Gibbs ?

capillary ?

disjoigning ?

PRESSURES IN A FOAM

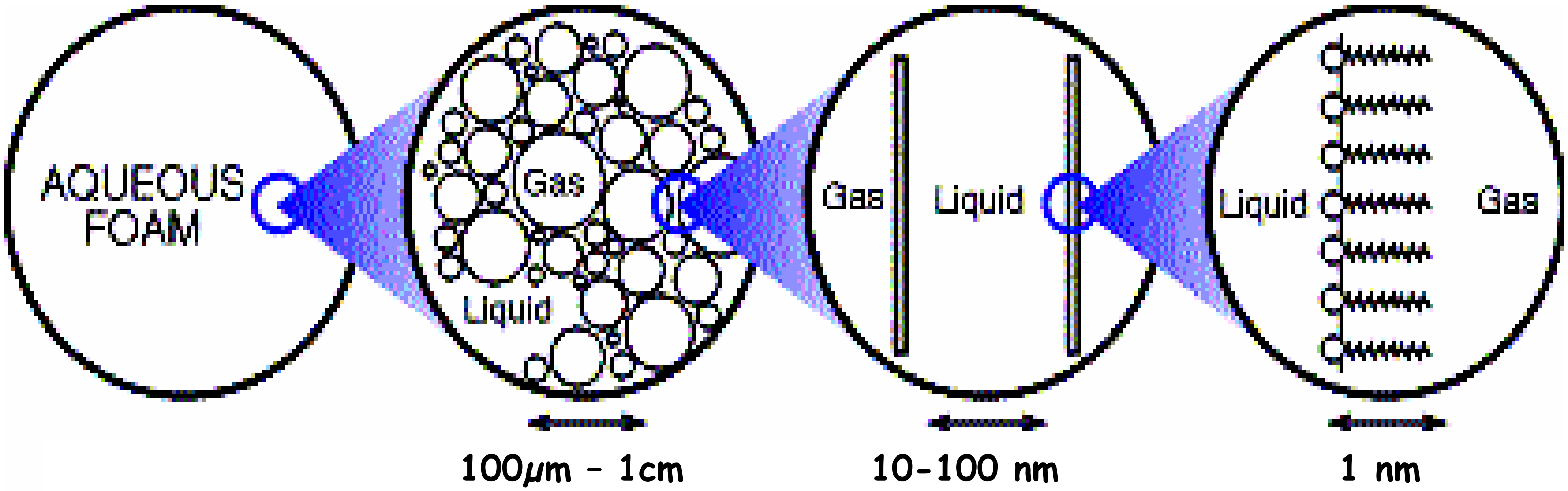
osmotic ?

Laplace ?

Langmuir ?

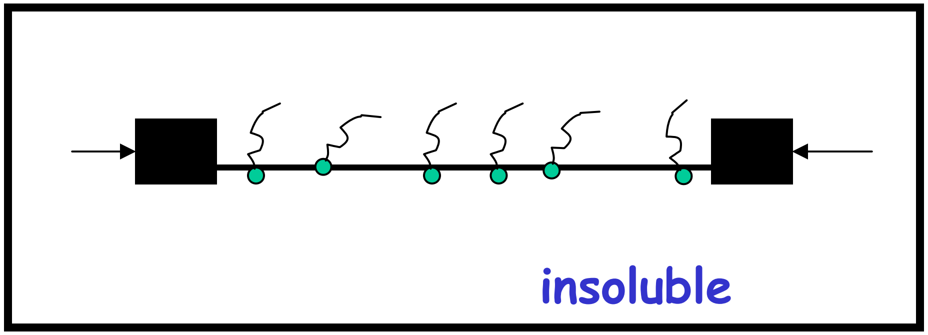
hydrostatic ?

different lengthscales…



3D foam bubble film monolayer

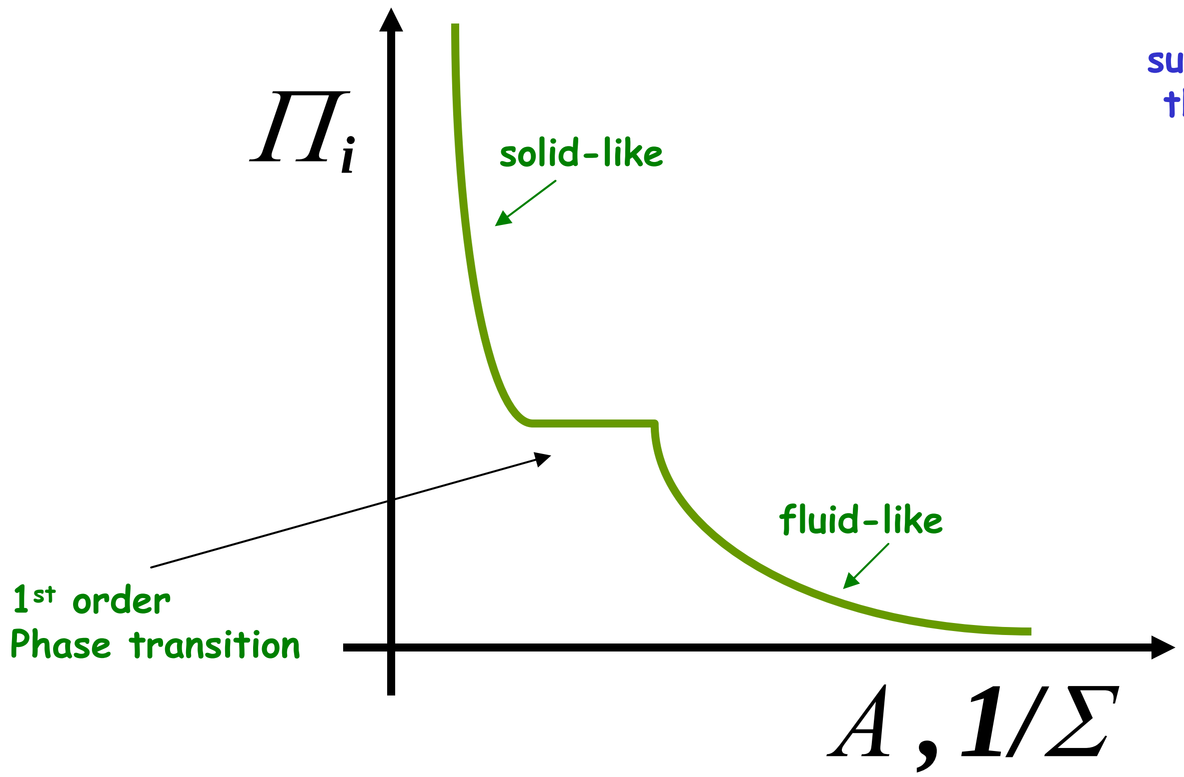
… different pressures



« Langmuir » monolayer

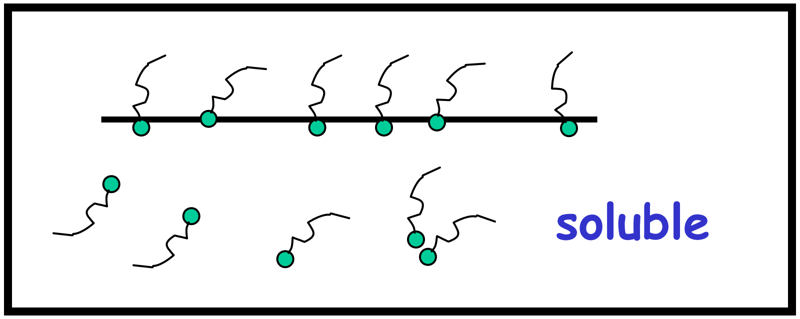
$$\Pi_i = \gamma_0 - \gamma$$

surface tension of the pure liquid



A = area per molecule

Σ = surface density



Liquid interface

Gibbs equation :

$$\Gamma = -\frac{1}{kT}\frac{\partial \gamma}{\partial \ln c}$$

A simple model (Langmuir) : equilibrium between adsorption and desorption

$$\Gamma / (\Gamma_\infty - \Gamma) = \frac{c}{a}$$

$$\Gamma = (a/c + 1)^{-1}\, \Gamma_\infty$$

With a = Szyszkowski concentration

With Γ_∞ = saturation surface concentration

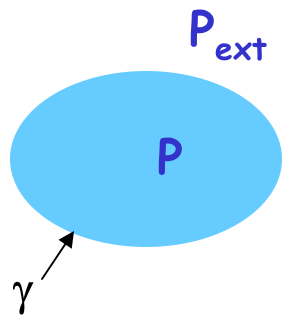
Finally, the « Langmuir » (interfacial) equation of state :

$$\Pi_i = -kT\, \Gamma_\infty \ln(1 - \Gamma/\Gamma_\infty)$$

More refinements are possible

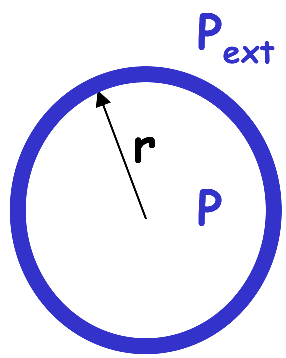
Though, it can be used dynamically

curved interfaces and Laplace pressure



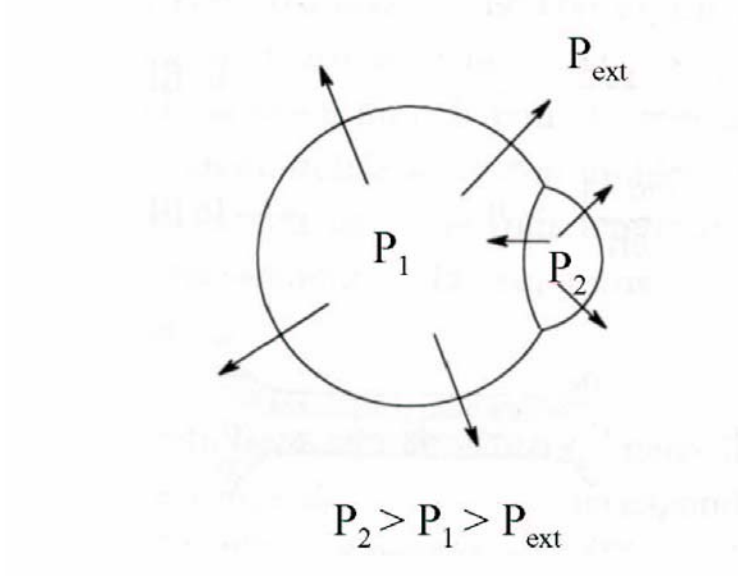
$$P - P_{ext} = \gamma\,(1/R_1 + 1/R_2)$$

For a single spherical bubble :



$$P - P_{ext} = 4\gamma / R$$

Two bubbles of different sizes, in contact :



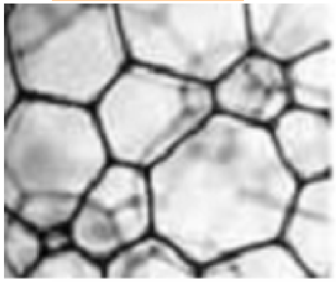
A useful lengthscale :

$$l_c = \sqrt{\frac{\gamma}{\rho g}}$$

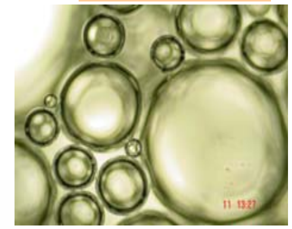
$l < l_c$: capillarity dominates gravity

Liquid pressure in Plateau borders

DRY



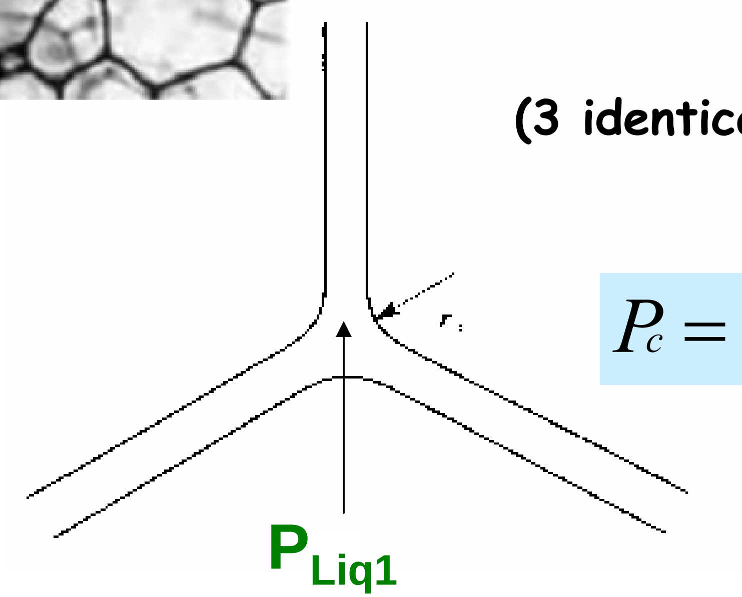
WET

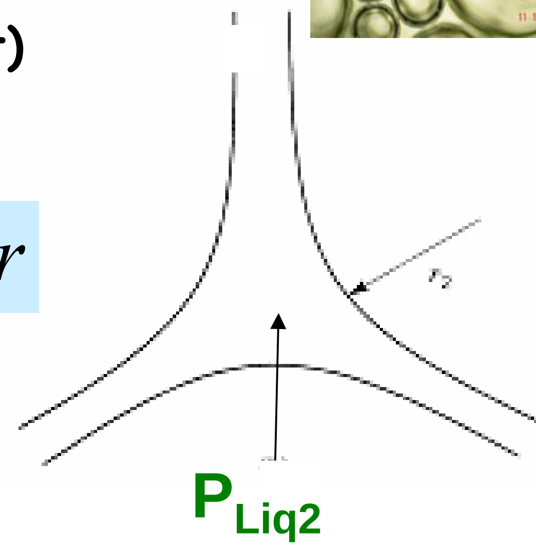


The Laplace pressure also describes the pressure inside the Plateau borders :

(3 identical bubbles at P_g =cst)

$$P_c = P_{gas} - P_{liquide} = \gamma / r$$

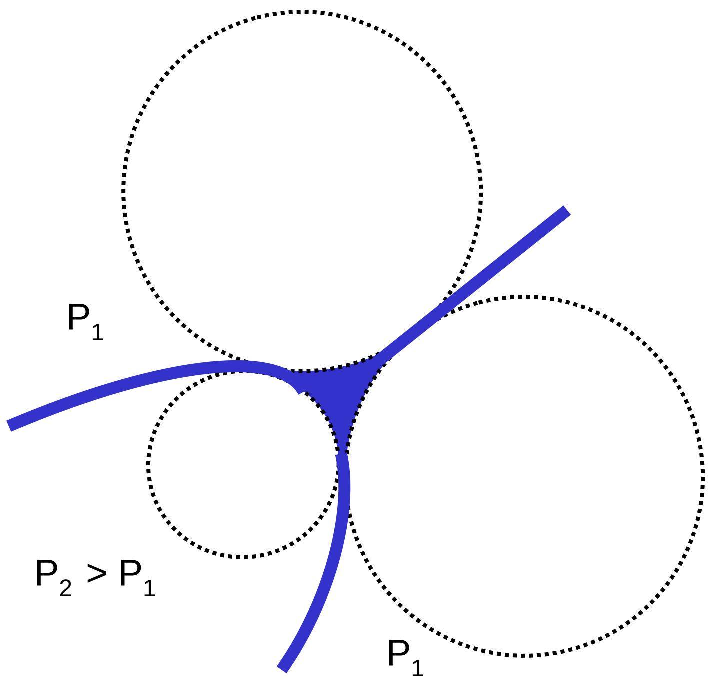




$$P_{Liq2} > P_{Liq1}$$

Gradients of liquid fraction = gradients of pressure = …

Considering bubbles of different volumes…

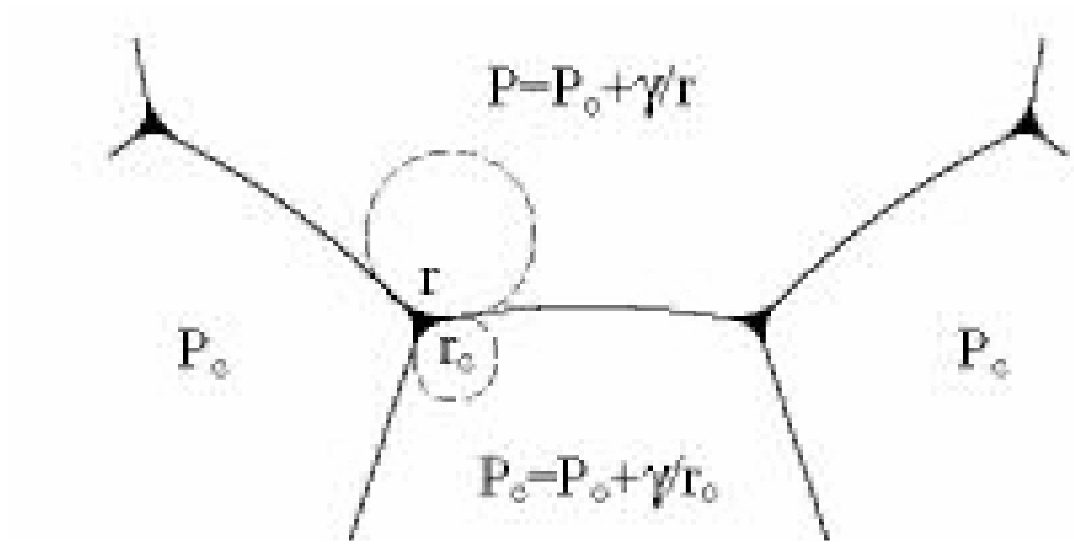


differences in thin film curvature

…as well as…

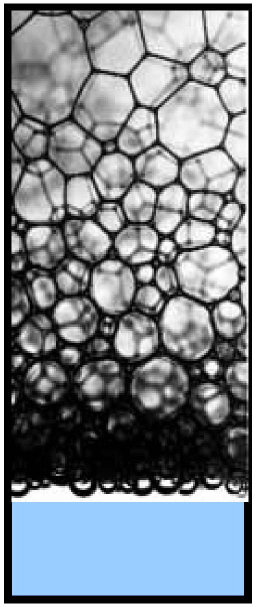
differences in Plateau borders radii

$$P_c = P_{gas} - P_{liquide} = \gamma / r$$



Equilibrium under gravity and hydrostatic pressure

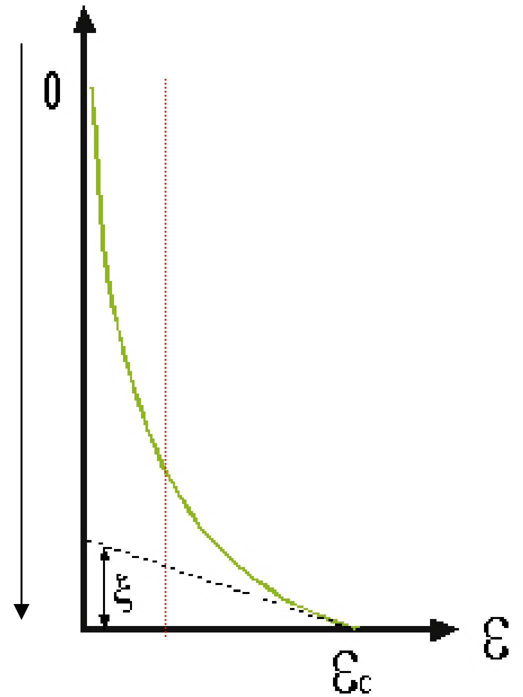
$$P_c = P_{gas} - P_{liquide} = \gamma / r$$



Hydrostatic pressure : $P_{liq} = P_0 + \rho g z$

$$\longrightarrow \quad r(z) = \frac{\gamma}{(P_g - P_0 - \rho g z)}$$

using $\varepsilon = c\,(r/D)^2$



$$\longrightarrow \quad \varepsilon(z) = \frac{c\gamma^2}{D^2}\frac{1}{(P_g - P_0 - \rho g z)^2}$$

With the bottom boundary condition :

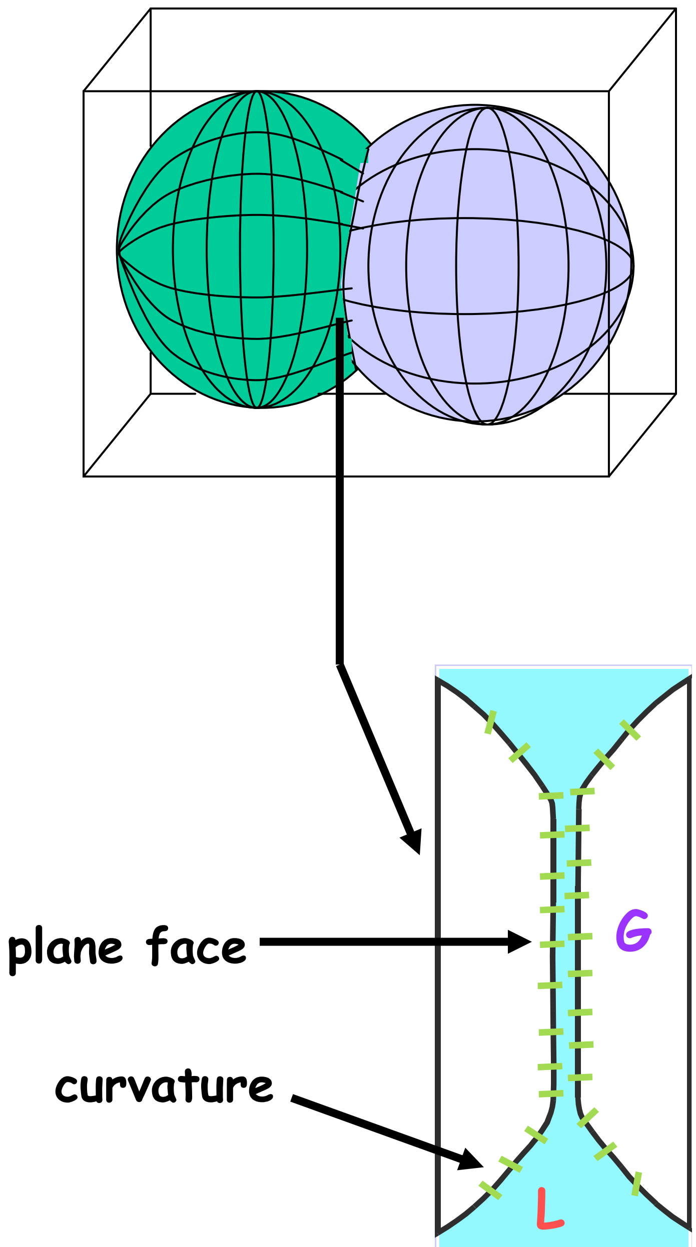
$\varepsilon_c = 0.36$

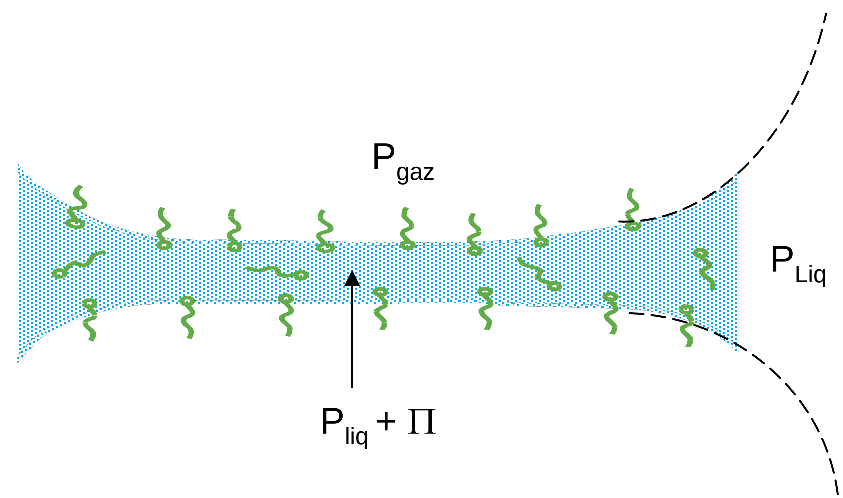
$$\longrightarrow \quad P_g - P_0 = \rho g H + \sqrt{\frac{c}{\varepsilon_c}}\,\frac{\gamma}{D}$$

Height of the « wet layer »:

$$\xi = \gamma / \rho g R$$

Something wrong in the thin films ?





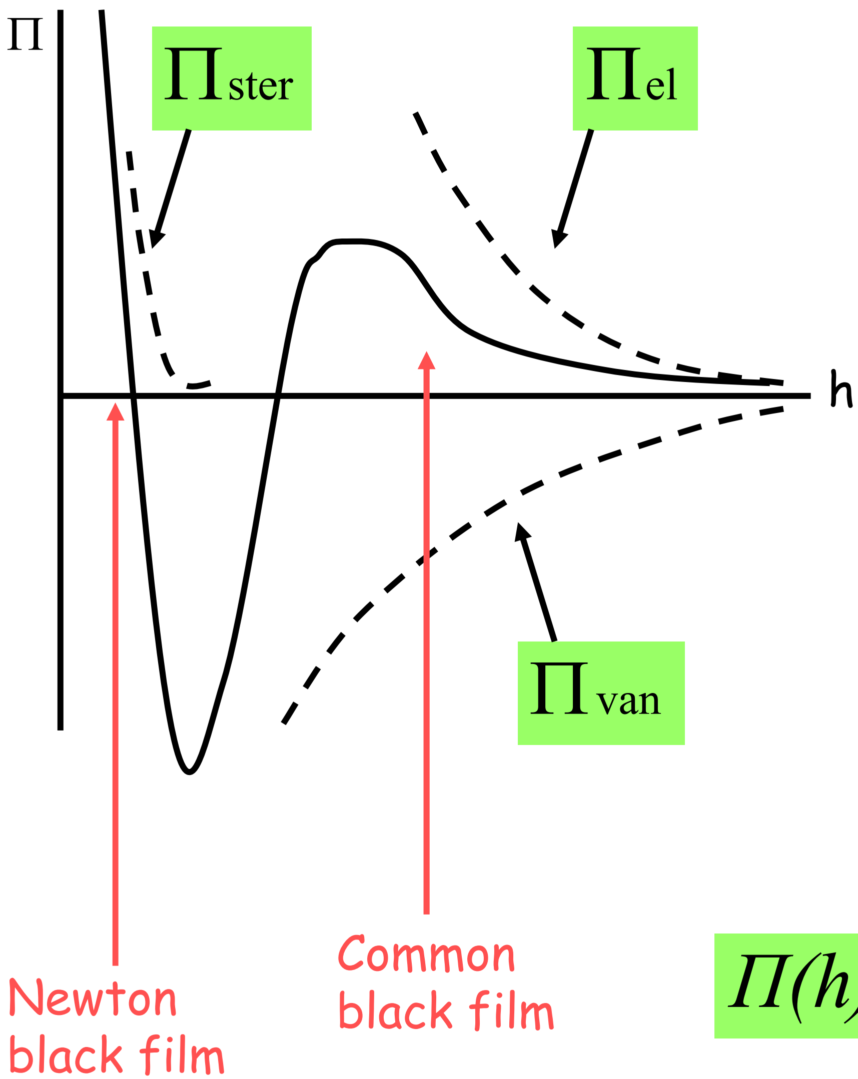
$$\Pi_d + P_{liquide} = P_{gas}$$

↓

$$\Pi_d = P_{gas} - P_{liquide} = P_c$$

At equilibrium

which forces between surfaces?



✓ **electrostatic repulsion :**

$$\Pi_{el} = 64\,kT\,\rho_\infty\,\gamma^2\,\exp(-kh)$$

✓ **dipolar interaction (Van Der Waals):**

$$\Pi_{van} = -\frac{A_h}{6\,\pi\,h^3}$$

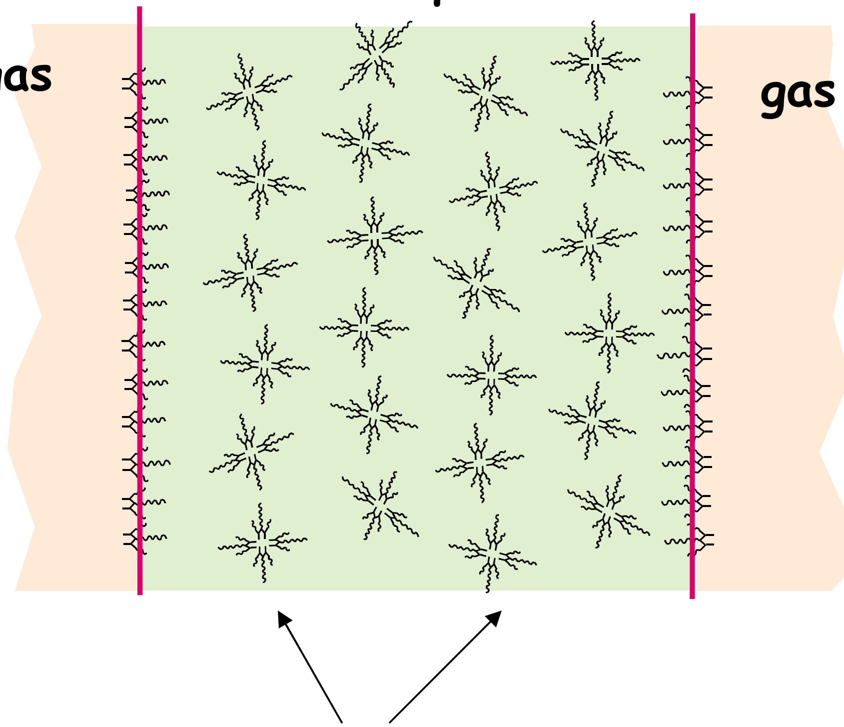
✓ **steric contribution : confinement**

$$\Pi(h) = \Pi_{el} + \Pi_{van} + \Pi_{ster}$$

(DLVO model)

Typical h, and Π are...

Another type of force : supramolecular forces

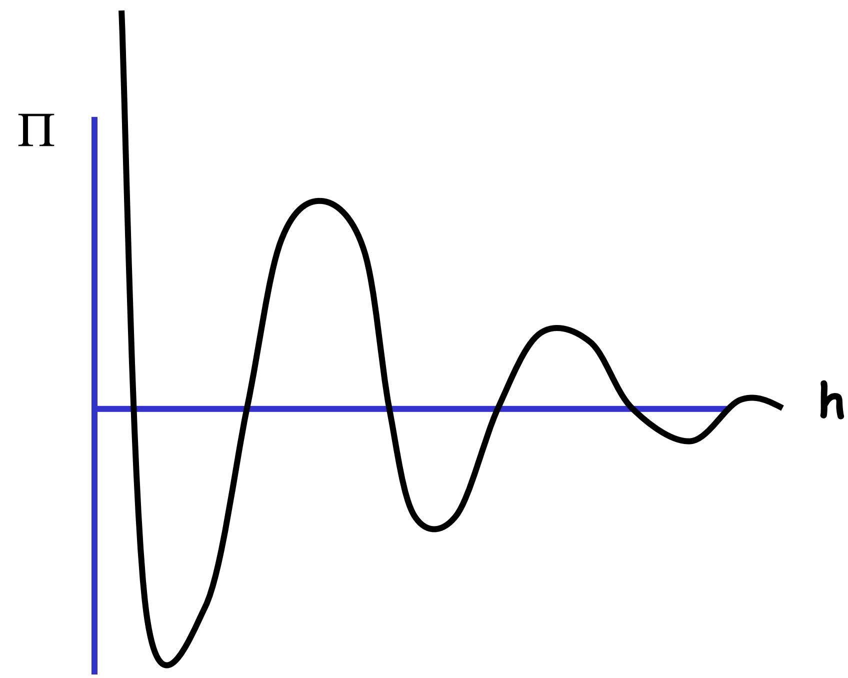


Layers of micelles

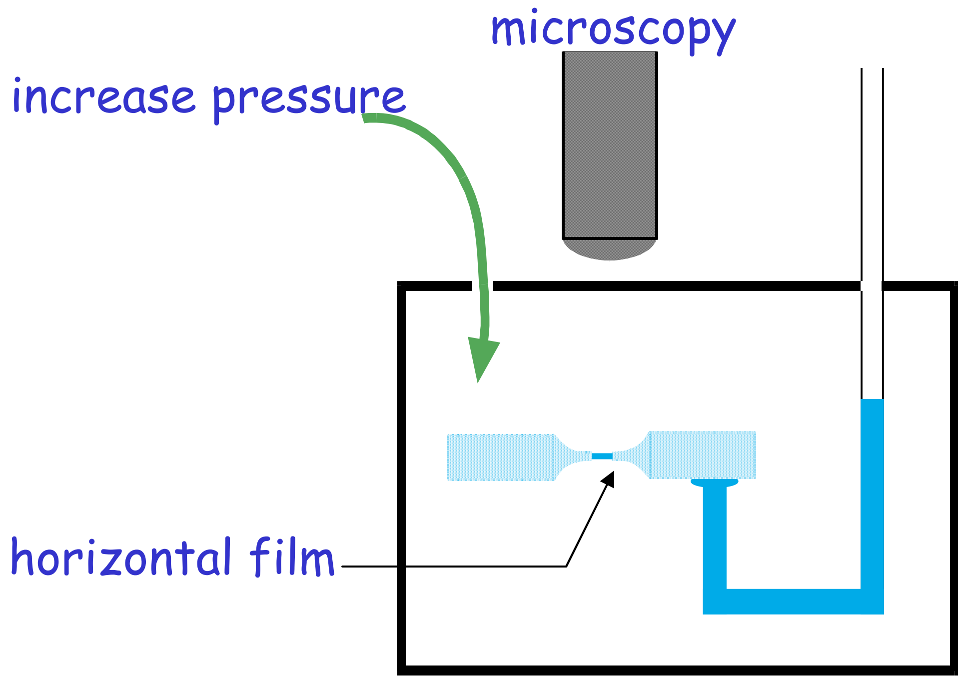
confinement effect in the film

Arrangements in layers

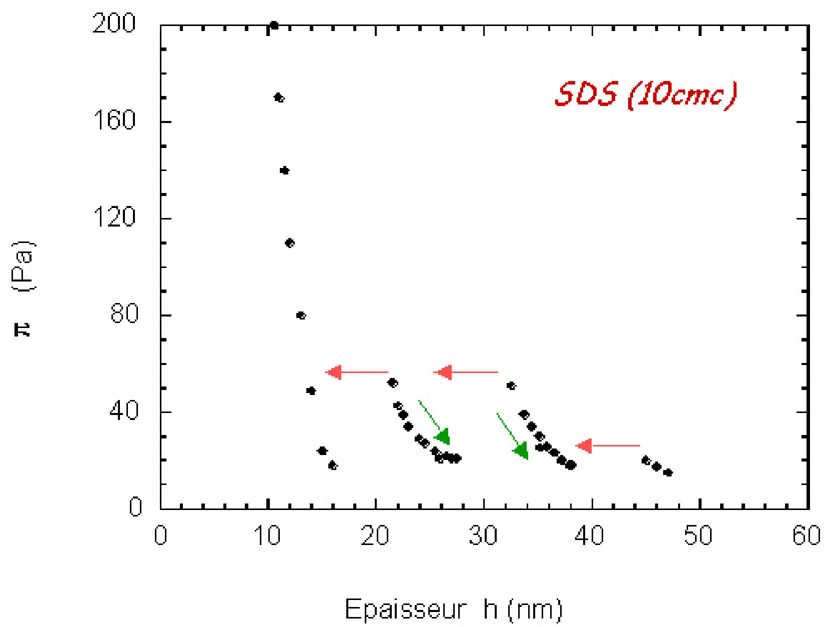
Oscillation in the disjoining pressure



implies thickness steps,
and a thinning layer by layer

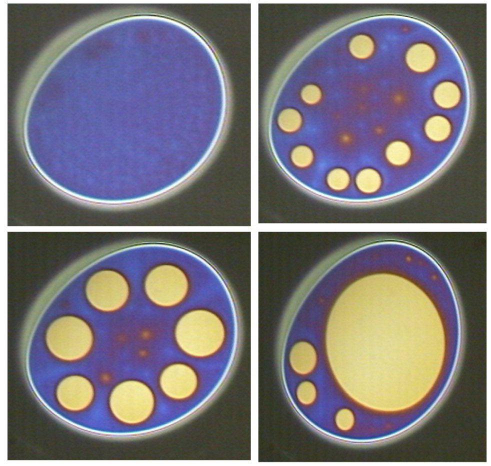


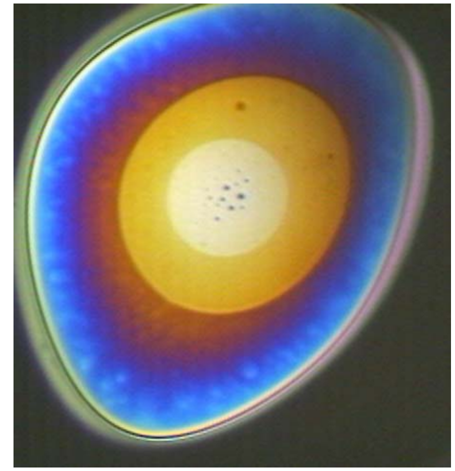
« thin film balance »



(data from V. Bergeron)

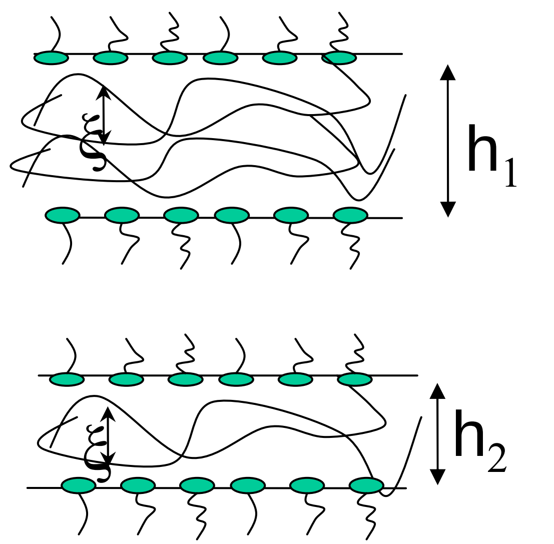
Other types of film stratification, at high thickness :





Stratification with surfactant-polyelectrolytes systems :

Confinement effects in thin films

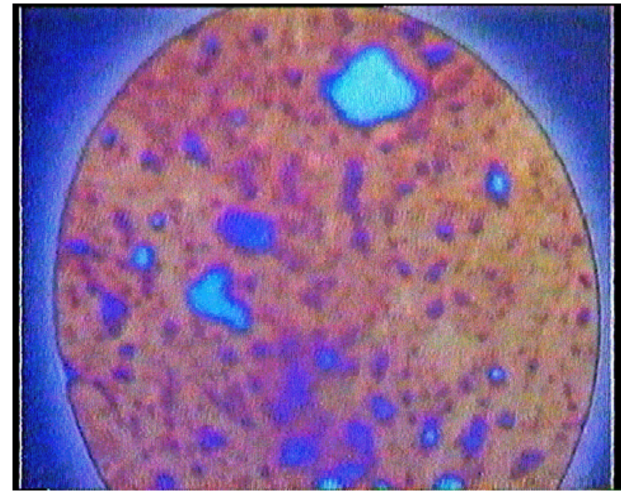


layer thickness corresponds to the bulk mesh size (!?)

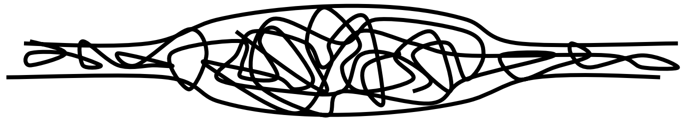
$$\xi \sim h_1 - h_2$$

high concentration of polyelectrolytes and surfactant :

→ non-homegeneous and non-flat films



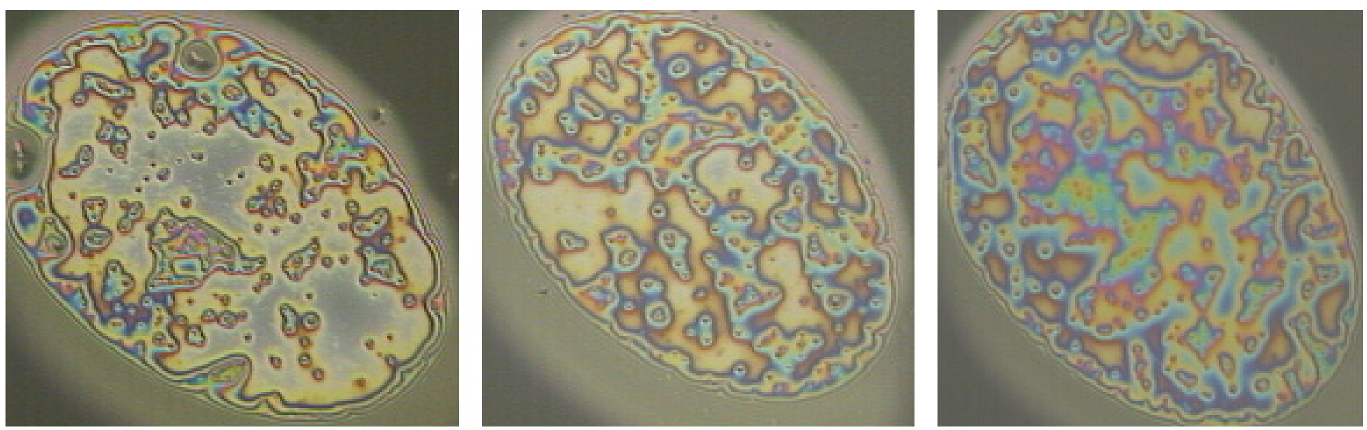
gelified structure : high local viscosity



Origins of stability ?

Increasing the protein concentration →

casein films



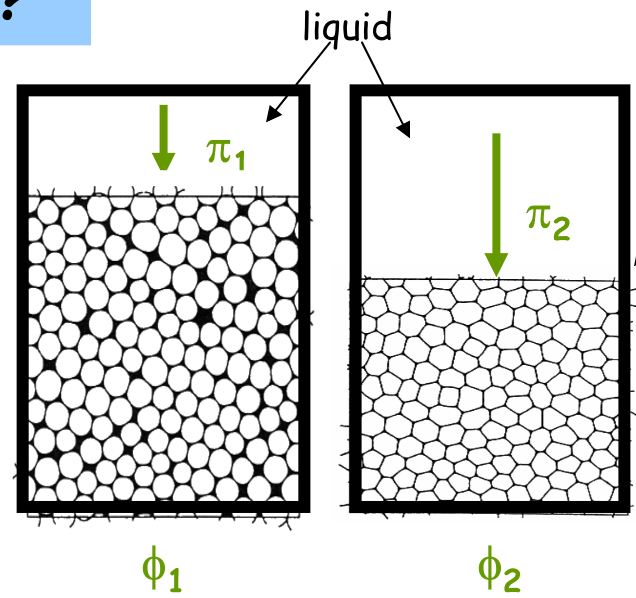
→ stability

osmotic pressure, π ?

Princen (1979)

$A(\phi)$? $E(\phi)$?

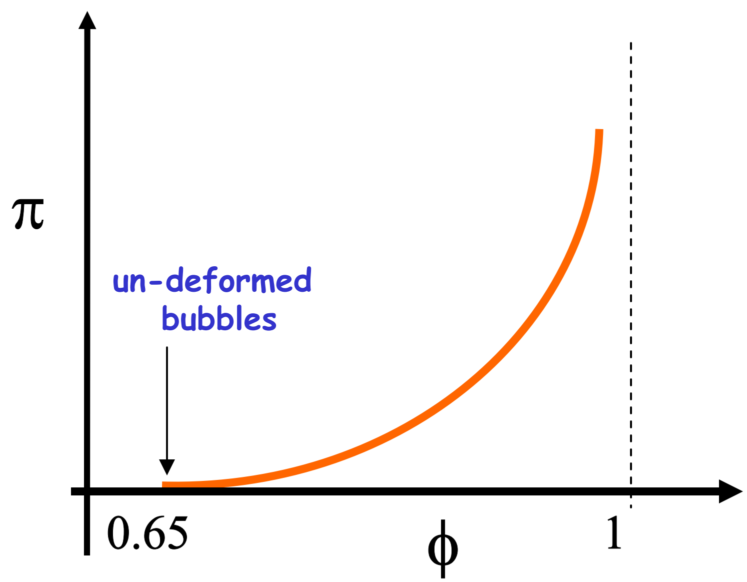
in analogy
with solutions…



A movable membrane, porous only for liquid

$\phi_2 > \phi_1$

$\pi_2 > \pi_1$



$$\pi(\varphi) = \frac{\gamma}{r}\,\phi^2 \frac{\partial}{\partial \phi}\left[\frac{A}{A_0}\right]$$