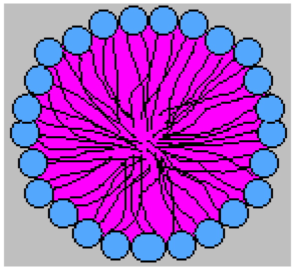
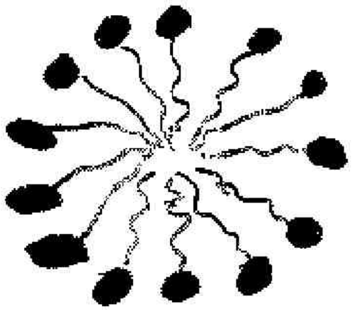
Lipid Self-assembly

Self-assembly occurs due to the thermodynamics, if the phospholipids are in water (or other polar solution) the tails will want to be 'away' from the solution. They could all go to the top (like oil on water), or they could have the tails point toward each other. With the tails pointing toward each other, this could result in 2 different forms.

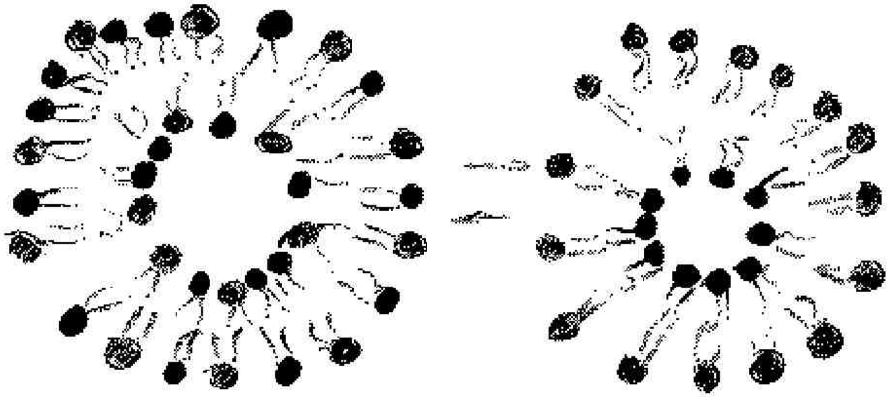
First would be a micelle which would like a ball with the phospholipid heads on the outside and the tails pointing together like this or in the form of a lipid bilayer:





Micelle
(Single chain)

Mixture of lipids in bilayers



homogeneous

segmented

Possibility of lateral phase
separation.

Micelles

Are made of single chain amphiphiles

Are aggregates with polar head groups exposed to the surface in contact with water and the hydrocarbon portion clumped together.

Micelle interior

Similar to pure hydrocarbon solution
Comparison of free energy of transfer

Water to micelle interior				Water to liquid hydrocarbon		
	ΔG	ΔH	ΔS	ΔG	ΔH	ΔS
Ethane	-3.45	+2.0	18.3	-3.9	+2.5	21
Propane	-4.23	+1.0	17.5	-4.9	+1.7	22
Butane	-5.13	+0.0	17.2	-5.9	+0.8	23

These data indicate that the micelle interior is similar to hydrocarbon

The size and the shape of a micelle depends on the ratio of the surface area

$$A_s$$

to the number of head groups

$$N_h$$

This is due to the importance of repulsive component. As the size of the micelle increases the ratio A_s/N_h decreases.

If l is the radius of a micelle, we can assume

$$l=aN_c=a'N_h$$

for single chain amphiphiles,

N_c is the number of hydrocarbon atoms per chain.

$$A_s=4\pi l^2=4\pi a^2(N_c)^2 \qquad \text{(sphere)}$$

$$V = 4/3\pi l^3 = 4/3\pi a^3 (N_c)^3$$

$$A_s/N_h = 3b/a$$

For a cylinder

$$A_s/N_h = 2b/a$$

For a large planar bilayer

$$A_s/N_h = b/a$$

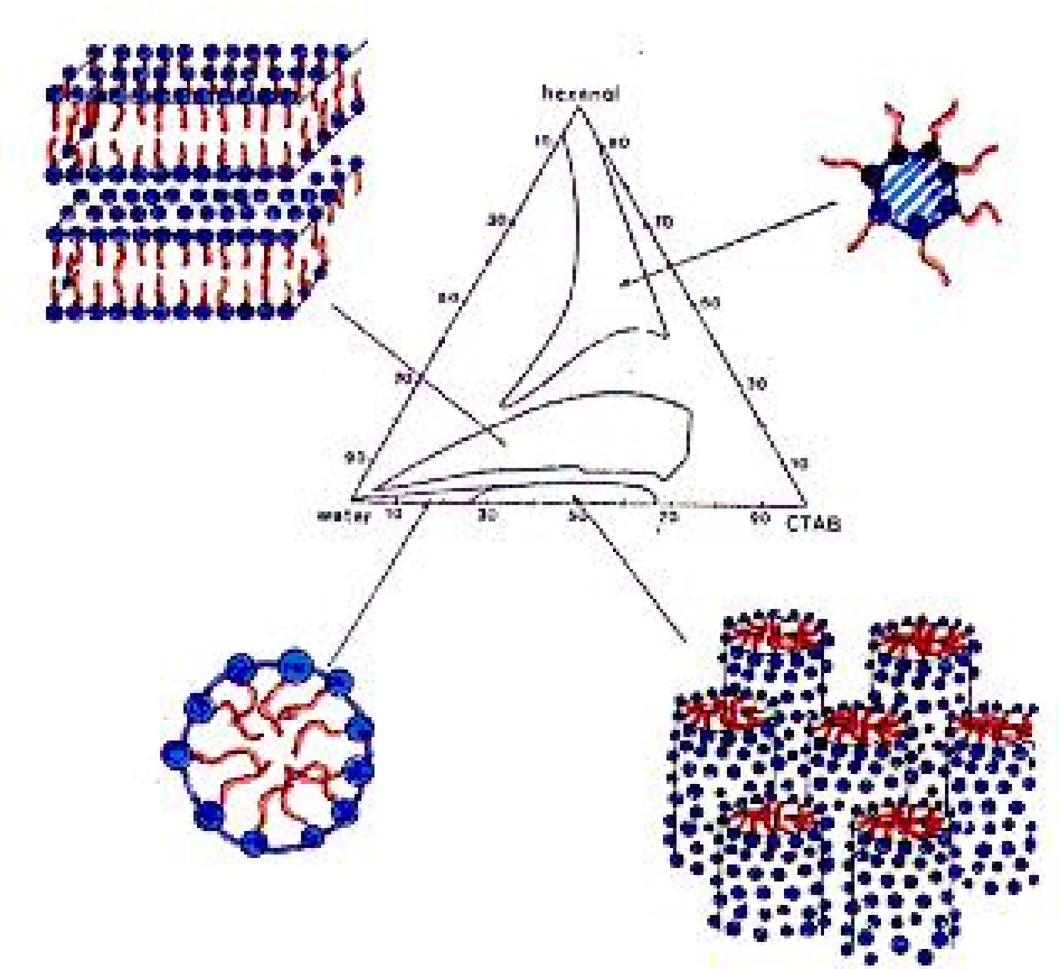
The larger the number of molecules per micelle, the more planar the structure of the micelle will be.

Reverse Micelles

In some organic solvents, amphiphiles form a micelle in which the charged groups are in the interior.

Driving force? Some water in the micelle interior

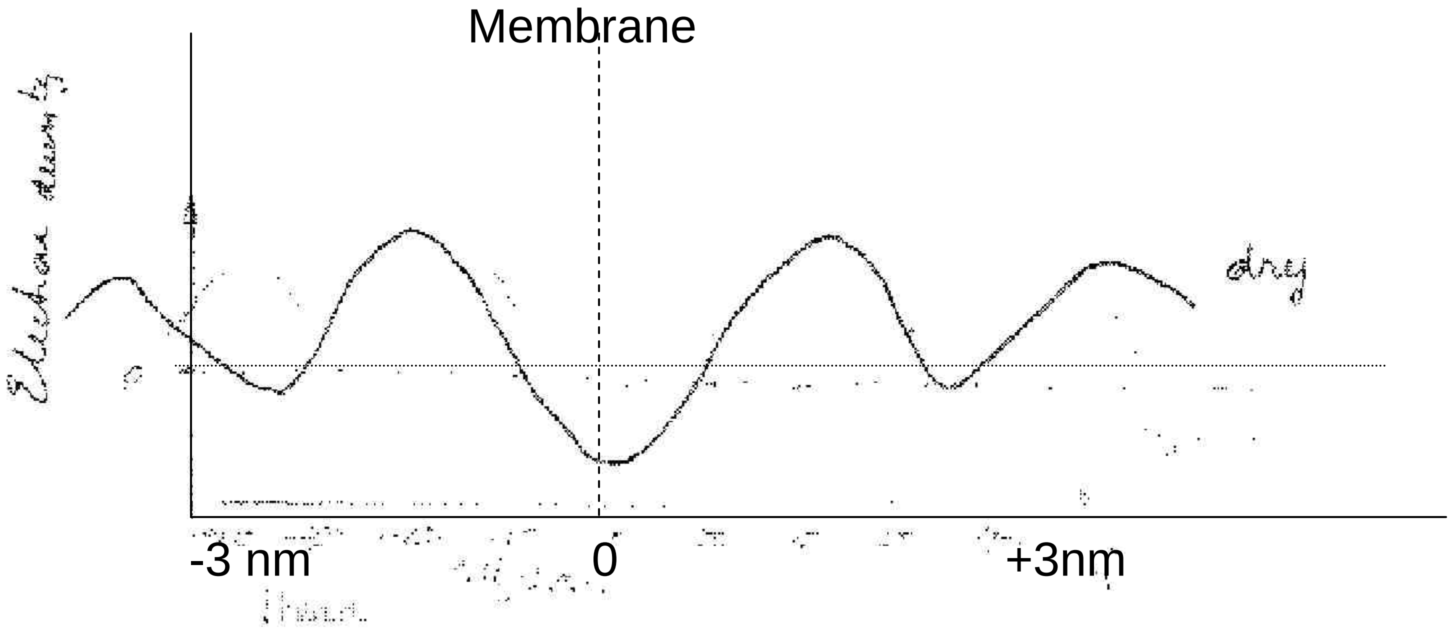
Micelles and Microemulsions



Amphiphilic molecules spontaneously self-assemble in solution to form a variety of aggregates. In our research we focus on two main topics: (i) the use of surfactant solutions as interesting and versatile model systems in polymer and colloid physics (micelles as equilibrium polymers and polyelectrolytes); and (ii) on the various non-equilibrium or metastable states and the pathway and kinetics associated with structural transitions and phase separation.

Bilayers

Structural and dynamical features of bilayers

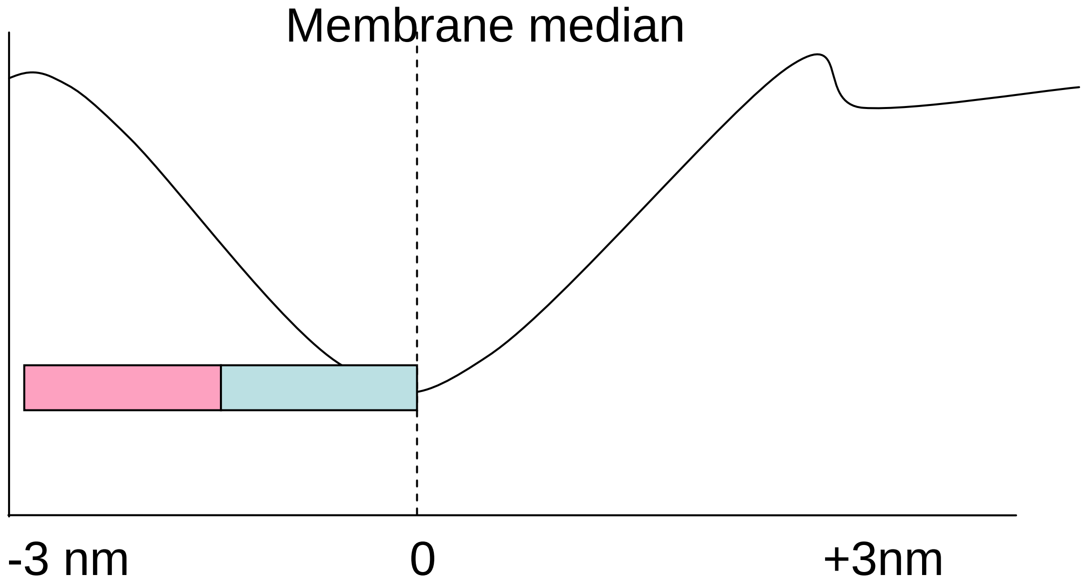


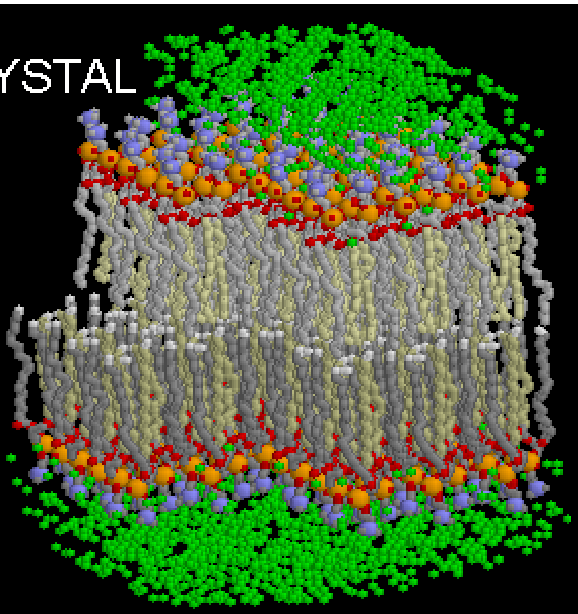
(from x-ray diffraction)

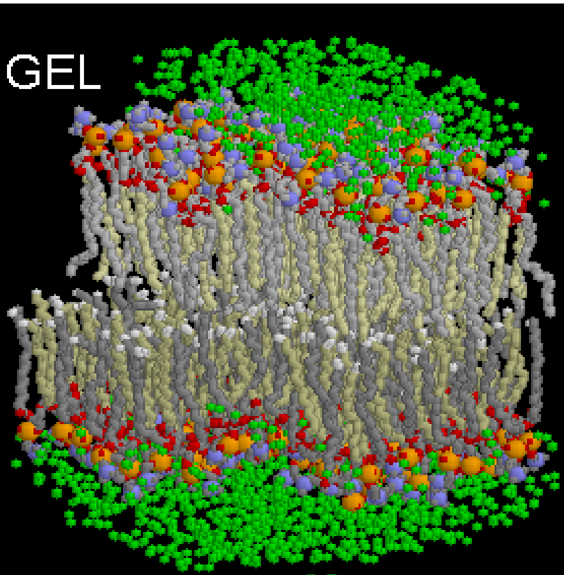
The minimum in electron density is due to CH_3 groups. They have the lowest density.

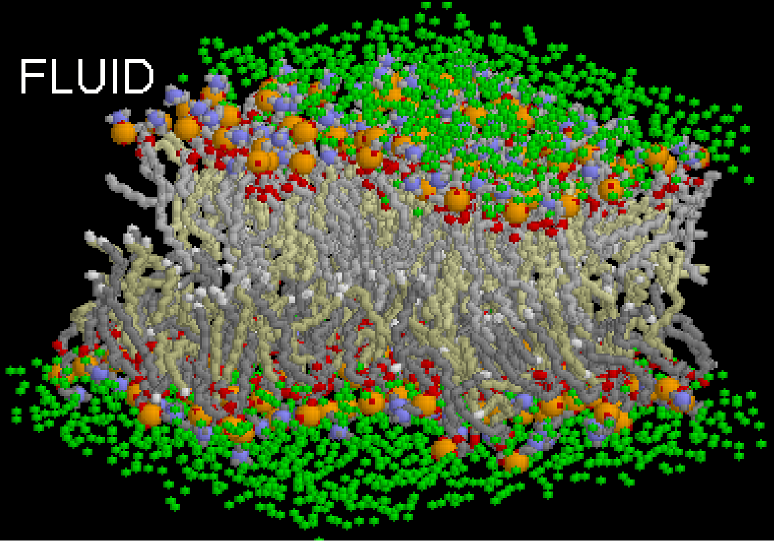
The hydrocarbon chains are not interdigitated. They are oriented perpendicular to the layer plane. (Effect of cholesterol)

Penetration of water (from EPR studies): Plot of polarity index   Water molecules penetrate a lot inside the bilayer




CRYSTAL


GEL


FLUID

Molecular Dynamics Simulation
of Phosphatidyl Choline Bilayer

Carbon/Palmitic Oleic

Nitrogen Oxygen Phosphorus

Water Oxygens

H Heller, M Schaefer, K Schulten,
J Phys Chem 97:8343, 1993.
RasMol Image by E Martz

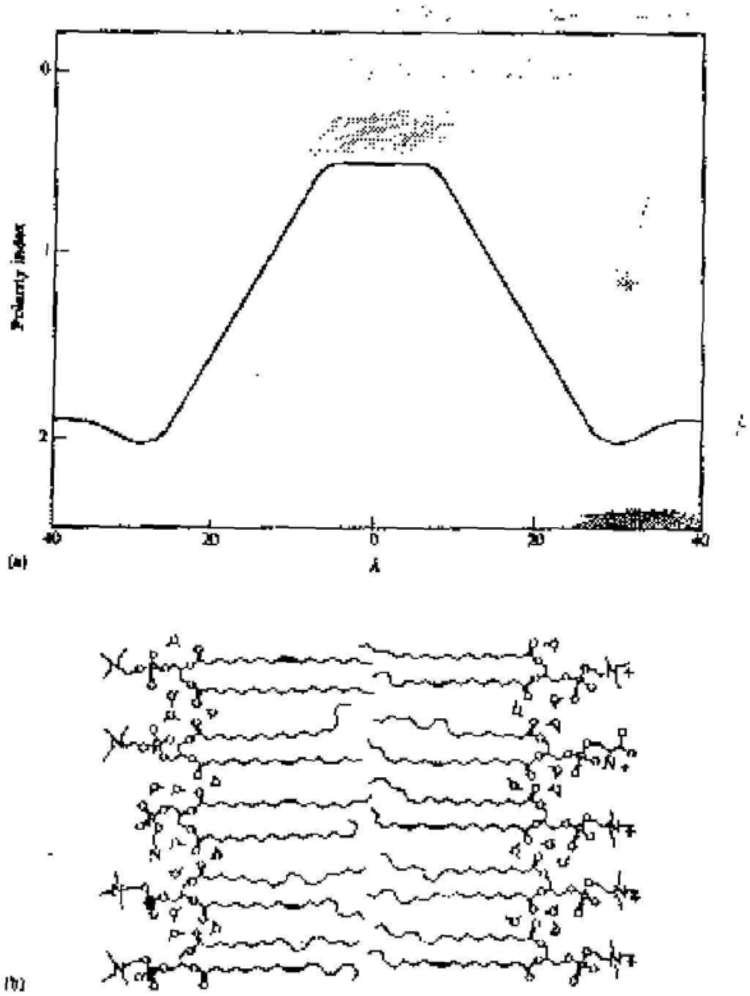


Figure 25-28

The hydrophobic barrier in a lipid bilayer. (a) Polarity index across the bilayer. (b) A schematic view of the bilayer. [After O. H. Griffith et al., *J. Membrane Biol.* 15:159 (1974).]

Time averaged transbilayer "*structure*" of a lipid functional group

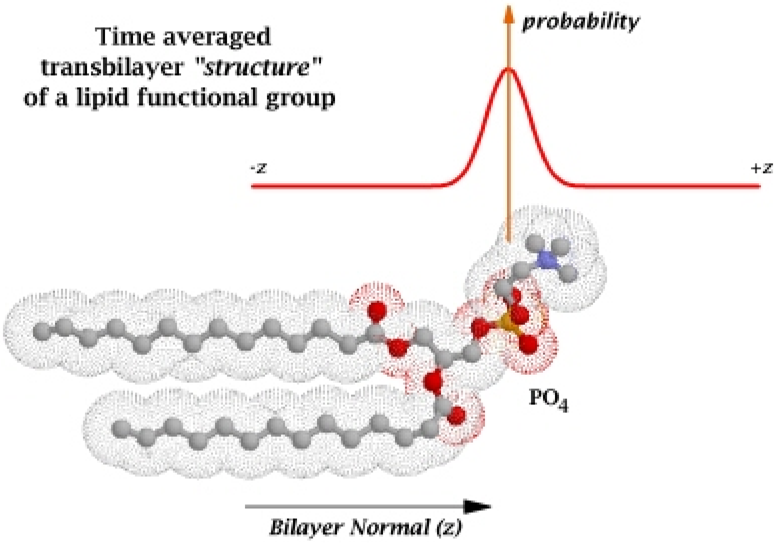


Figure 2. (A) The Structure of a Fluid DOPC Bilayer and (B) Its Polarity Profile (go to Fig. 1 or Fig. 3)

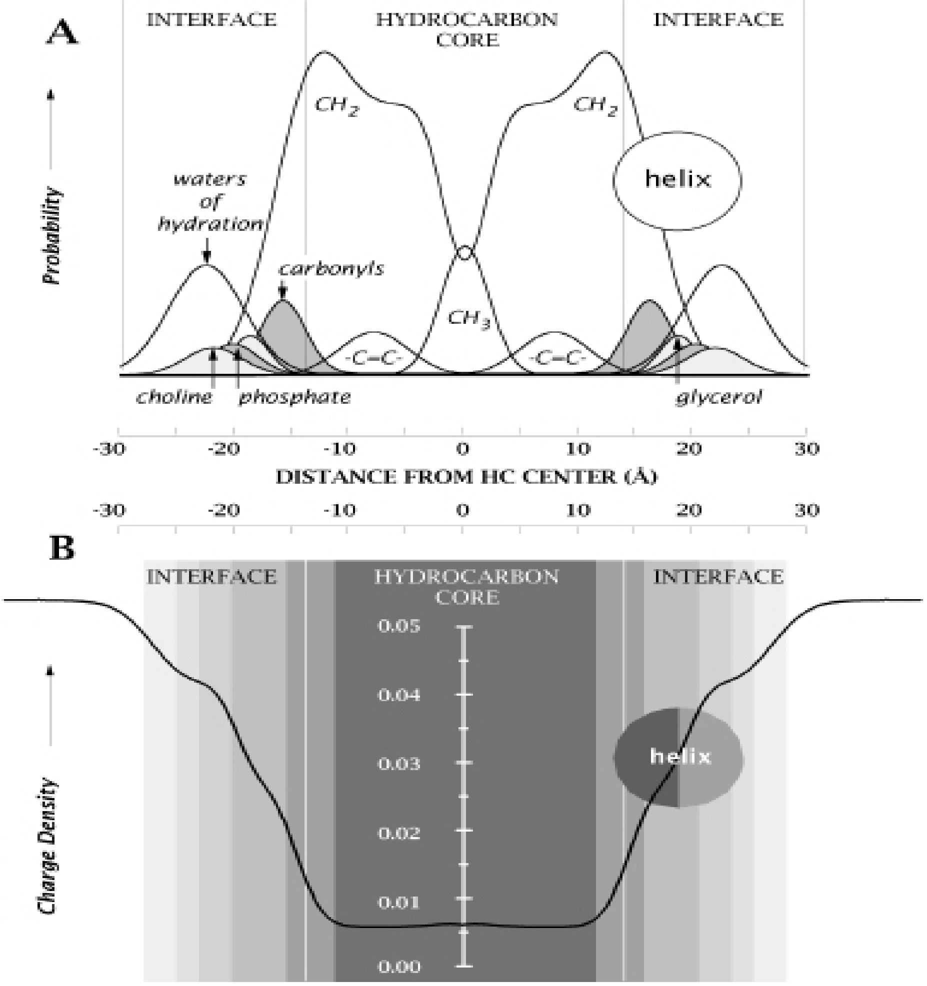
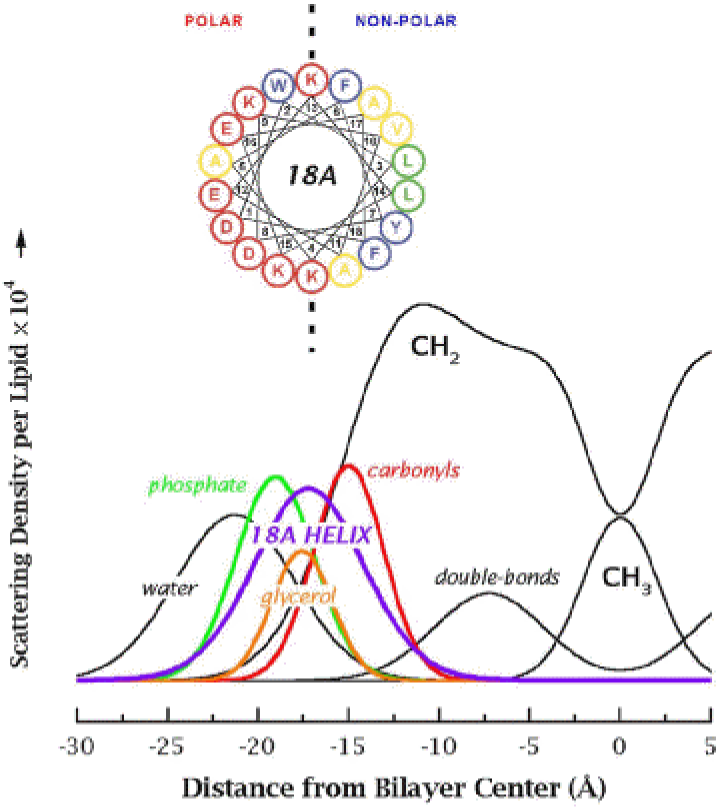


Figure 3. An Amphipathic Alpha-Helix in the Fluid DOPC Bilayer (go to Fig. 1 or Fig. 2)

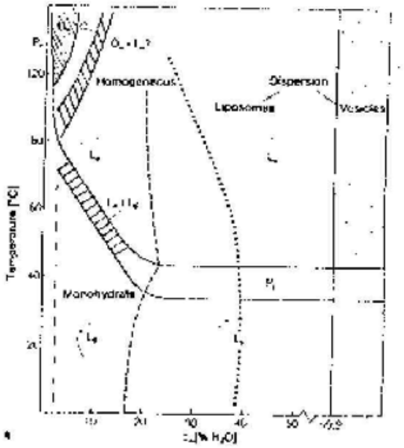


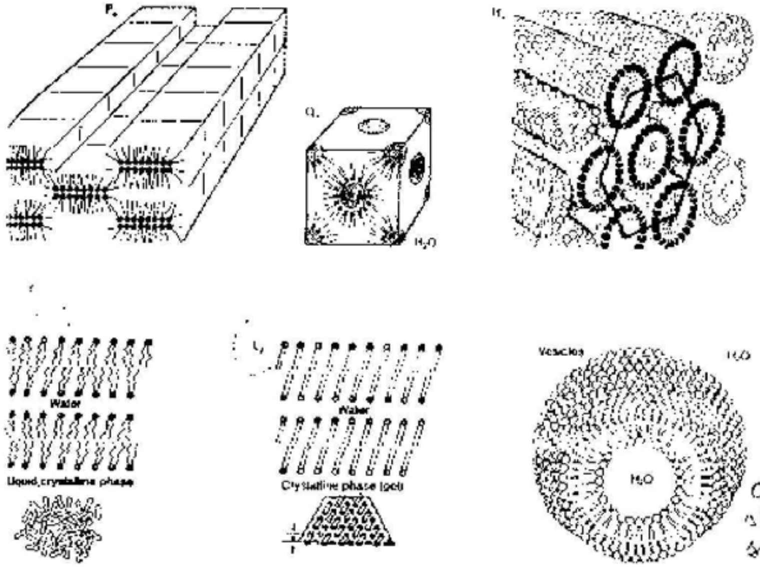
Flip-flop transitions and lateral diffusion

F-F are very rare
lateral diffusion is relatively fast (EPR) 1.8$\mu m^2/s$

Bilayers undergo a thermal transition between a low temperature gel-like ordered state and a high temperature liquid-crystalline state

II.7. a Phase diagram of dipalmitoylphosphatidylcholine (PC) in water. The abscissa is the concentration of water, with pure PC at the left. The lamellar phases L_α and L_β are liquid and spond to the smectic phase A of thermotropic liquid crystals. L_β are crystalline phases in which the lipid chains form a gular lattice. Dashed curve shows the maximal water absorption a vapor, and dotted curve the corresponding absorption from id water. To the right of the latter curve the lipid-water system is ogeneous. Below 2.5 % water there could be coexistence between ohydrate and water free, crystalline lipid. The shaded area ote regions of coexistence between L_β and L_α and between Q_α and For $c_w < 20\%$ and at high temperatures there are several lyotropic d crystal states, such as the hexagonal phase H_α, the cubic phase d the ribbon phase P_α, whose structures are shown schematically (Powers and Pershan, Biophys. J. 20, 137 (1977); Chapman et al., m. Phys. Lipid 1, 445 (1971); Jürgens, F., Dissertation, University lm, 1981)





Onion
shell
structure

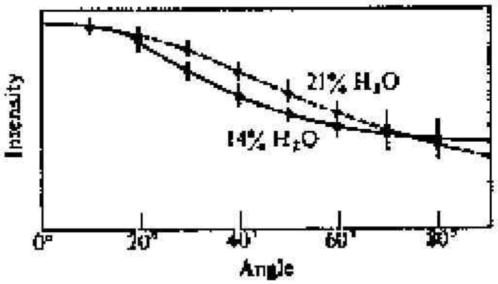


Figure 25-11

Angular variation of intensity of the hydrocarbon-chain band of egg lecithin bilayers. The radially integrated intensity of the 4.6 Å diffraction band is shown from the equator (0°) to the meridian (90°). [After Y. K. Levine and M. H. F. Wilkins, *Nature New Biology* 230:69 (1971).]

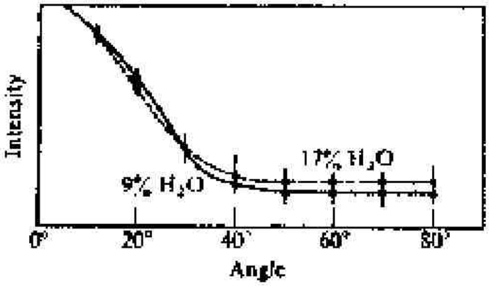


Figure 25-12

Angular variation of intensity of the hydrocarbon-chain band of egg lecithin bilayers in the presence of cholesterol. The radially integrated intensity of the 4.75 Å diffraction band is shown from the equator (0°) to the meridian (90°). [After Y. K. Levine and M. H. F. Wilkins, *Nature New Biology* 230:69 (1971).]

Biological membranes

The fluid mosaic model
(Singer)

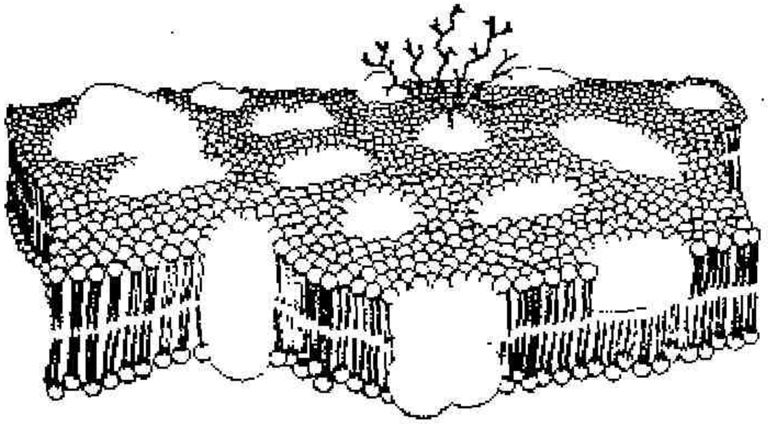


Figure 4-13

A general model for the structure of biological membranes. [After J. M. Clark, Jr., and R. L. Switzer, *Experimental Biochemistry*, 2nd ed. (San Francisco: W. H. Freeman and Company. Copyright © 1977).]

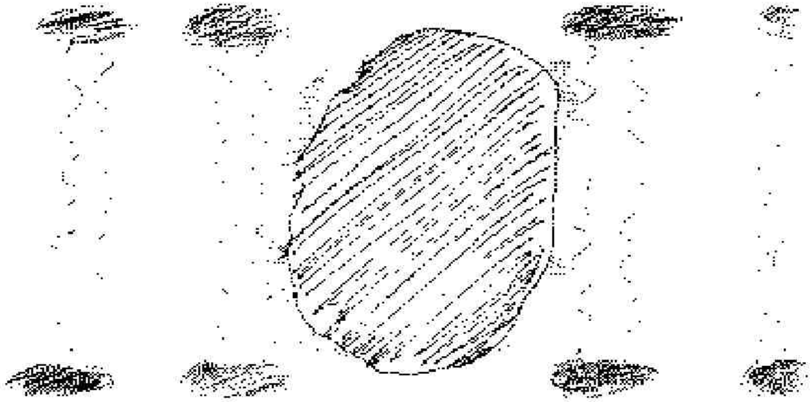
Composition

	Protein	Lipid	Carbohydrate
Myelin	18%	79%	3%
Erythrocite	48%	43%	8%
Choloroplast	70%	30%	(2%)
Mitochondrial	76%	24%	(1-2%)
Purple membrane	75%	25%	

Protein-lipid interactions

Lipids	Proteins
Hydrophobic tail	Non-polar aminoacid Side chains
Polar heads	Polar aminoacids

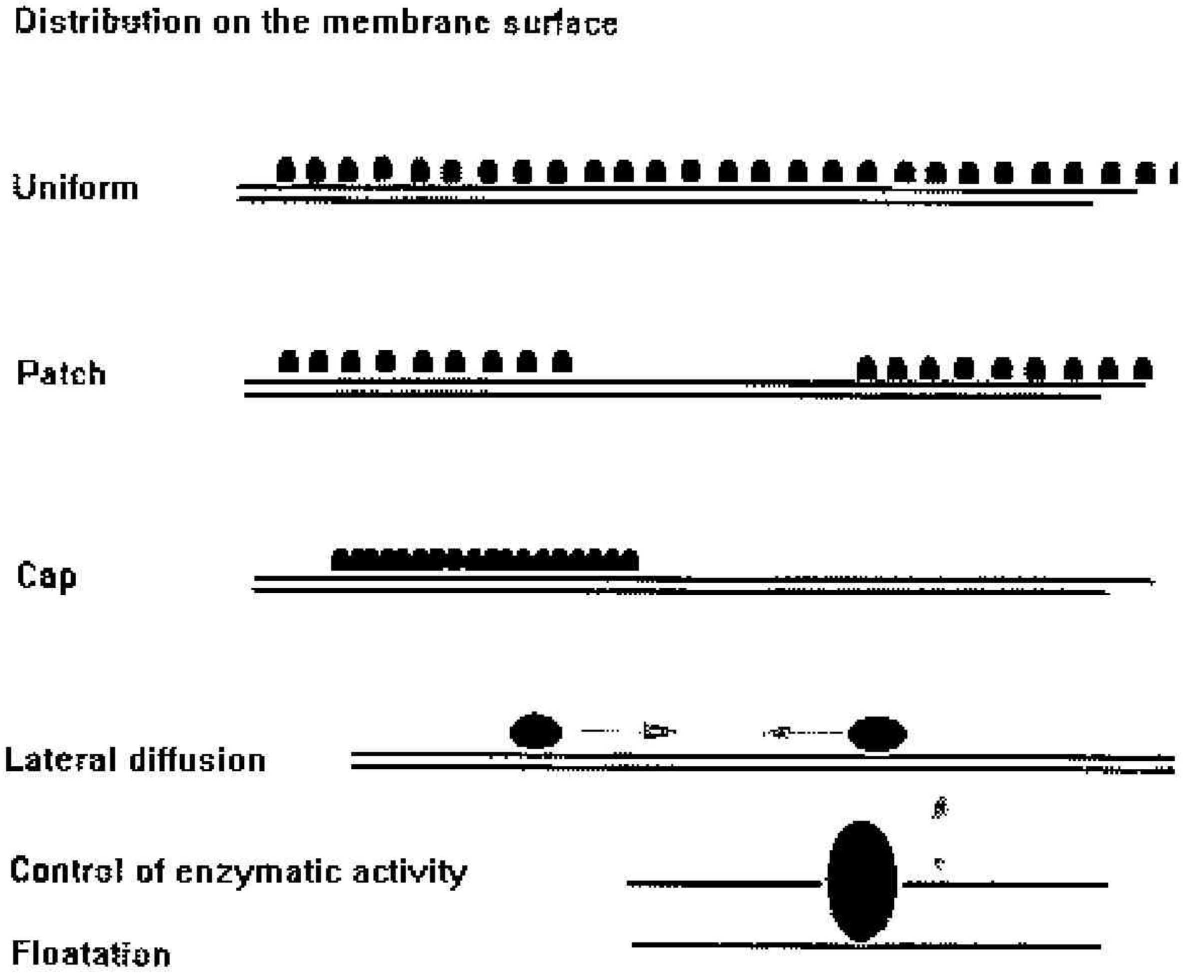
Protein -lipid interface

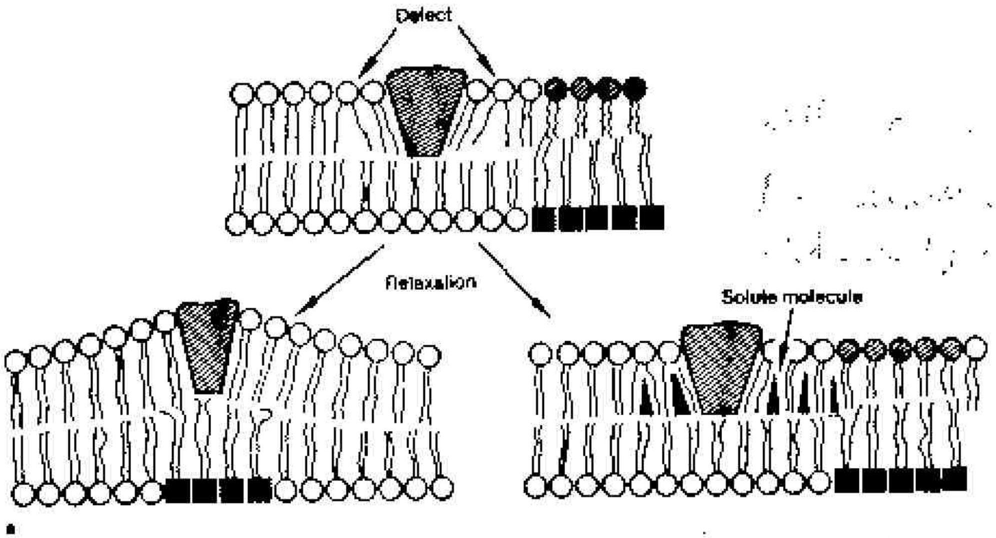


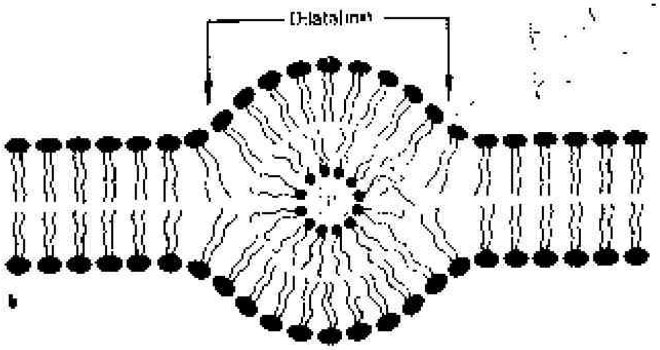
Perturbed sate
(similar to hydrocarbons?)

- Recognition of a particular lipid
- Penetration of lipids into the protein

Arrangement of Membrane proteins







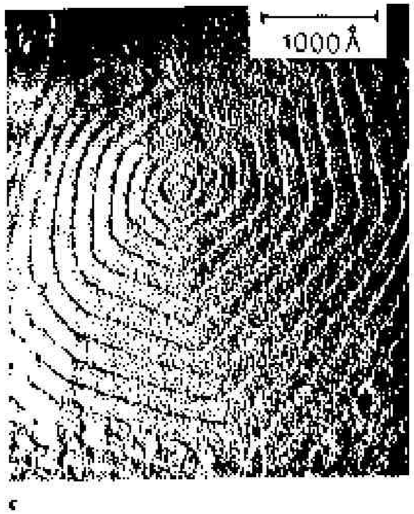
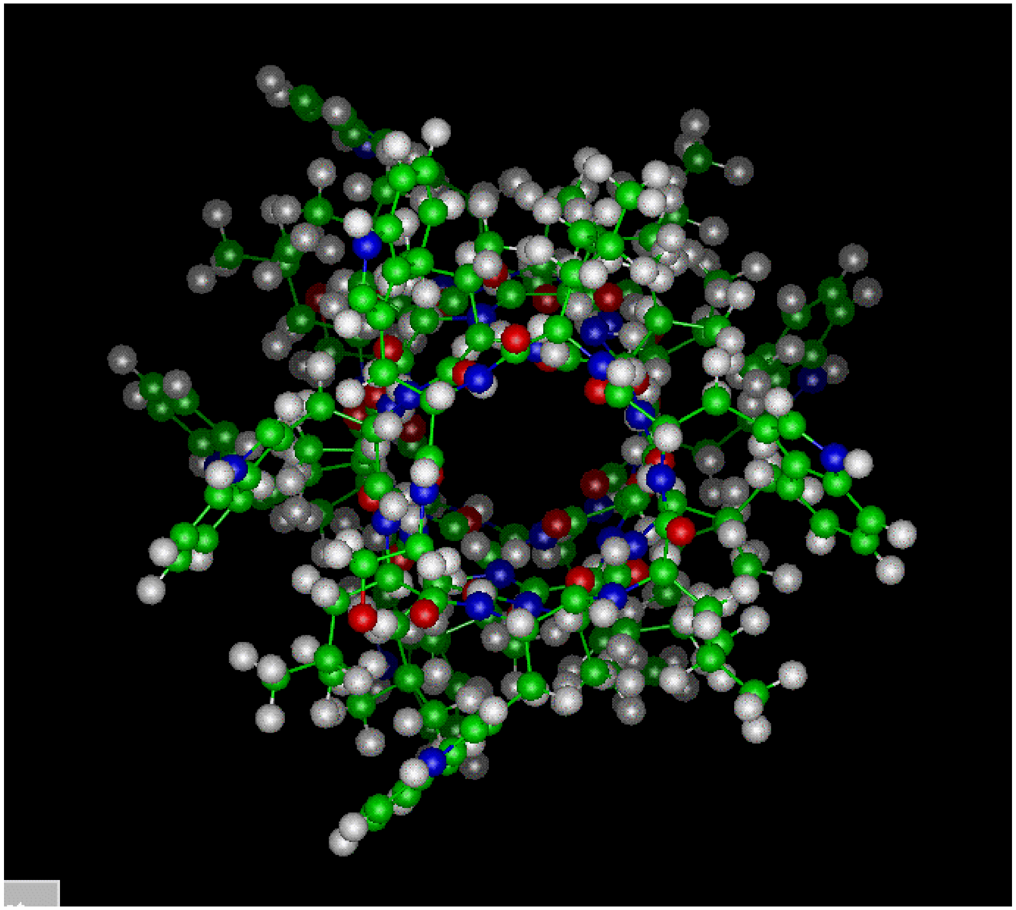
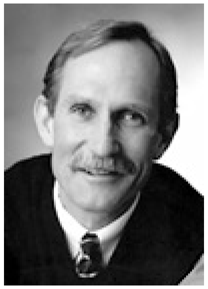


Fig. 12.21. **a** Schematic representation of two possible mechanisms for relaxation of elastic stress at orientation defects around a conical protein. *Left*: escape into the third dimension and subsequent redistribution of lipids in the lower monolayer. *Right*: incorporation of a swarm of foreign molecules. **b** Schematic representation of the intercalation of a protein between monolayers. Protein is enclosed in an inverted micelle. The intercalation leads to the formation of a dilation region inside the bilayer. **c** Electron microscope image of a freeze-etched DMPC bilayer below the main transition showing a defect structure which has been stabilized by the incorporation of 4 mol cholesterol. (cf. Fig. 12.8a where the defect line forms a spiral ra than closed hexagons)



Gramicidin channel

Aquaporin Channel



Peter Agre