Soft Condensed Matter

Keyser and Knowles
Lent 2023

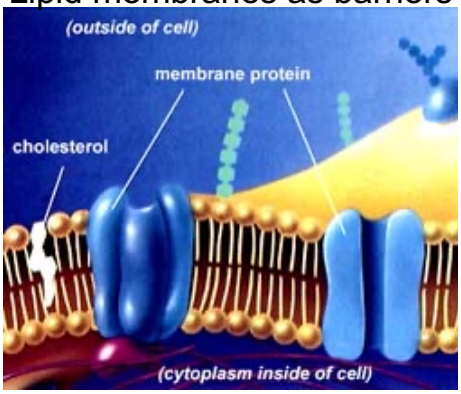
Ulrich Keyser (ufk20) & Tuomas Knowles (tpjk2)

Self Assembly II (Chapter 7)
Lecture 12 2/3/2023

Upcoming: Tue 7/3 9am, Thu 9/3 9am Tue 14/3 9am, Thu 16/3 9am

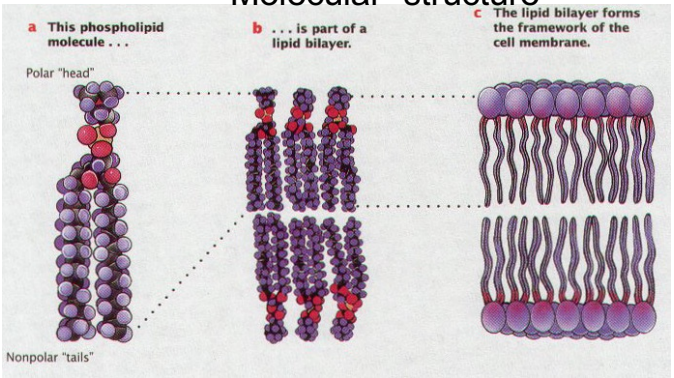
7.1 Cells are surrounded by membranes

Lipid membranes as barriers



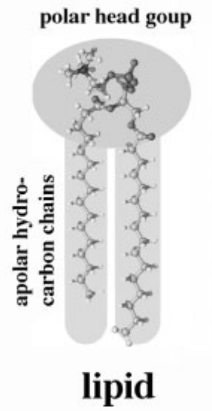
and scaffolds for proteins

"Molecular" structure



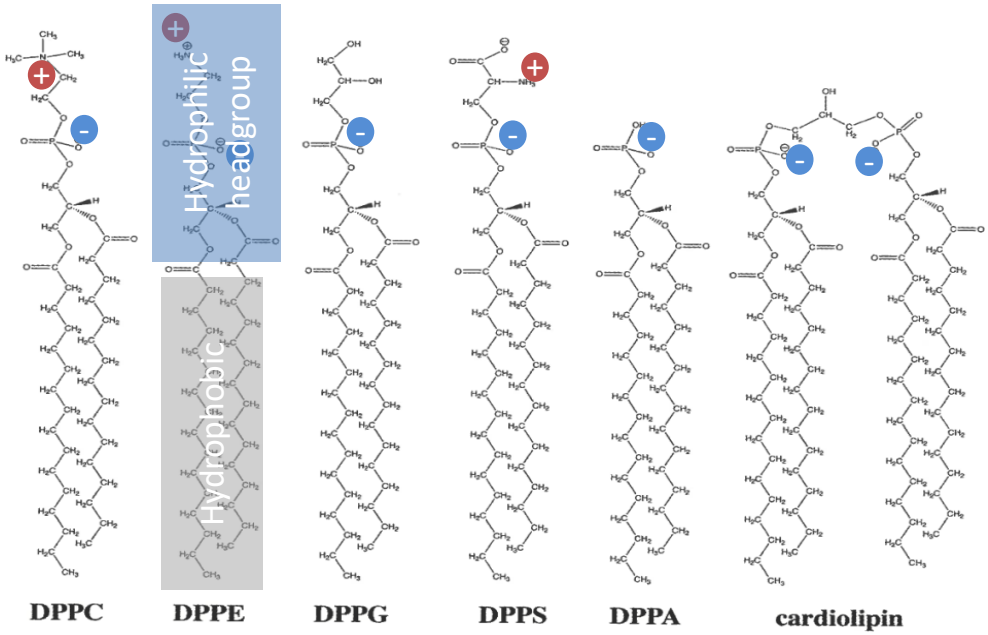
A bit of Chemistry …

7.1 Predominant lipid structure in biological systems



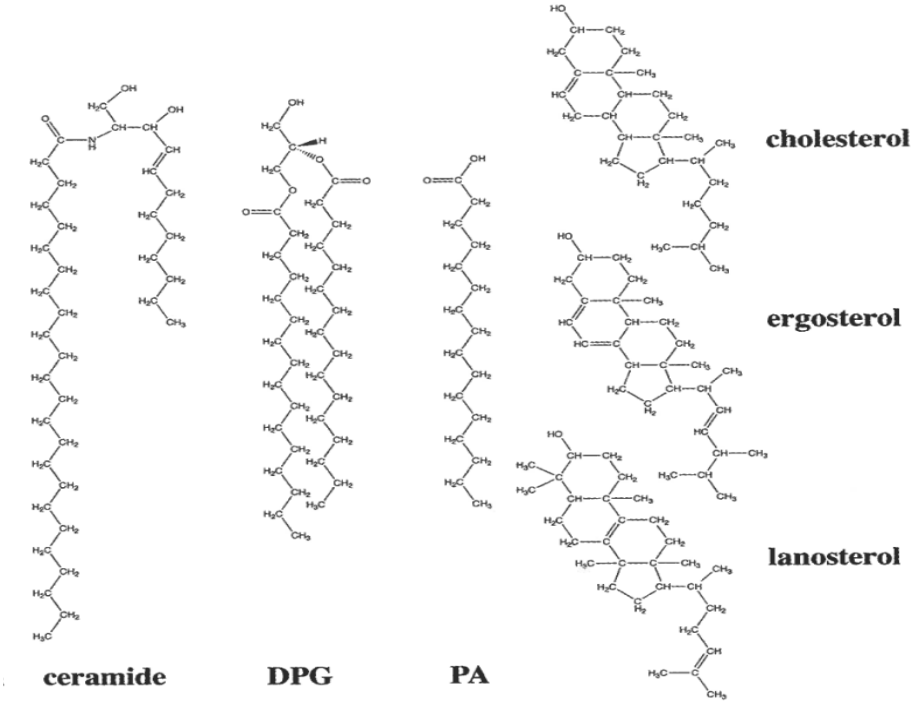
7.2 Lipids have widely varying structures

- Some of the most abundant phospholipids



7.2 Other lipids without phosphate head group

- Chains do not need to be same length, there could be only a single chain, no chain



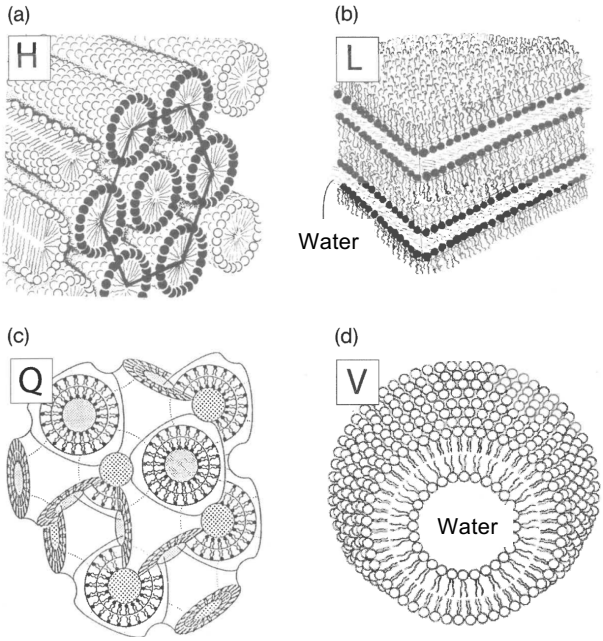
7.2 Composition of biomembranes is complex

Membrane	PC	PE	PS	PI	SM	CL	Glycolipid	Cholesterol	Others
Erythrocyte (human)	20	18	7	3	18	–	3	20	11
Plasma (rat liver)	18	12	7	3	12	–	8	19	21
ER	48	19	4	8	5	–	tr	6	10
Golgi	25	9	3	5	7	–	0	8	43
Lysosome	23	13	–	6	23	≈ 5	–	14	16
Nuclear membrane	44	17	4	6	3	1	tr	10	15
Mitochondria	38	29	0	3	0	14	tr	3	13
Neurons	48	21	5	7	4	–	3	11	1
Myelin	11	17	9	1	8	–	20	28	6

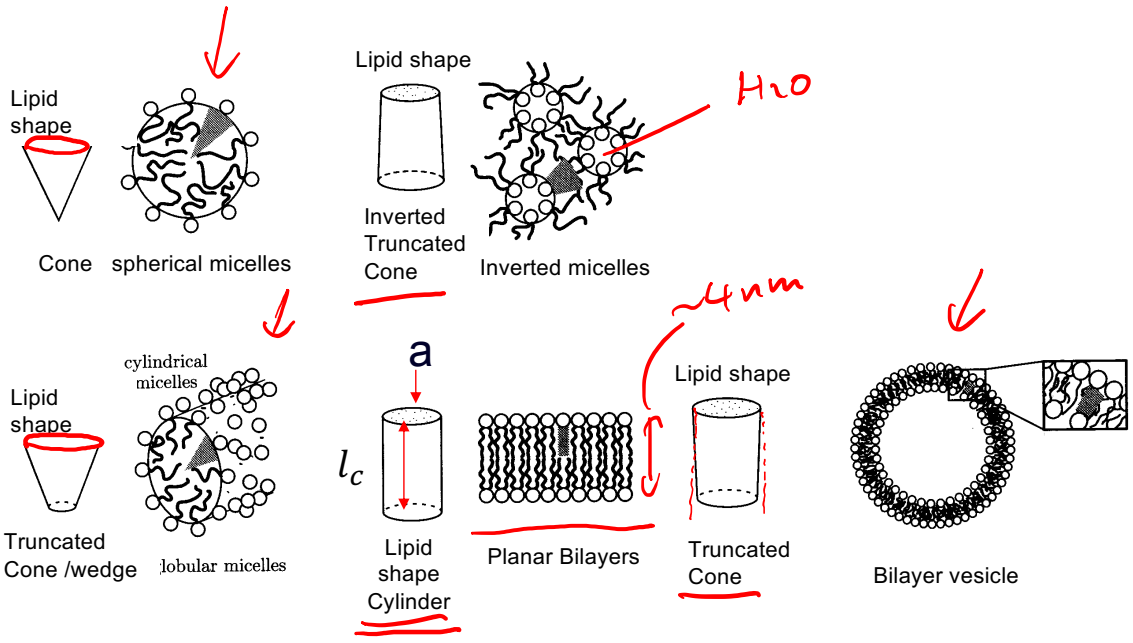
Take home messages:

- Biological system control membrane composition and thus their properties tightly
- Use many different lipid molecules with a range of headgroups and tail length
- Lipid shape and composition vary widely
- **In this part of the course, we will see that despite the complexity of composition we are able to understand and model these systems with our tools from physics**

7.2 Lipid phases with increasing water content

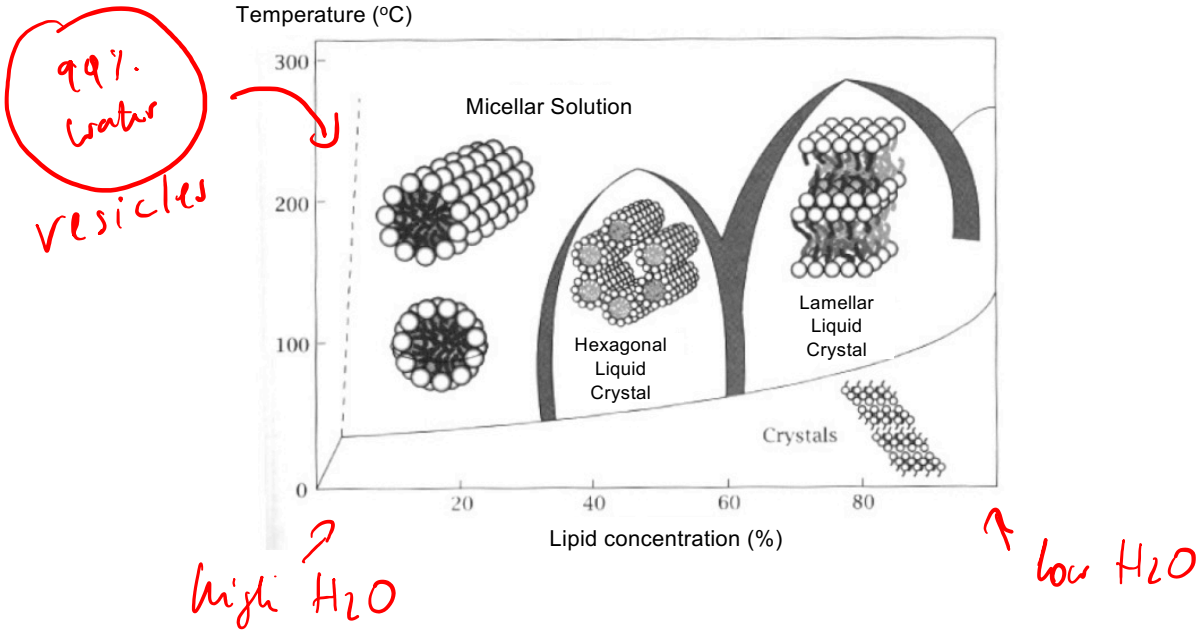


7.2.1 Shapes of aggregates are determined by lipid shape



ENTROPY FAVOURS SMALLEST AGGREGATE @ EN

7.2.1 Phase diagram with micelles, nematic, hexagonal and lamellar structures



Take home messages lipids I

- Lipids are extremely important as they are a barrier for molecules and ions
- Biological systems tightly control and adapt their membrane composition
- **Microscopic (molecular) properties** – lipid shape, charge, headgroup, tail etc. – determine **macroscopic characteristics and shape of membranes**

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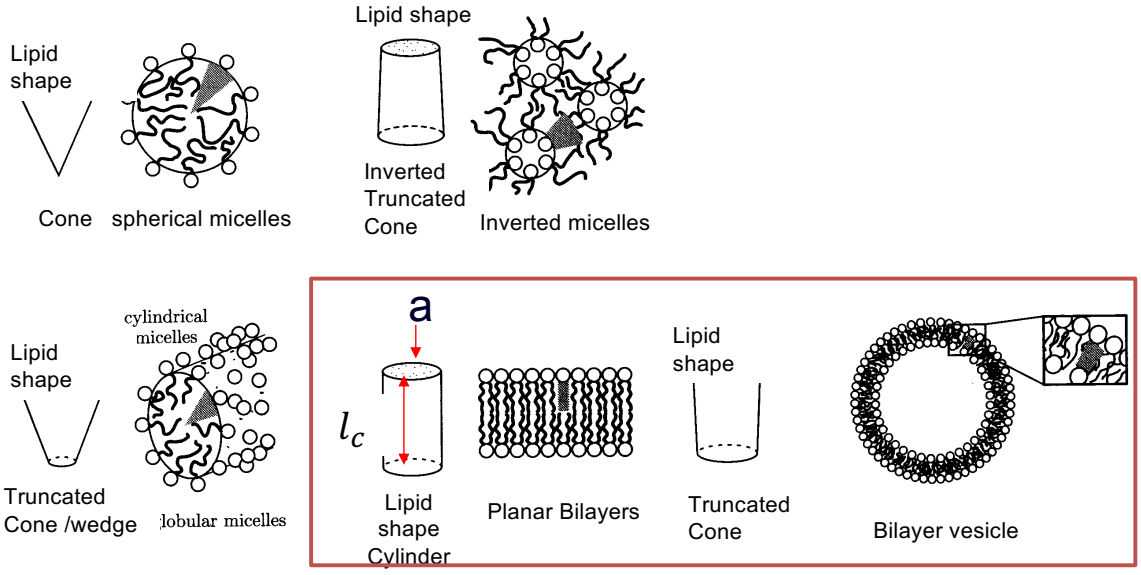
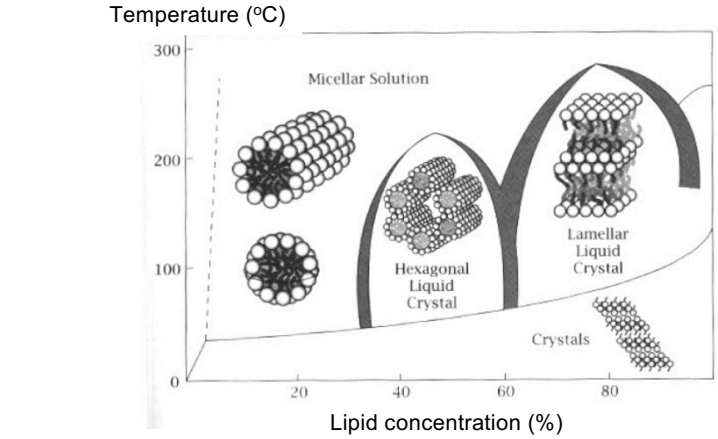
Self assembly II (Chapter 7)
Lecture 13 7/3/2023

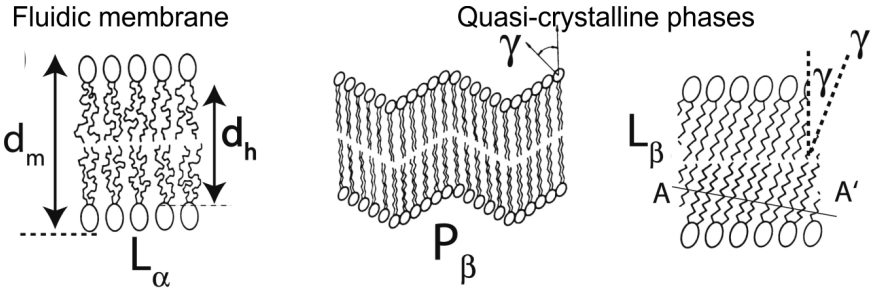
Upcoming: Thu 9/3 9am, Tue 14/3 9am, Thu 16/3 9am

7.2 Shapes of aggregates are determined by lipid shape

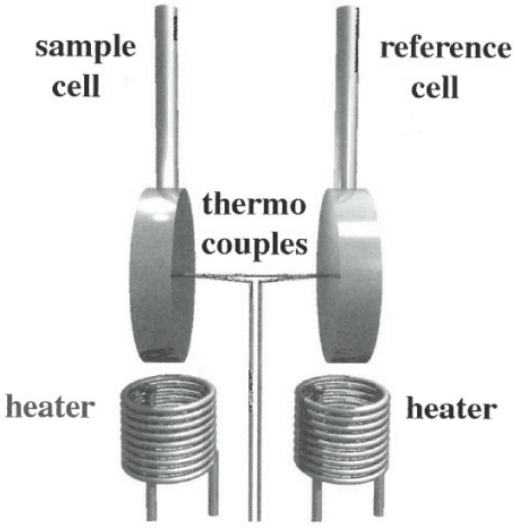


7.2.2 Phase transitions in planar lipid bilayers

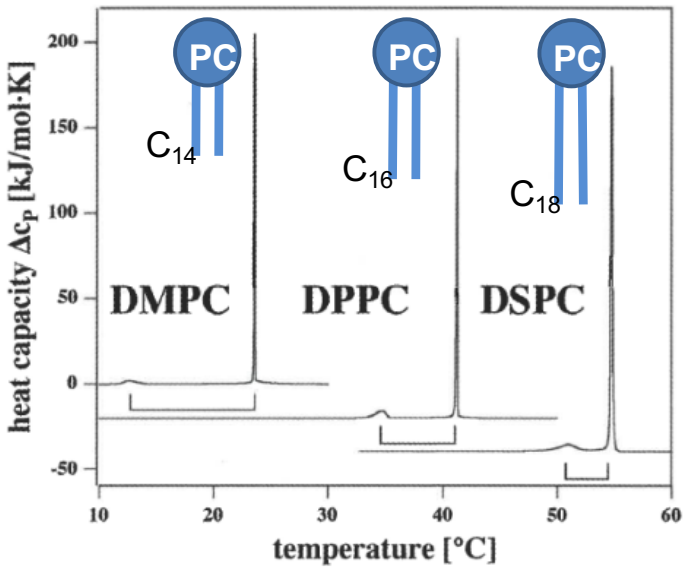




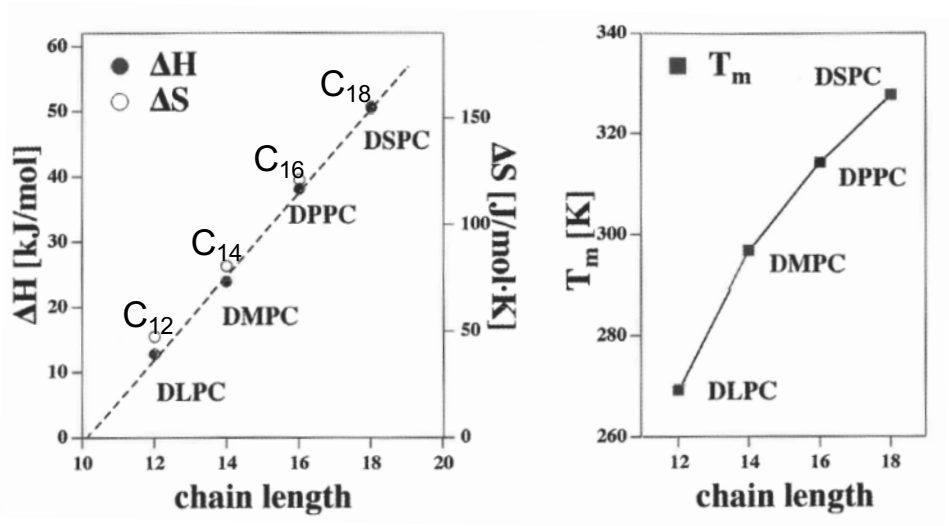
7.2.2 Differential scanning calorimetry (DSC) to investigate phase transitions in lipid bilayers



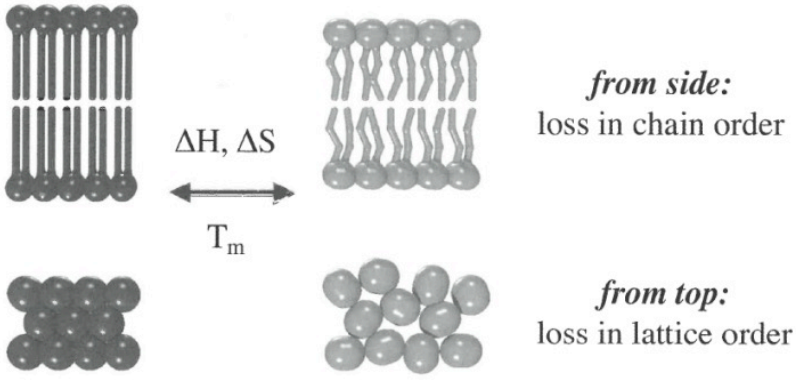
7.2.3 DSC results for lipids with increasing tail length



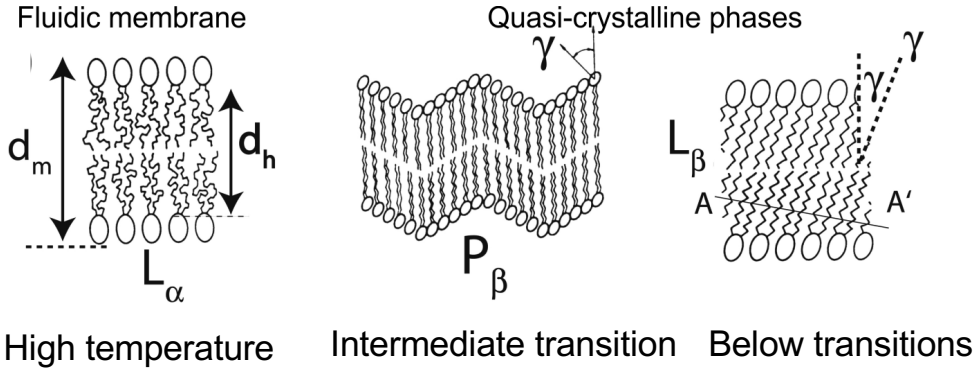
DSC results for lipids with increasing tail length

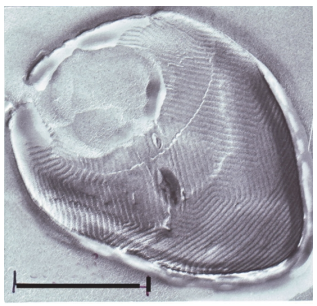


7.2.3 Lipid bilayer structure changes with temperature
Order changes

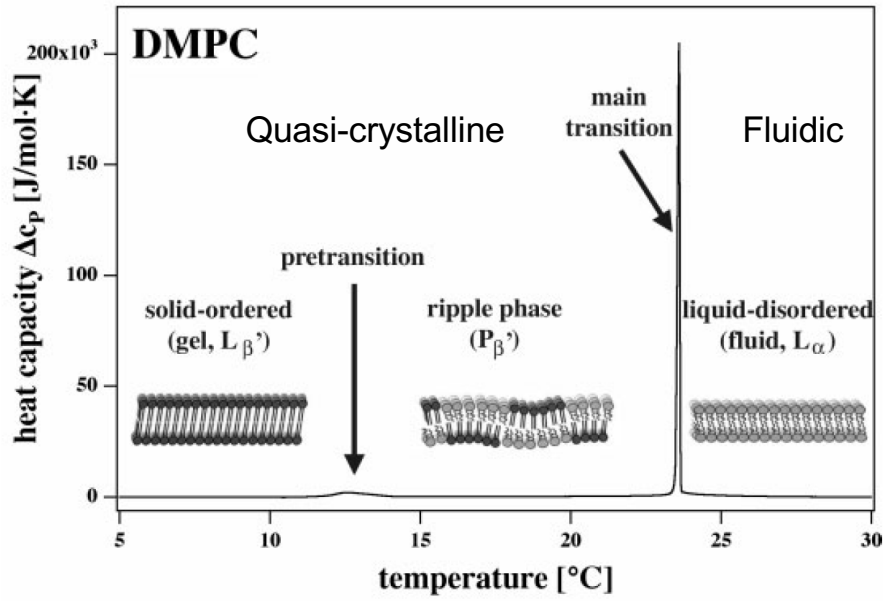


7.2.3 Phase transitions in lipid bilayers





7.2.3 Change in heat capacity indicates transition



7. Take home messages lipids II

- Phase transitions in lipid membrane reflect changes in lipid ordering
- At the phase transition temperature, the heat capacity of lipid membranes diverges
- Phase diagrams of lipids are complex and reflect the molecular behavior
- Shape of (macroscopic) lipid aggregates are informed by the molecular shapes of the lipids

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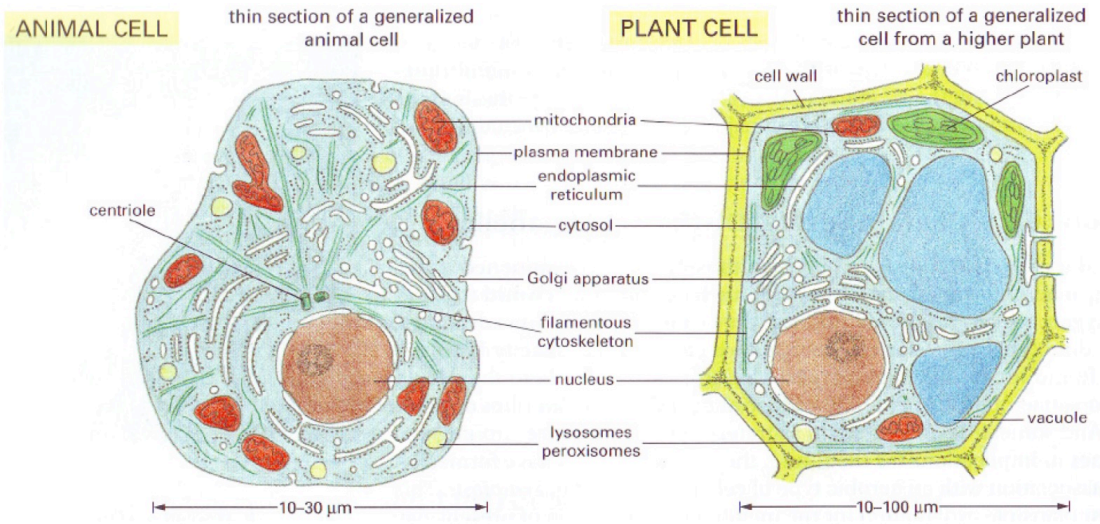
Self assembly II
Lecture 14 9/3/2023

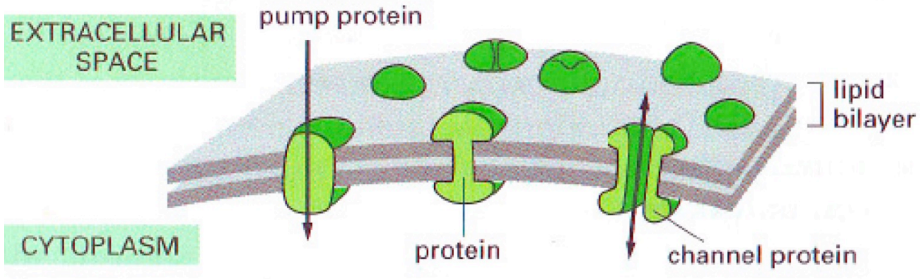
Upcoming: Wed 14/3 10am, Thu 16/3 9am

7.3 Animal and plant cells – compartments & boundaries

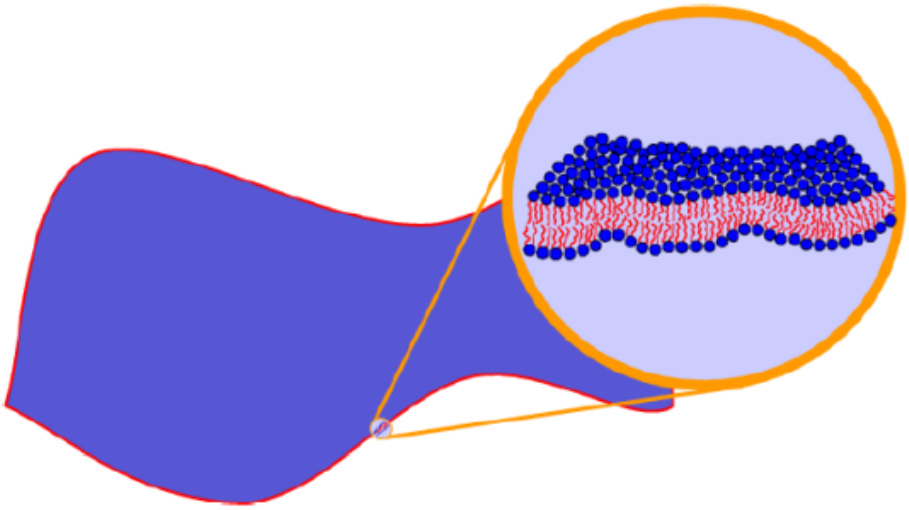


7.3 Plasma membrane example for "planar" membrane

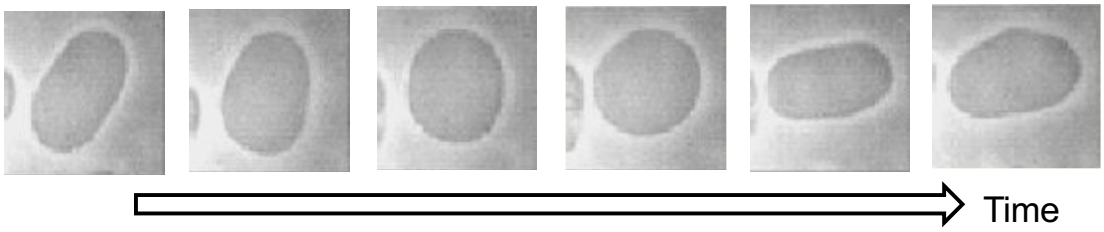
The outer boundary of the cell is the plasma membrane, a continuous sheet of phospholipid molecules about 4–5 nm thick in which various proteins are embedded.

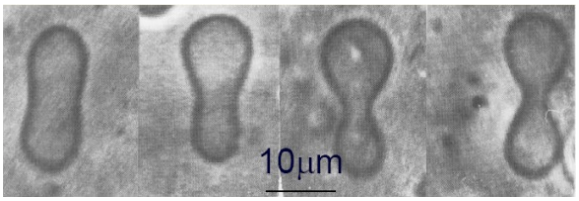


7.3 Bilayer membranes are soft shells



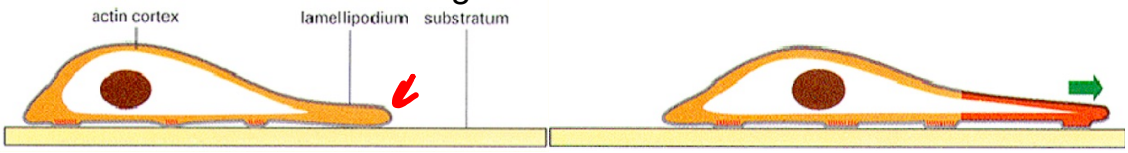
7.3 Fluctuating membranes

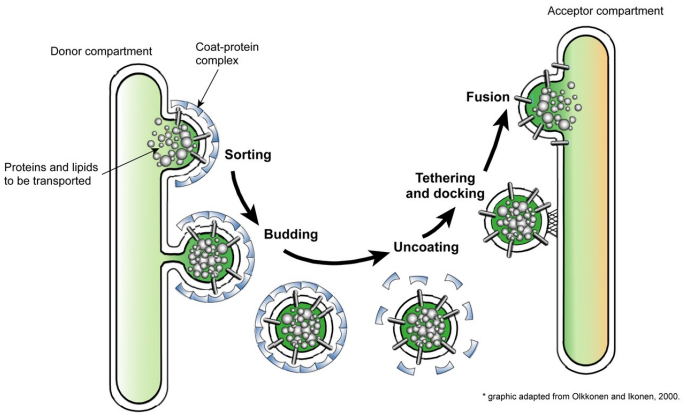




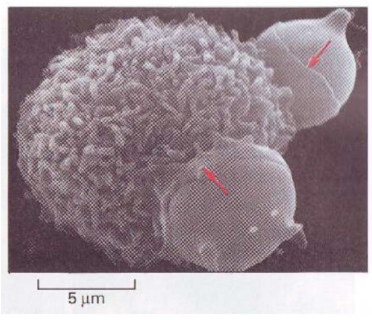
7.3.4 Relevance of membrane curvature: examples

Cell motion through extension and deformation of membrane





Material transport by vesicle fusion



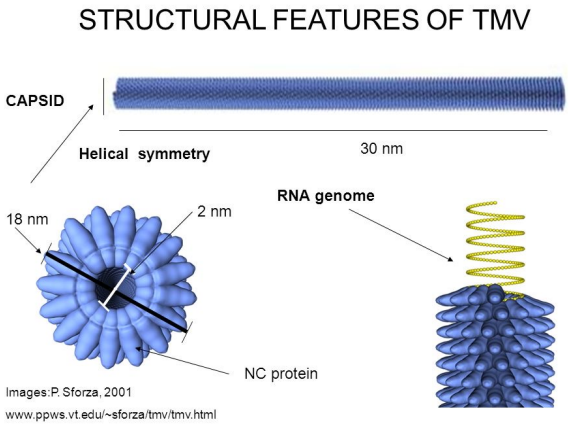
Macrophage taking up blood cells

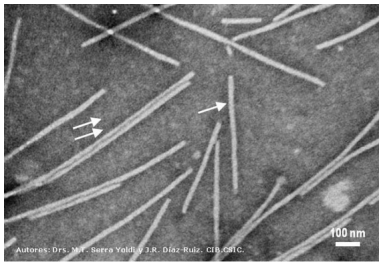
Take home message: Soft membranes

- Lipid bilayers can be described as soft membranes
- For small distortions, the spectrum of fluctuations can be predicted with simple geometric models
- **Membrane fluctuations and the spectrum** can be measured by microscopy and these thermally excited modes **provide information on bending modulus of the membrane**

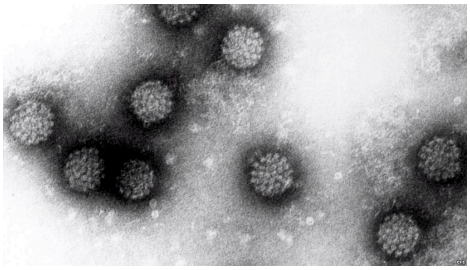
7.4.1 Other self-assembled structures: viruses

Tobacco Mosaic Virus (TMV)

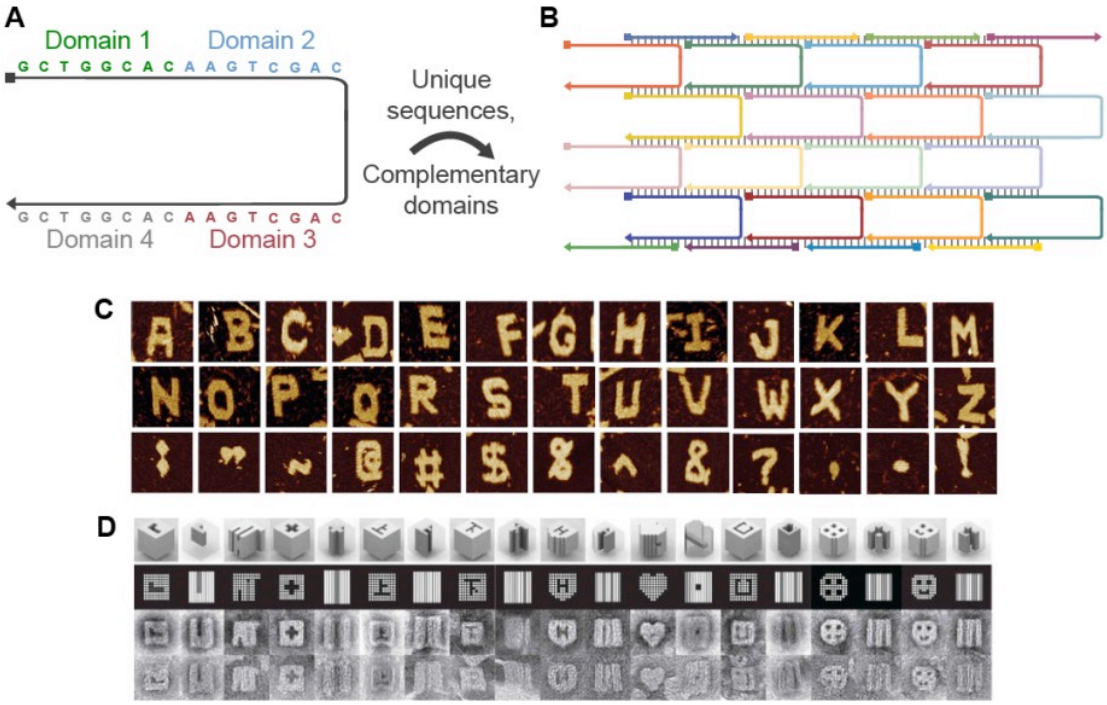




Humanes Papillomvirus (TEM)



7.4.2 DNA self assembled structures



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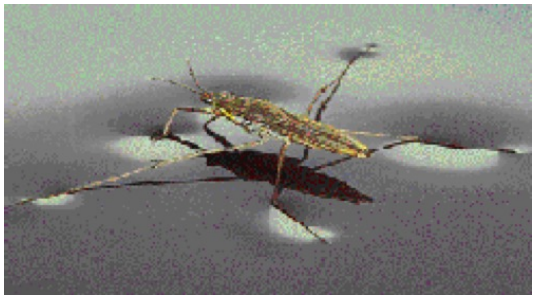
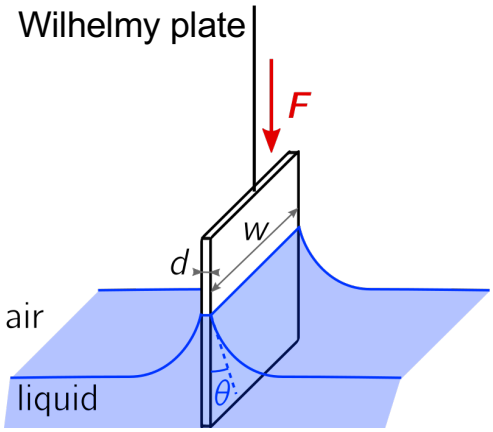
Surface energy (Chapter 8)
Lecture 15 14/3/2023

Upcoming: Thu 17/3 9am

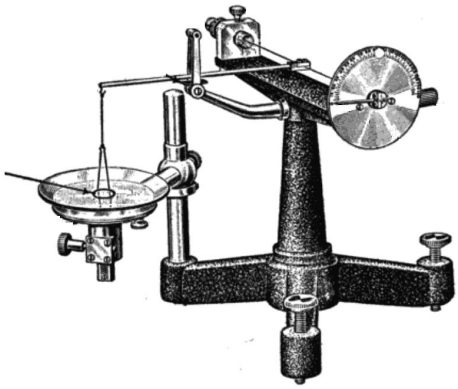
8.1 Surface energy

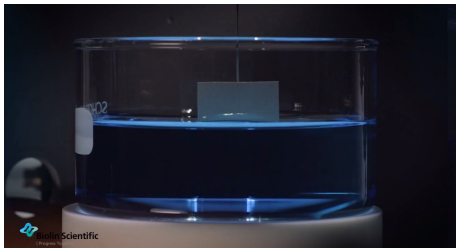


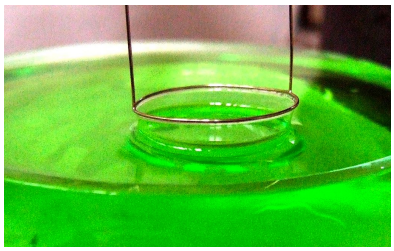
8.1 Surface energy classical methods



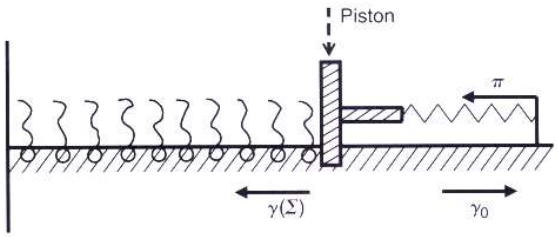
du Noüy ring tensiometer

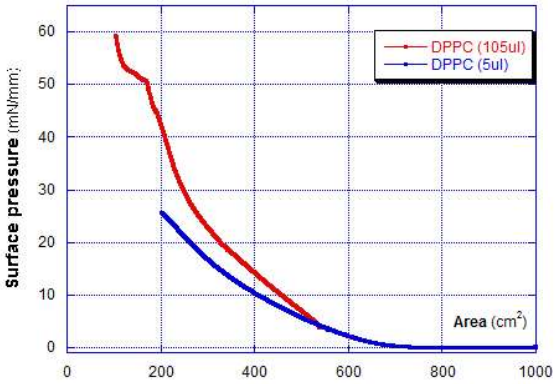


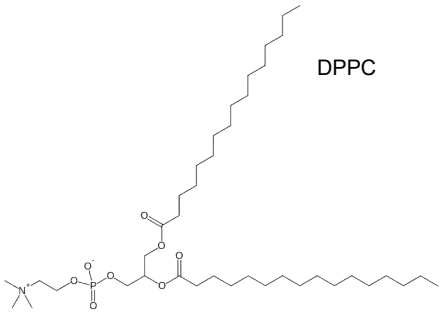




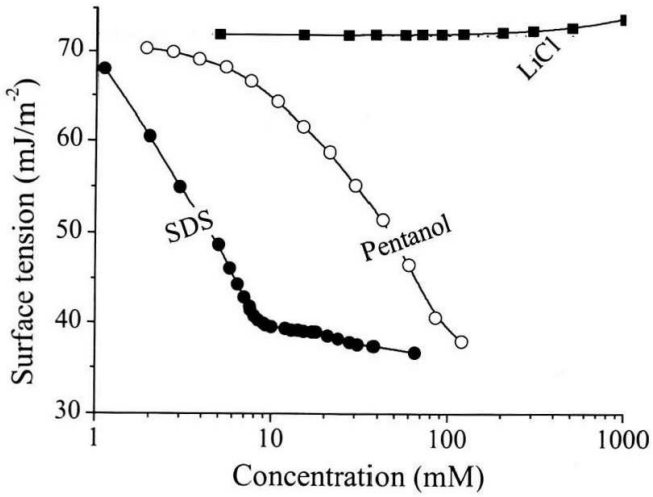
8.1 Surface pressure







8.1.2 Surface tension surfactants



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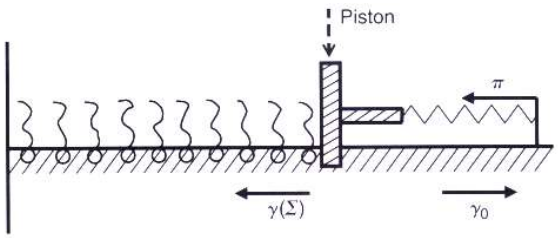
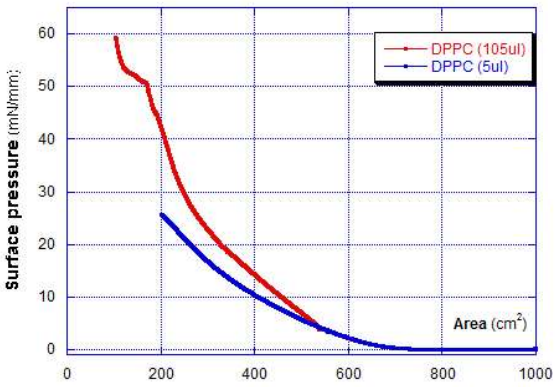
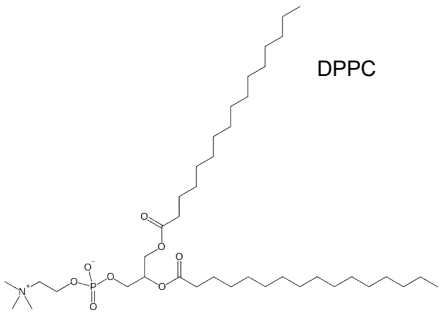
Surface energy and surfactants (Chapter 8)
Lecture 16 17/3/2023

Upcoming: Break …

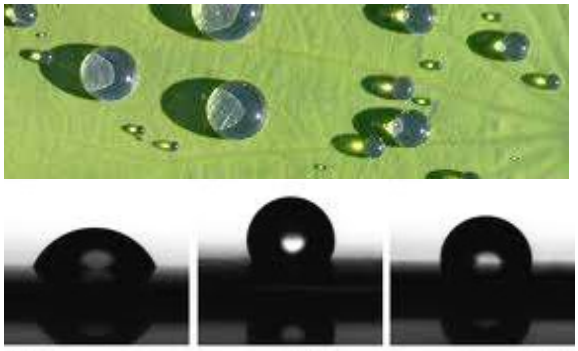
8.1.2 Surface pressure



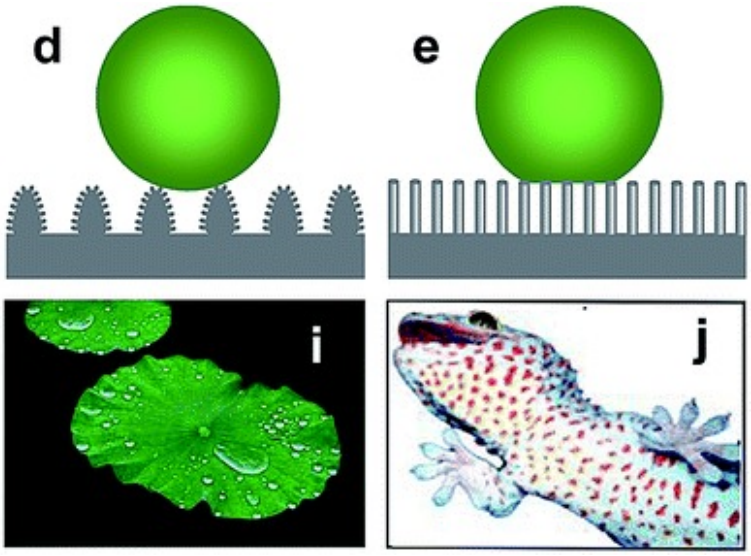




8.2 Contact angles



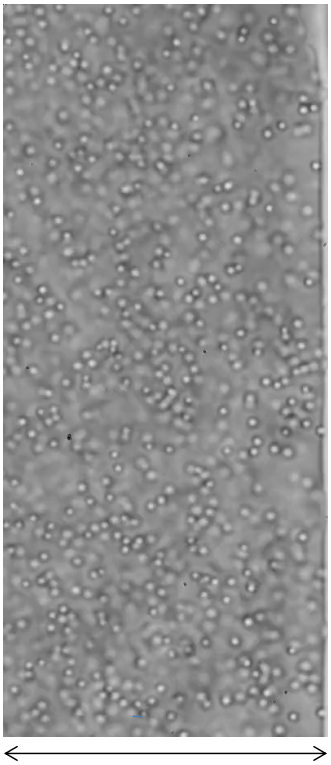
8.2 Structured hydrophobic surfaces in nature



Take home messages: Surface tension

- Work required to create a new surface scales linearly with area
- Stabilising interfaces requires a counter balancing force
- Keep track of all relevant relative surface tensions – for a water-liquid-gas interface and calculate the shape
- Surfactants can be used to change surface tension and adsorb to the interface between phases

Outlook to Easter term: Colloidal particles & Diffusion



Colloidal particles in aqueous solution
at room temperature

Negatively charged

Diameter 0.5um (500 nm)

Images with an inverted microscope Replay in real time