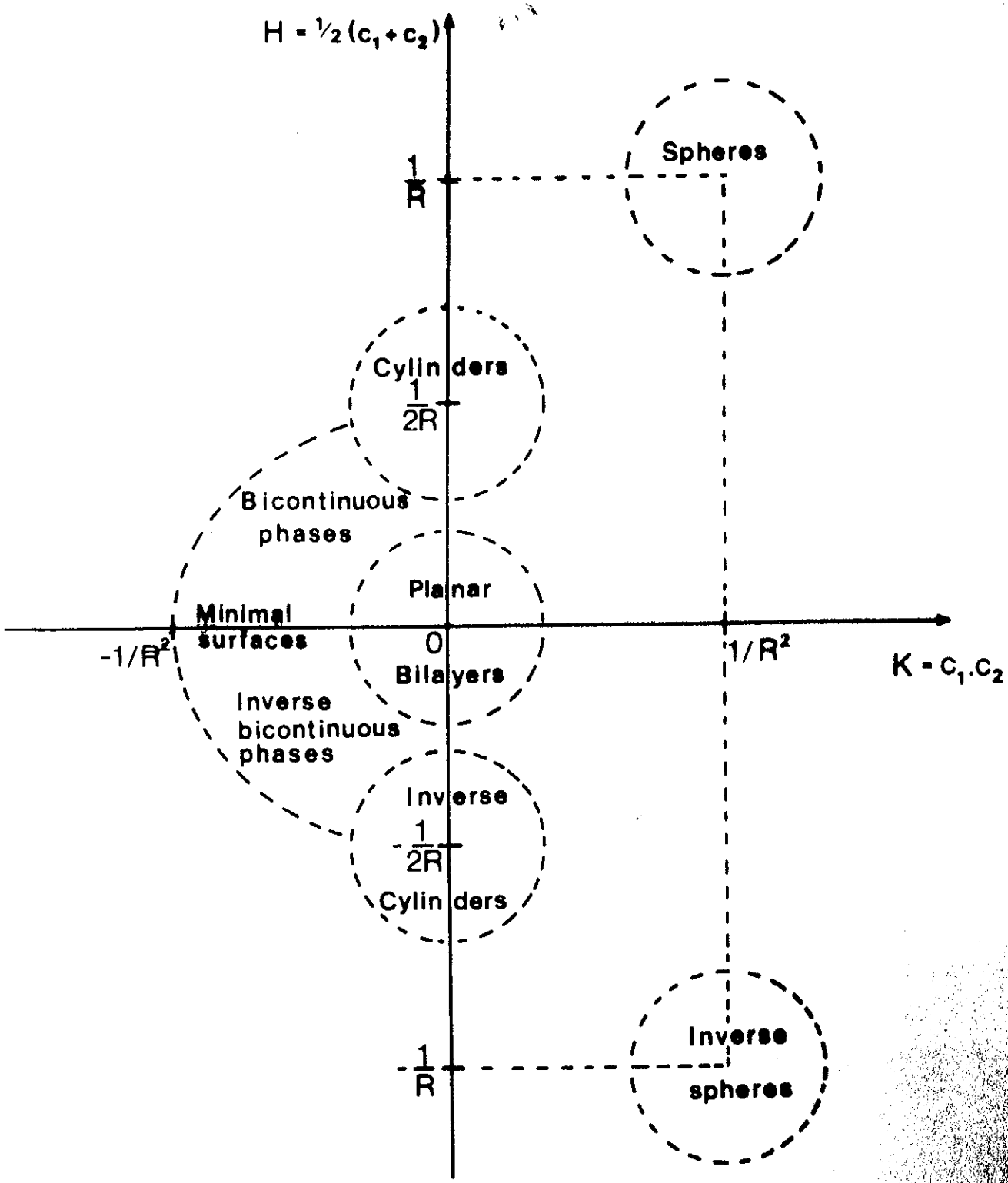
Gaussian curvature

$$H = 1/2(c_1 + c_2)$$

$$K = c_1.c_2$$

Principal curvatures: $c_1 = 1/R_1$; $c_2 = 1/R_2$

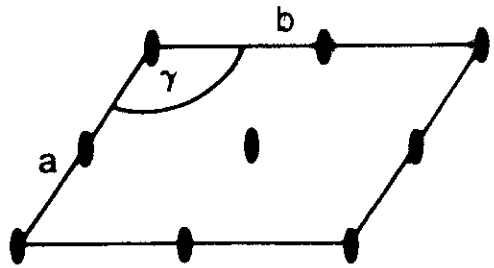
K	H	Form of surface	Example
>0	> or < 0	Elliptic	Sphere
0	> or < 0	Parabolic	Cylinder
0	0	Parabolic	Plane
<0	> or < or = 0	Hyperbolic	Saddle surface


H = ½ (c1 + c2)
Spheres
1/R
Cylinders
1/2R
Bicontinuous phases
Planar
Minimal surfaces
-1/R²
0
Bilayers
1/R²
K = c1.c2
Inverse bicontinuous phases
Inverse
1/2R
Cylinders
Inverse
1/R
spheres

a) M_{II}

oblique

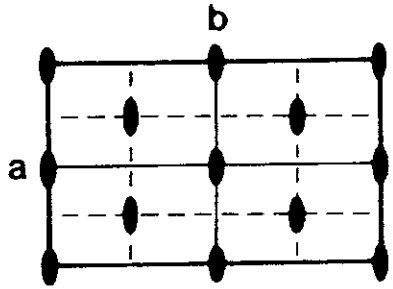
p2

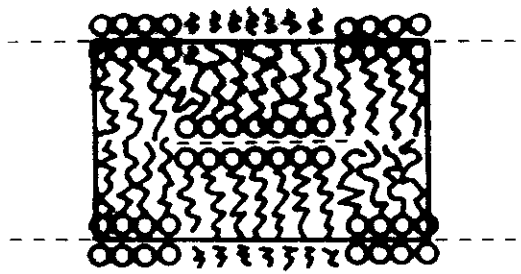


b) P_{II}

centred rectangular

cmm

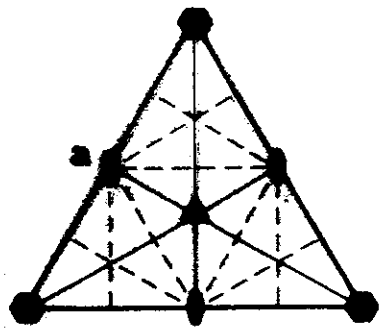


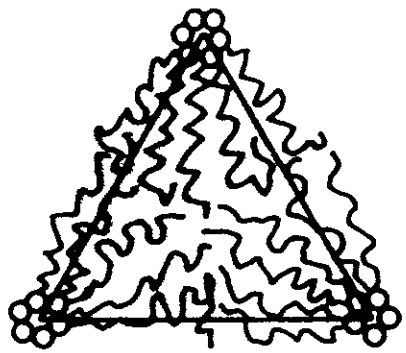


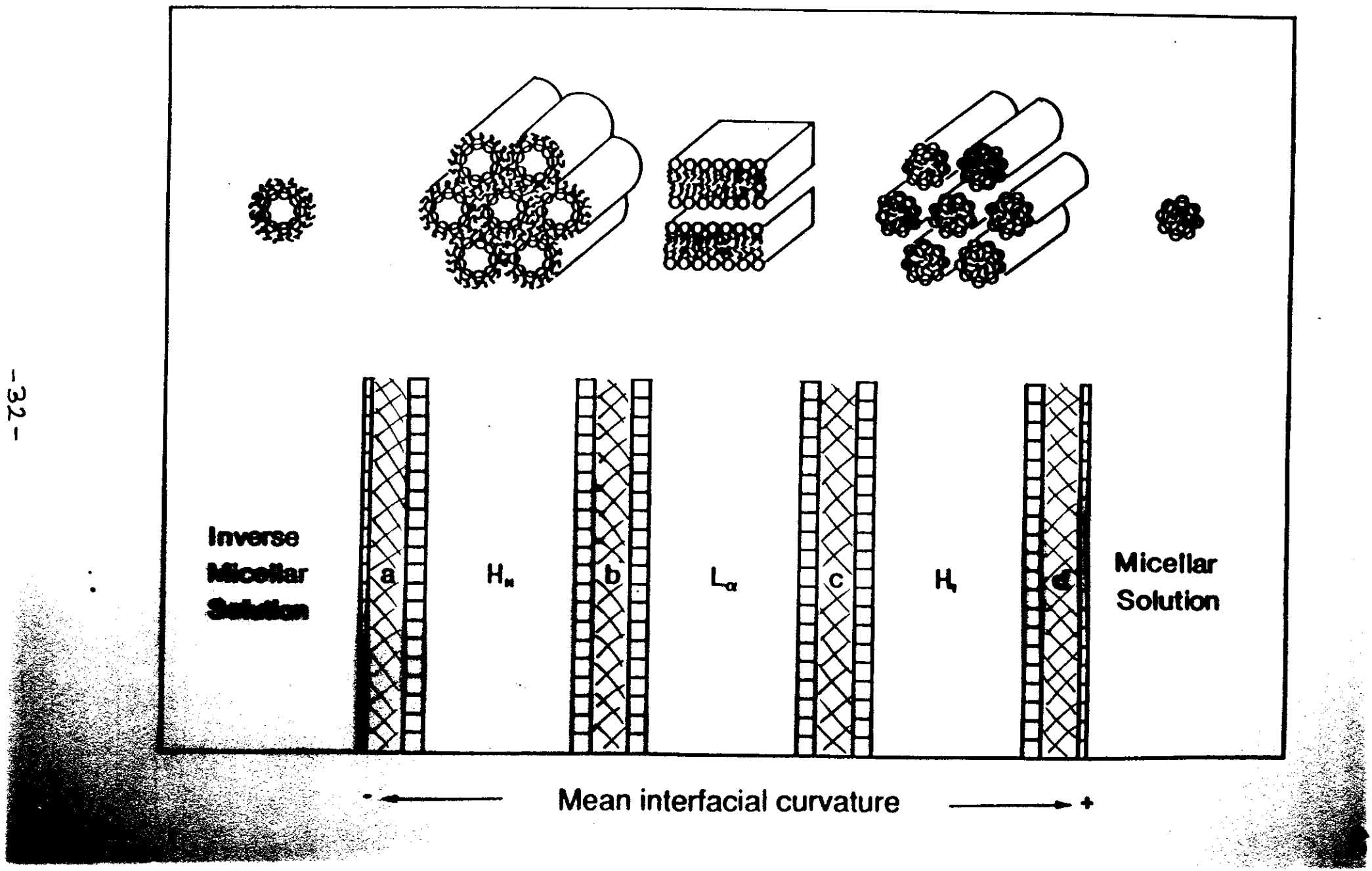
c) H_{II}

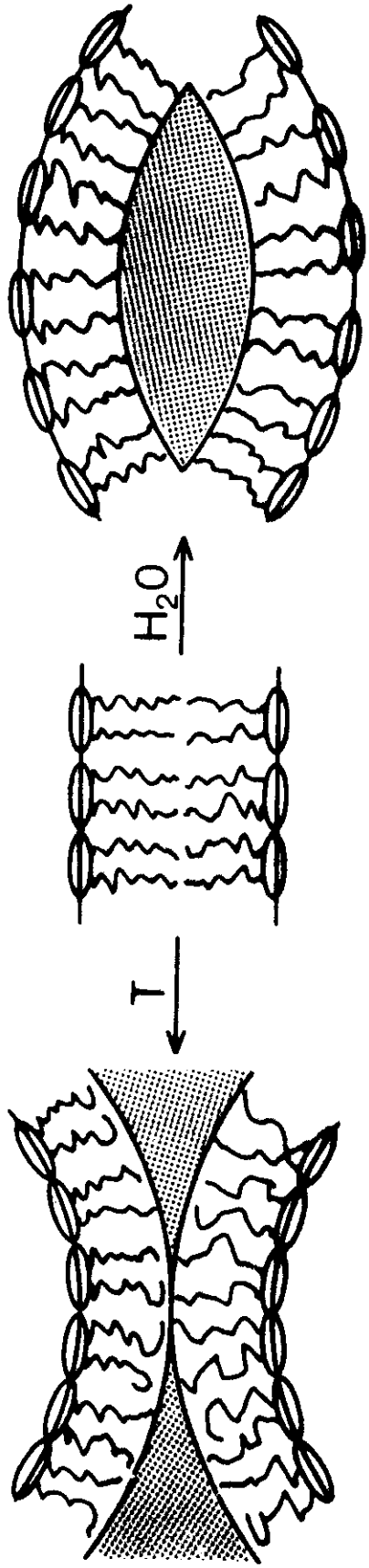
hexagonal

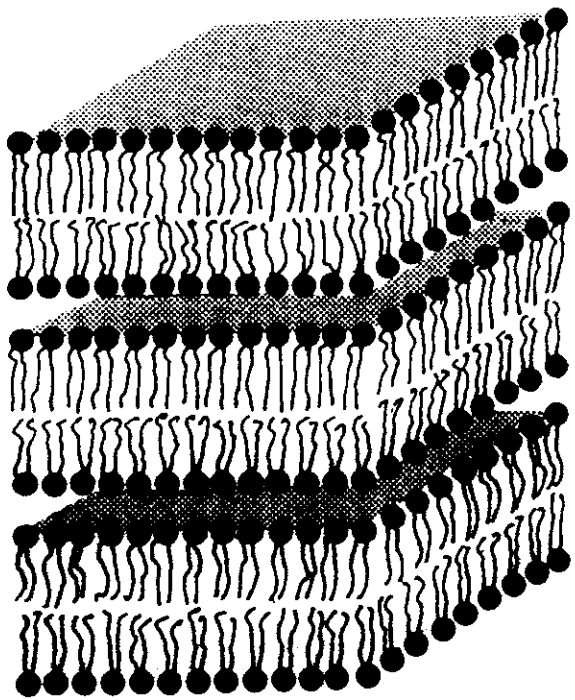
p6m



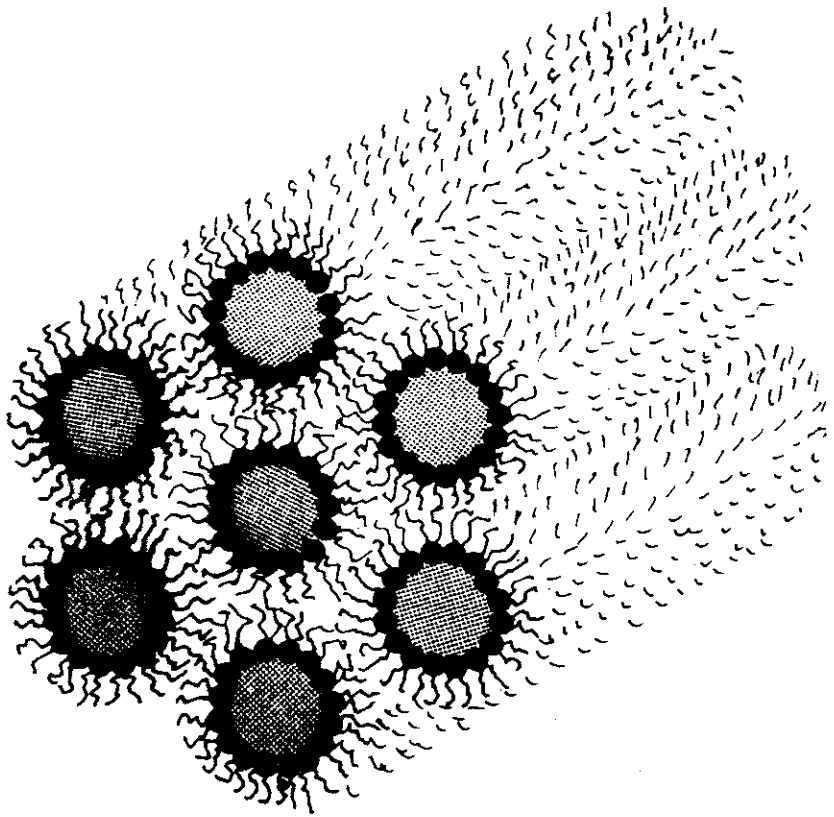



Inverse
Micellar
Solution
a
H_α
b
L_α
c
H_1
d
Micellar
Solution
- ← Mean interfacial curvature → +

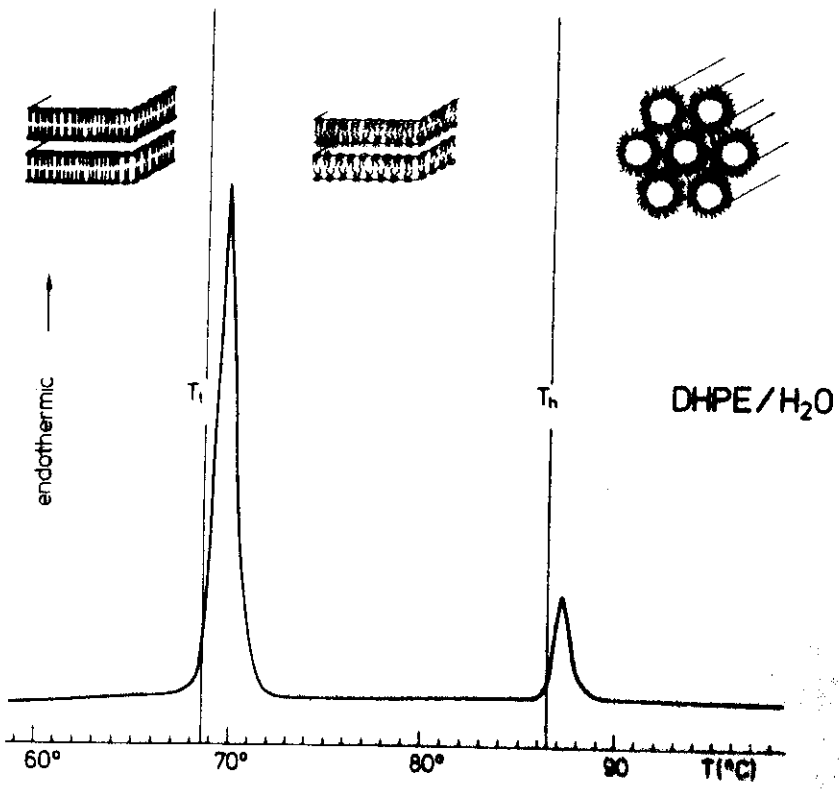

H2O
T

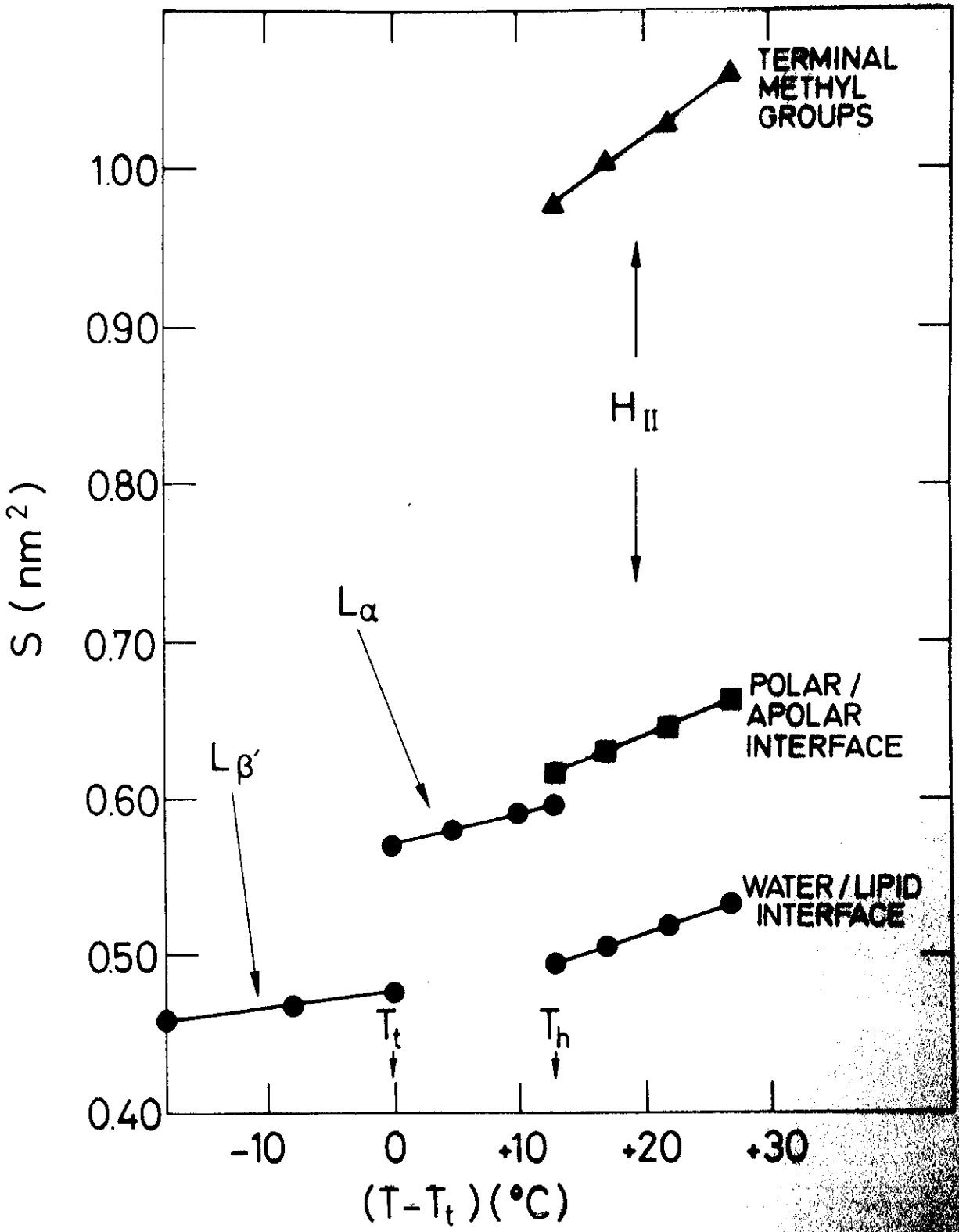


LAMELLAR L_α

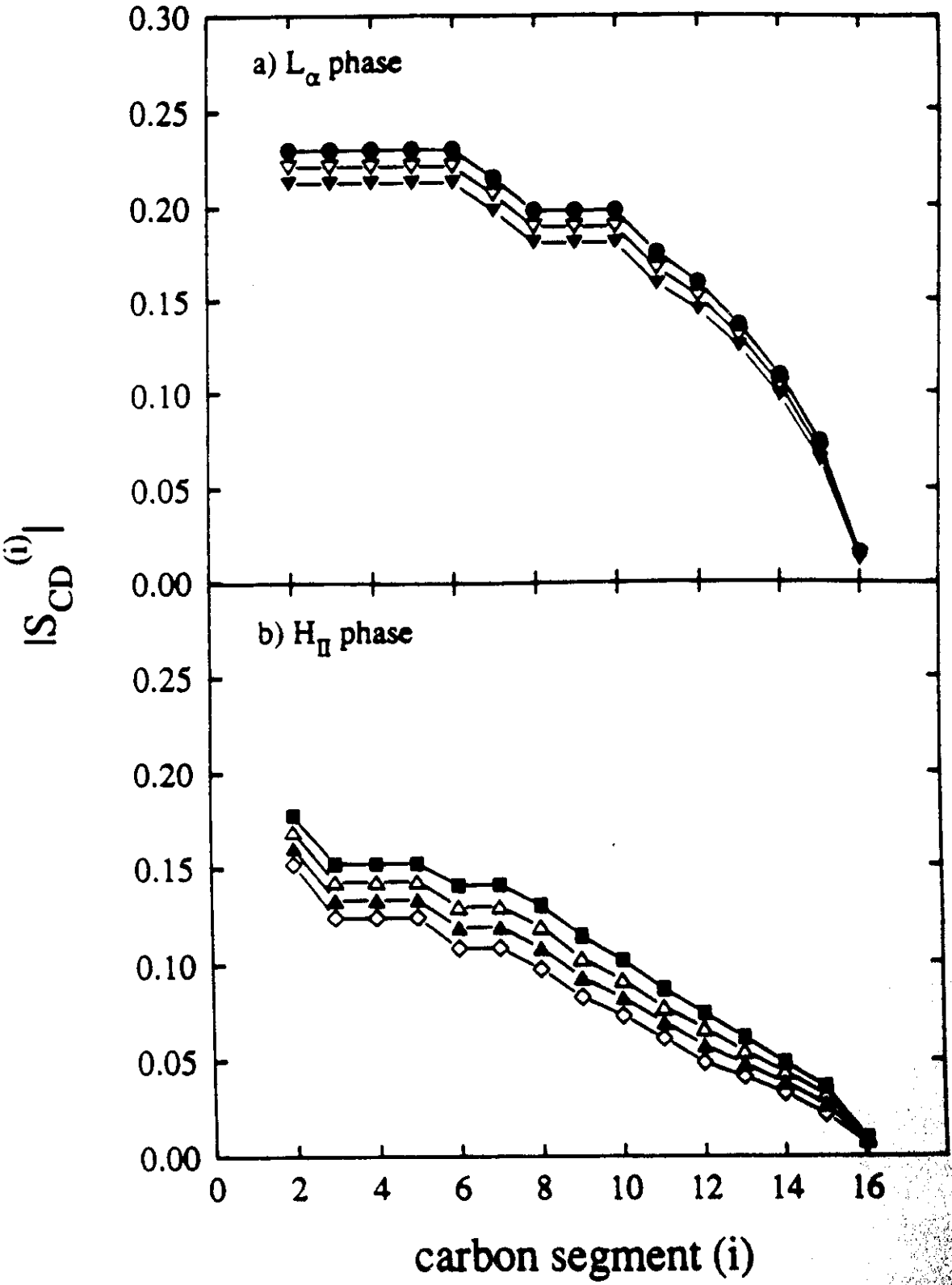


HEXAGONAL H_{II}

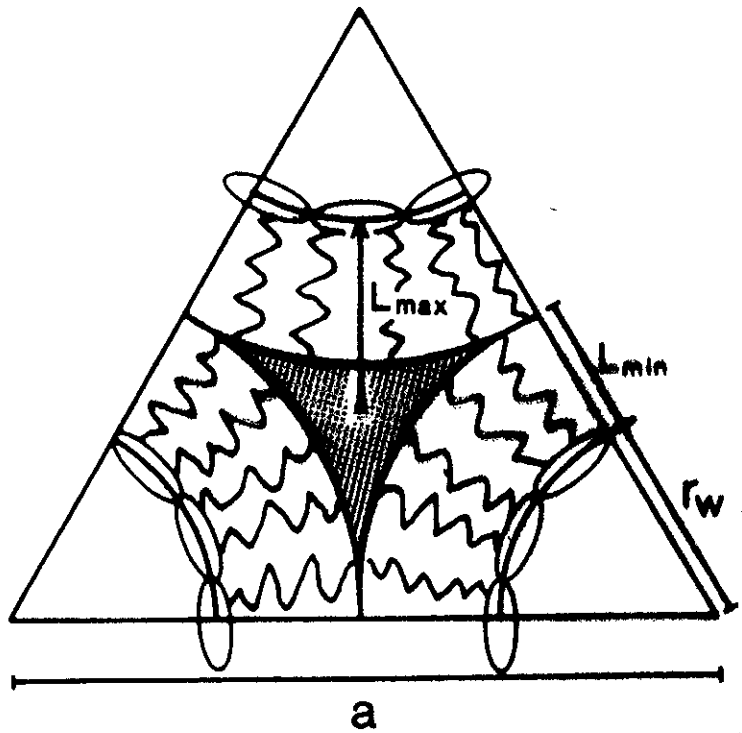

endothermic
T_l
T_h
DHPE/H_2O
60°
70°
80°
90
T(°C)

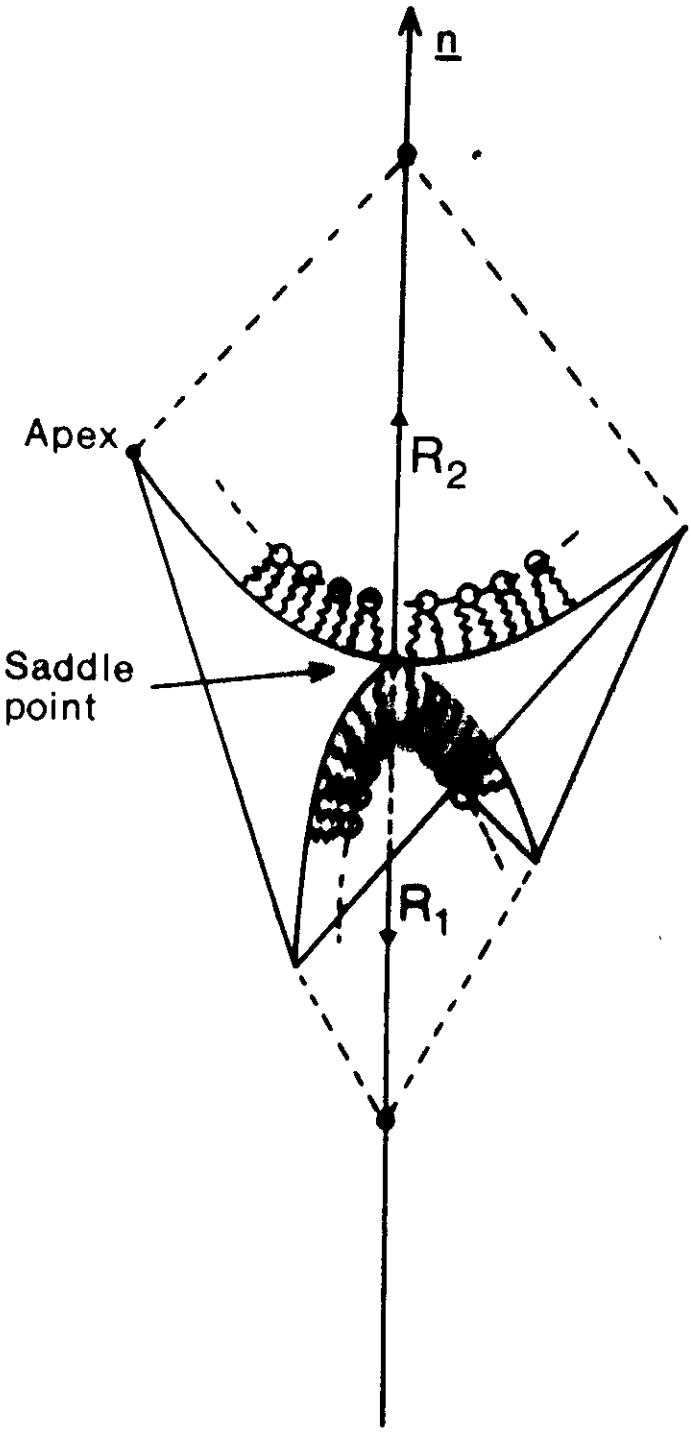

TERMINAL METHYL GROUPS
1.00
0.90
0.80
0.70
0.60
0.50
0.40
S (nm^2)
H_{II}
L_α
$L_{\beta'}$
POLAR / APOLAR INTERFACE
WATER / LIPID INTERFACE
T_t
T_h
-10
0
+10
+20
+30
(T-T_t) (°C)

Order parameter profiles of PLPE in the L_α and H_{II} phases



From: R. L. Thurmond et al., Biochemistry, 1993, 32, 5394-5410


Lmax
Lmin
rw
a

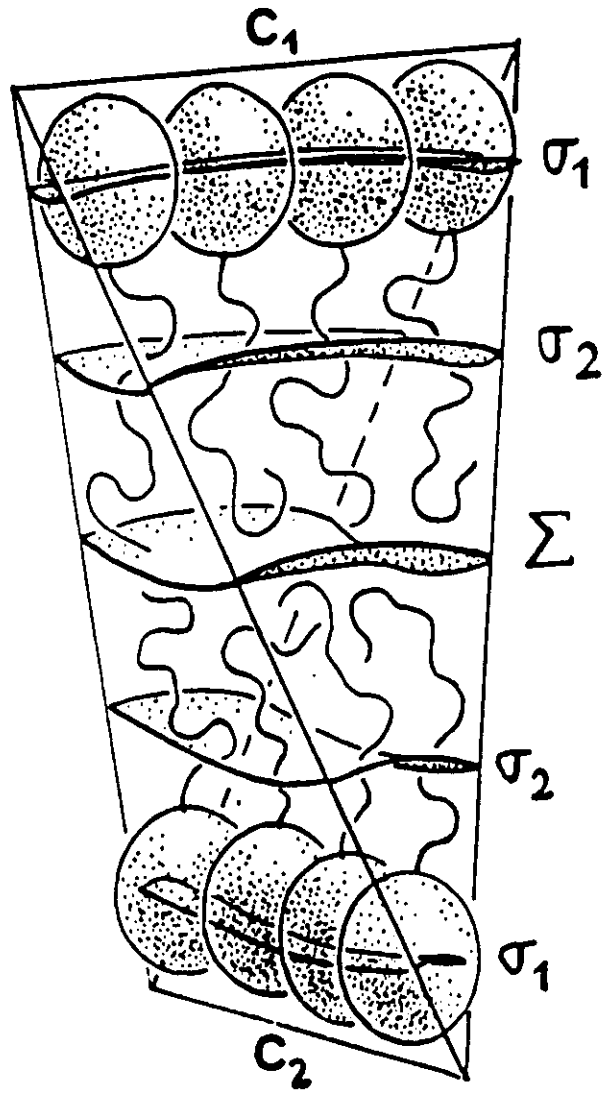


$c_1 < 0$
$c_2 > 0$

$\underline{K < 0}$

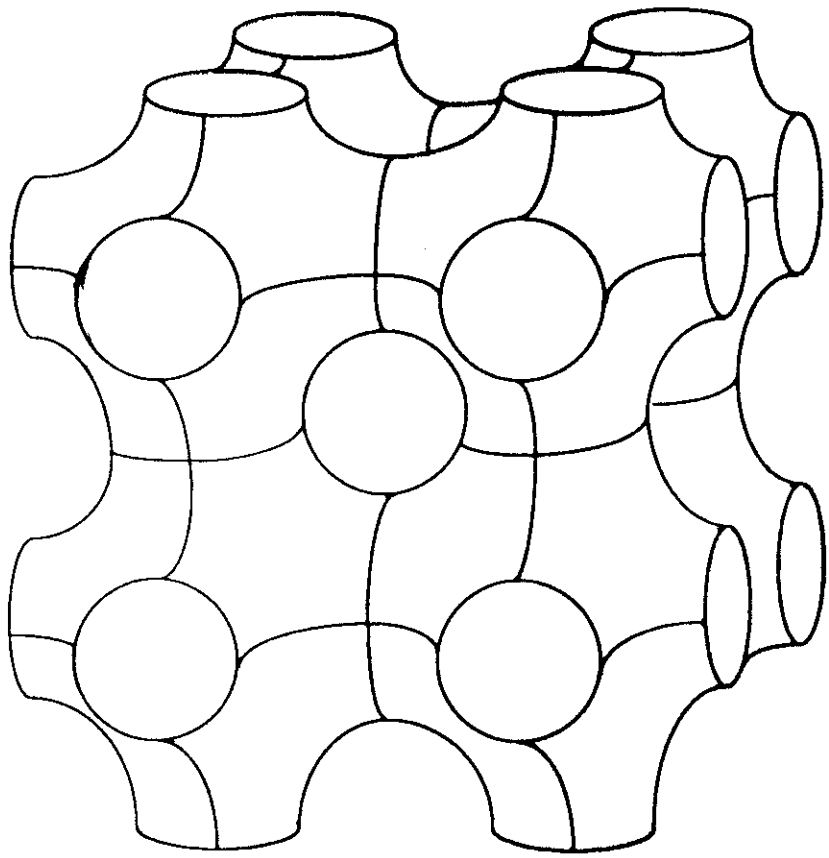
$(H <$ or $>$ or $= 0)$

Saddle deformation of a bilayer

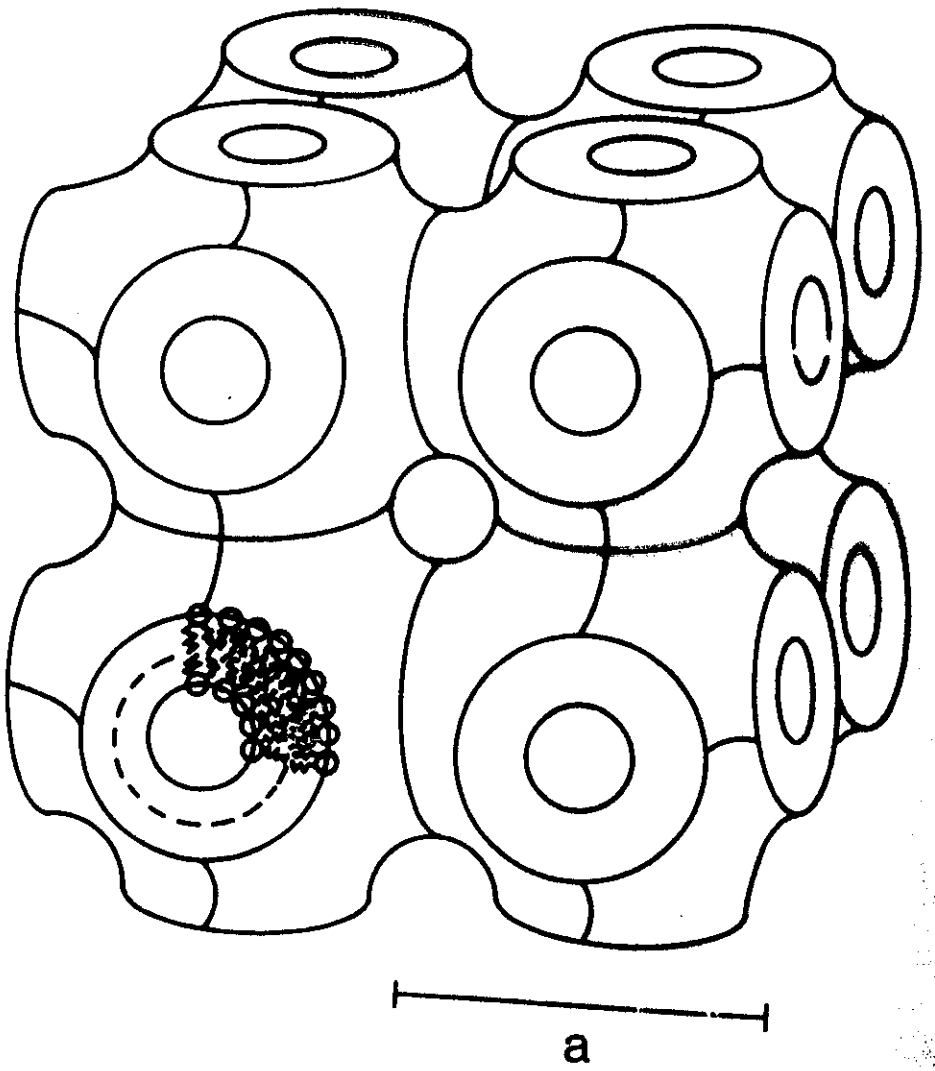


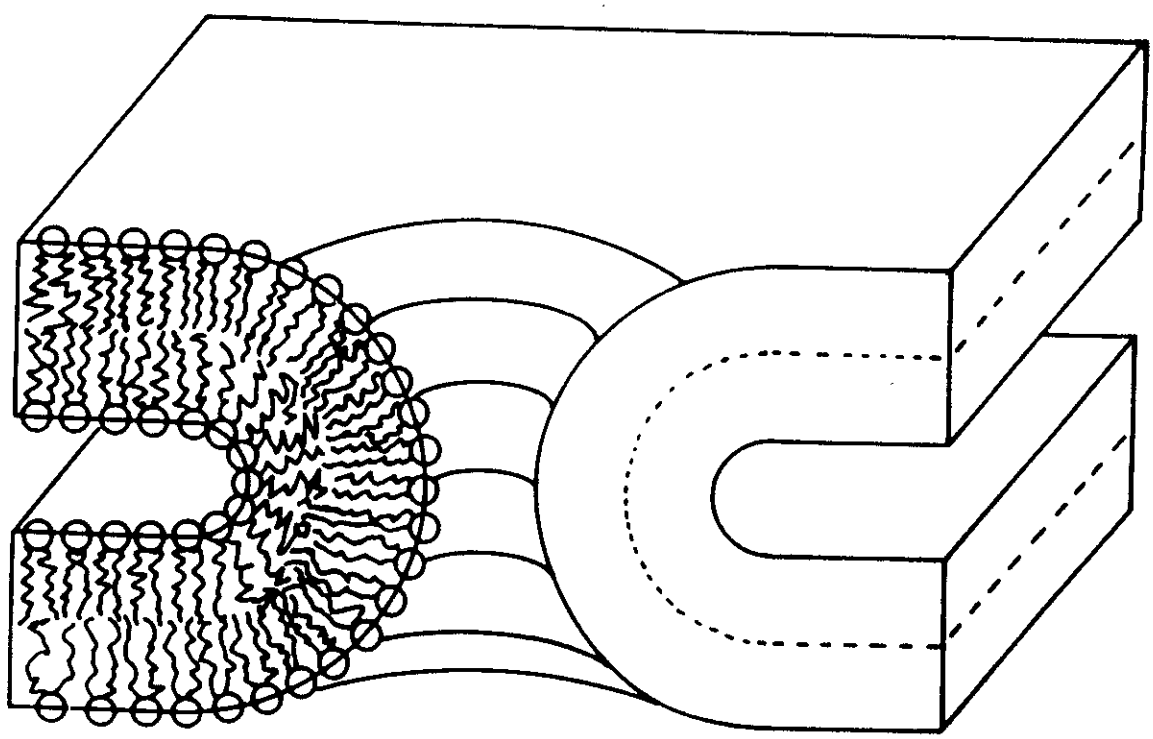
From: Y. Bouligand, J. Phys. (Paris), 1990, 51(C7), 35-52

Schwarz's P-surface ($Im\bar{3}m$)

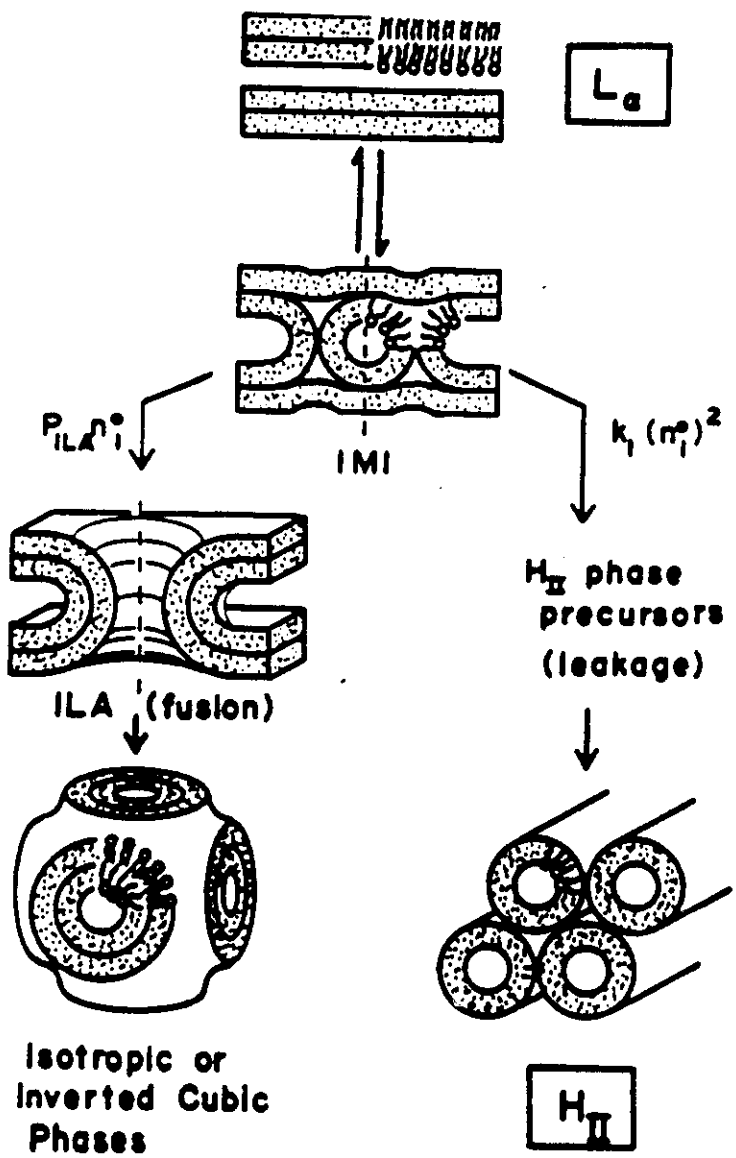


$Im3m$ (Q^{229})



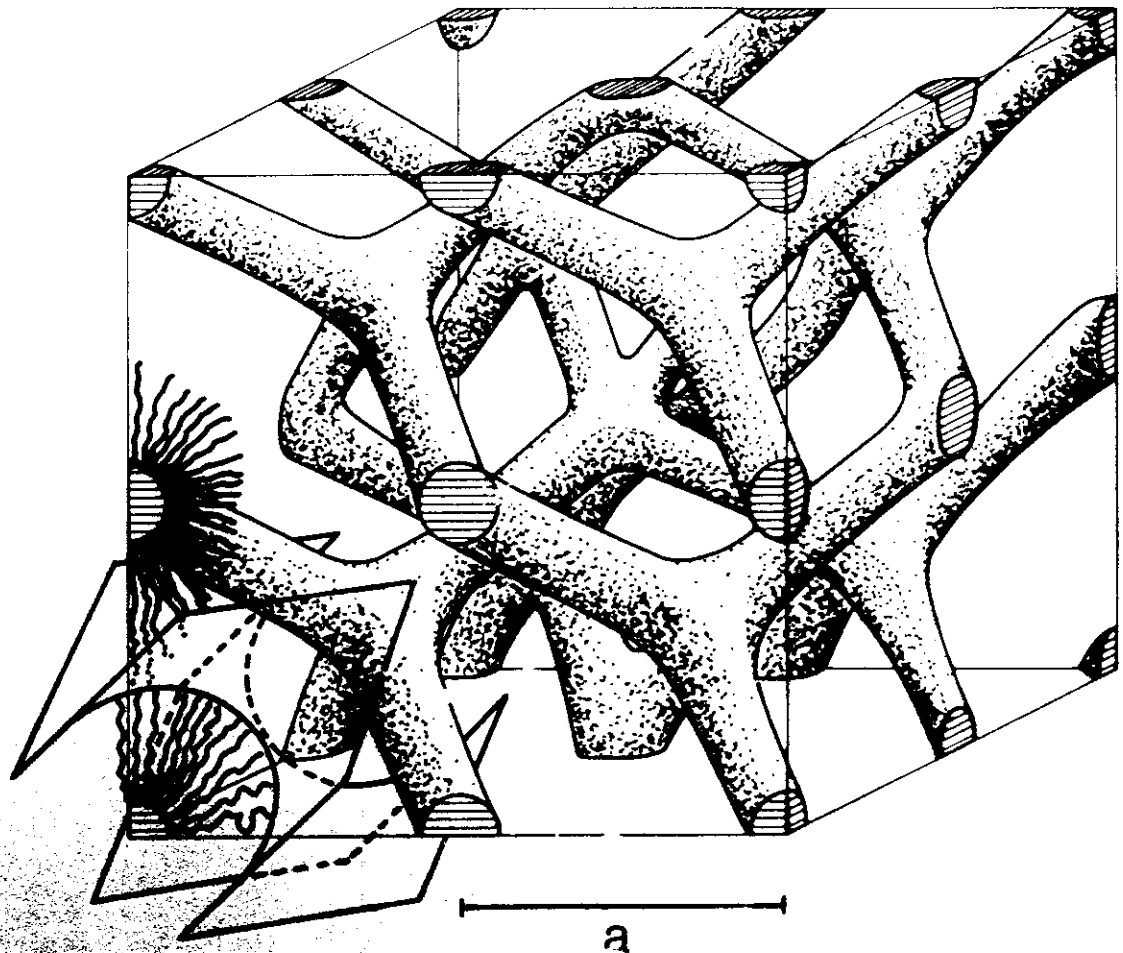


Formation paths of inverse phases



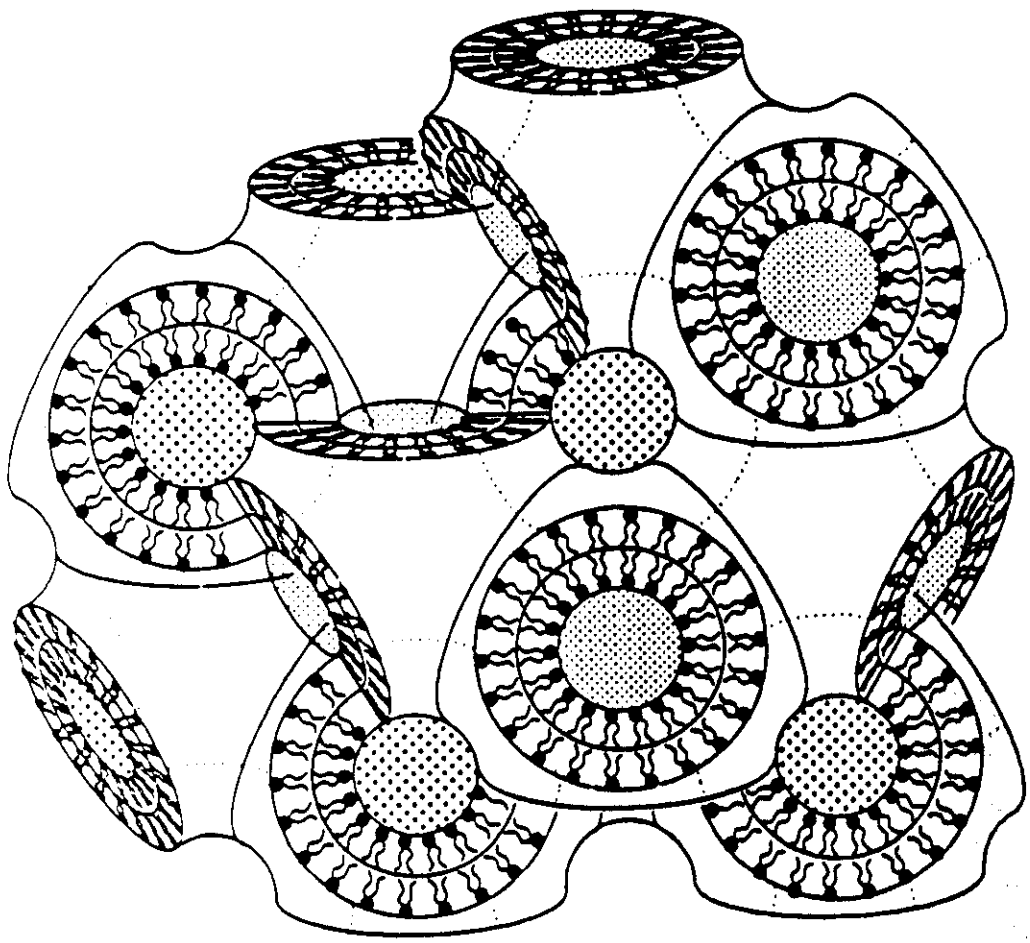
From: D. P. Siegel et al., Biophys. J., 1989, 56, 161-169

Pn 3m (Q^{224})



Inverse bicontinuous cubic phases

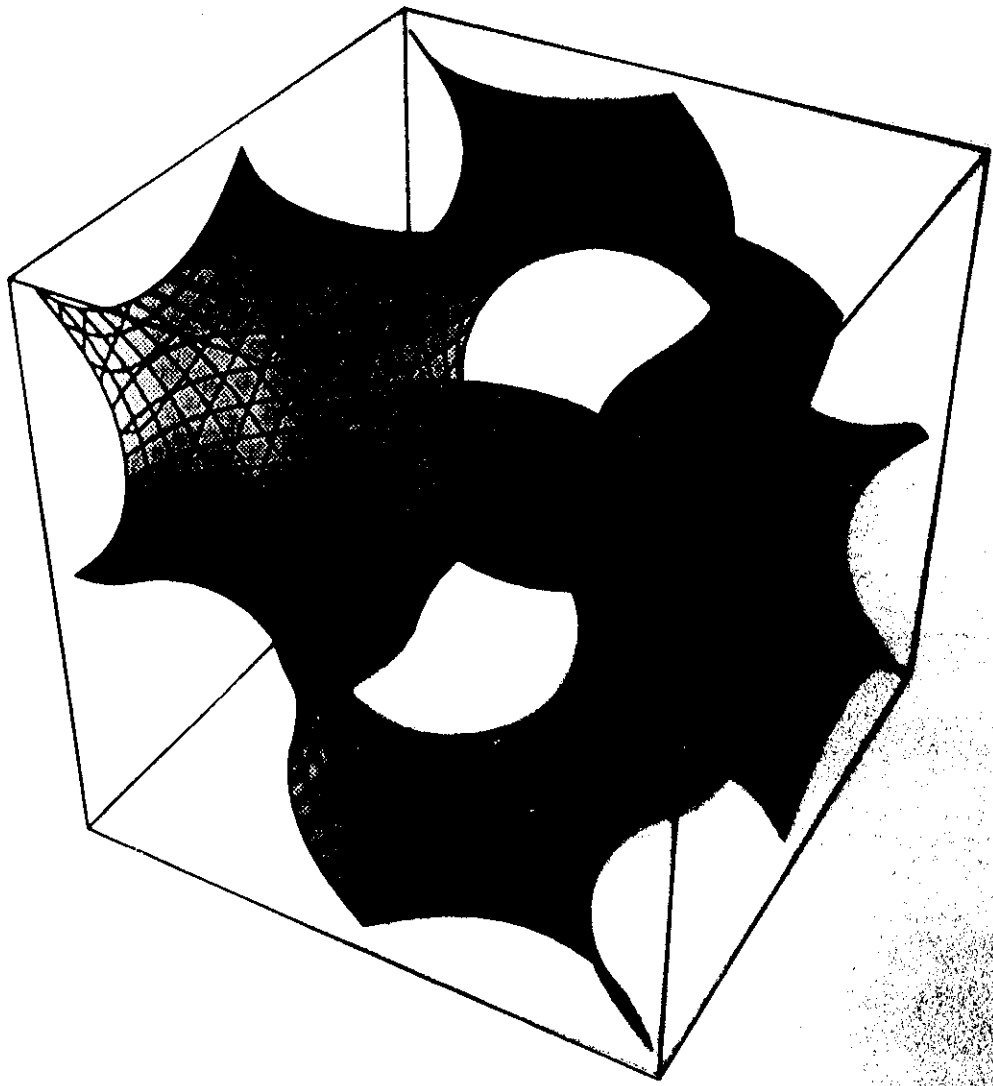
Pn3m (Q224)



From: M. W. Tate et al., Chem. Phys. Lipids, 1991, 57, 147-164

Gyroid Minimal Surface

(Nodal Approximation)



Ia 3d