Biogenesis of Lipid Droplets

From a Physical Point of View

Florian Wodlei

Institute of Physical Chemistry / Institute for Theoretical Physics

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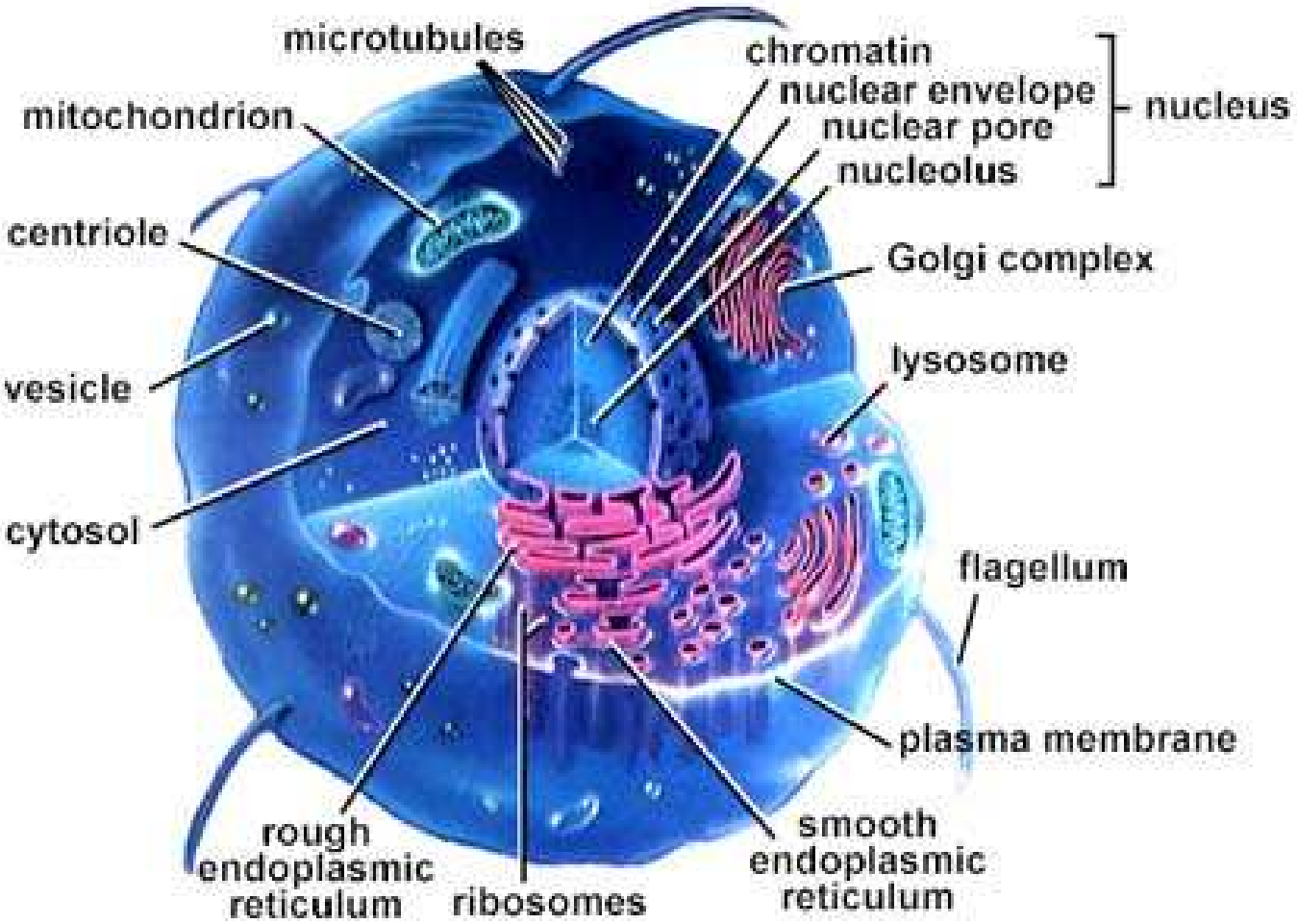
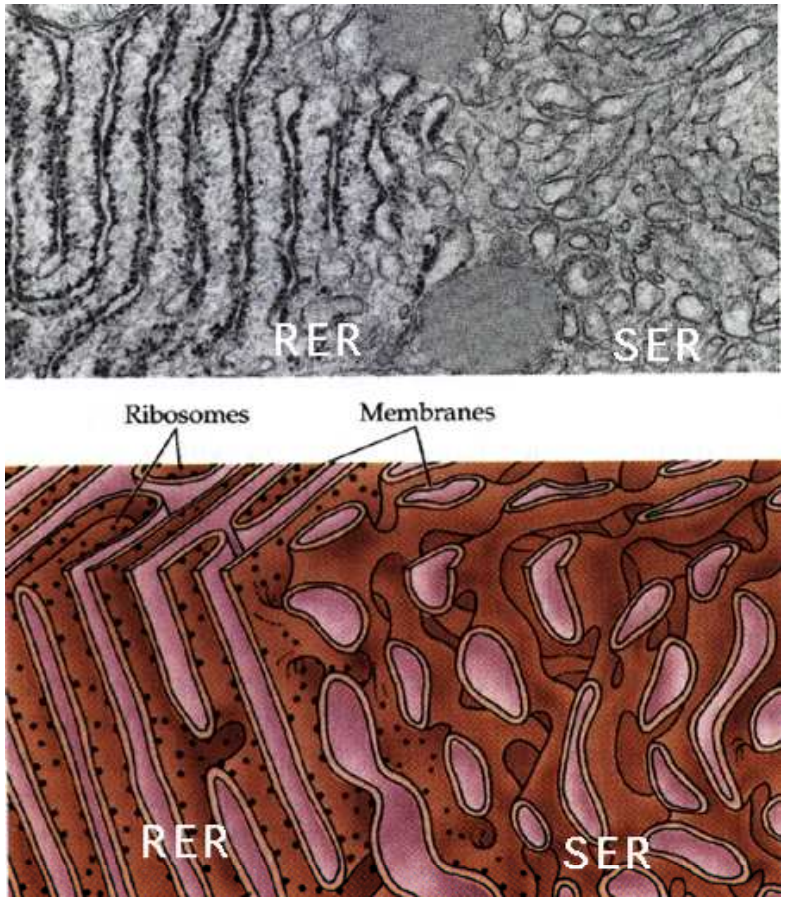
Content

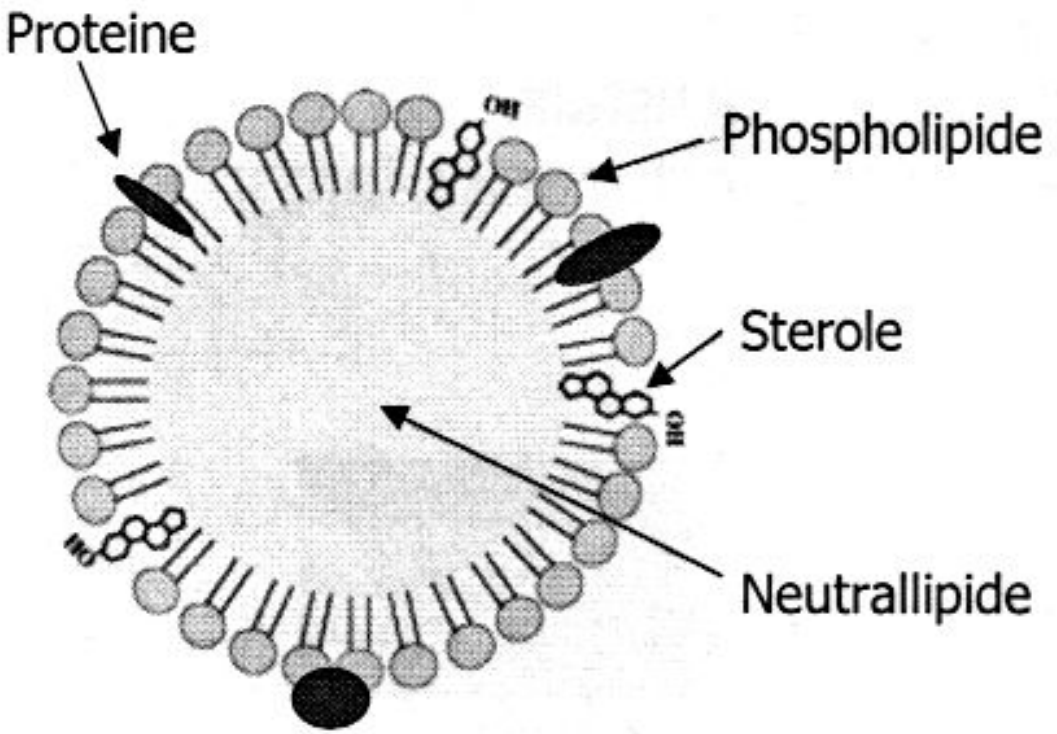
The Cell


microtubules
mitochondrion
centriole
vesicle
cytosol
chromatin
nuclear envelope
nuclear pore
nucleolus
nucleus
Golgi complex
lysosome
flagellum
plasma membrane
rough endoplasmic reticulum
ribosomes
smooth endoplasmic reticulum

Endoplasmatic Reticulum



Lipid Droplet



Membranes

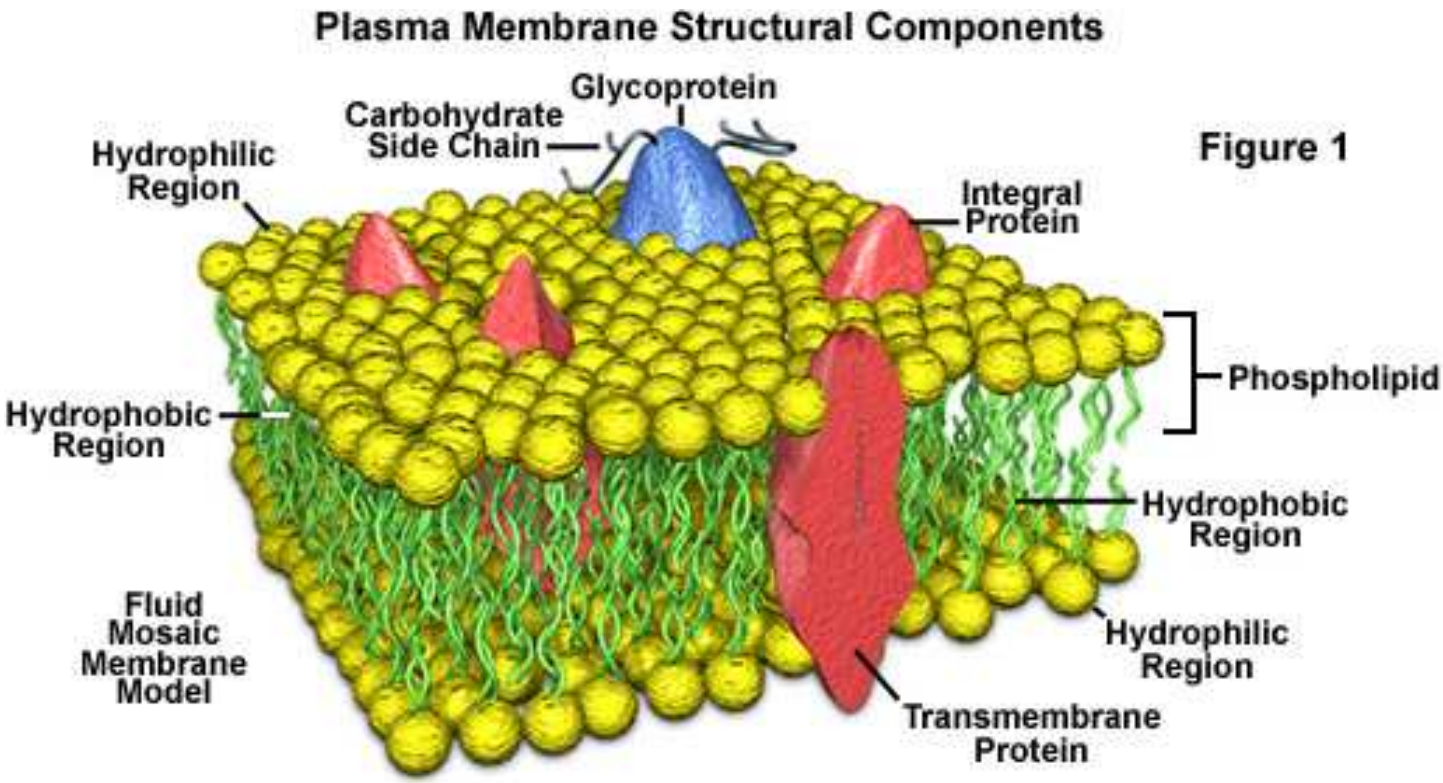
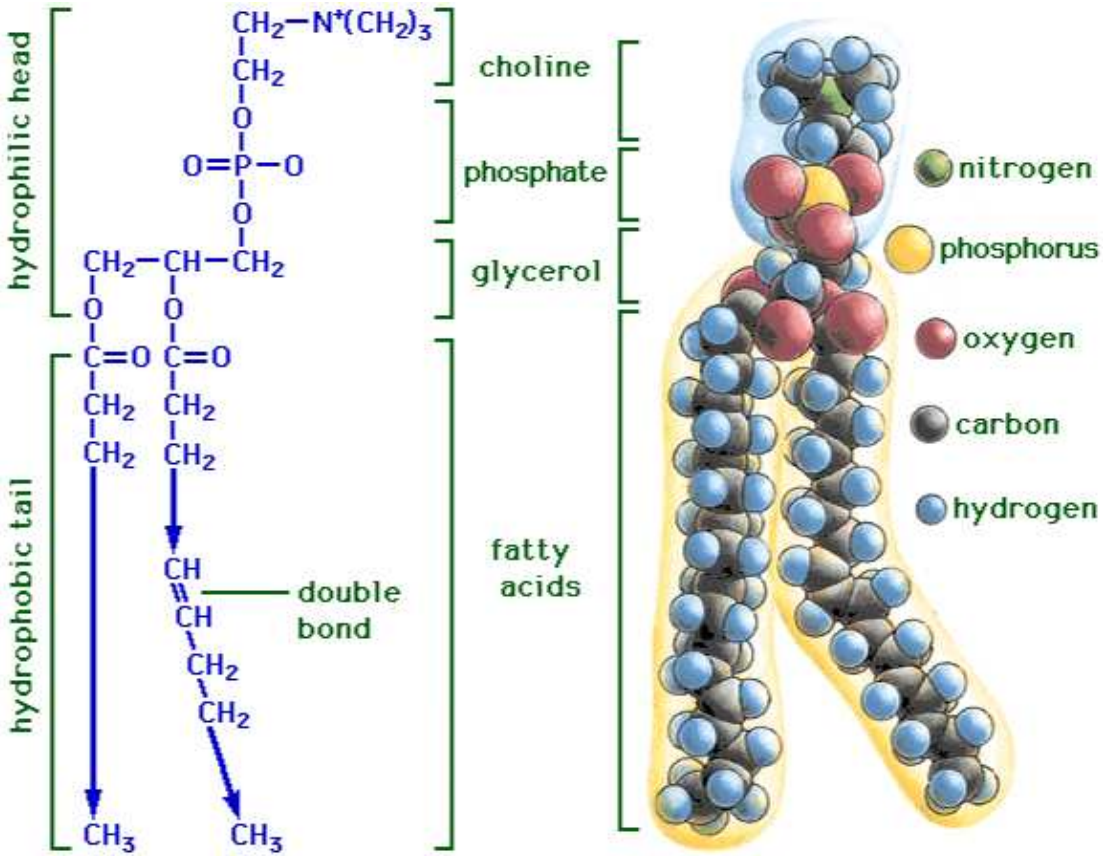
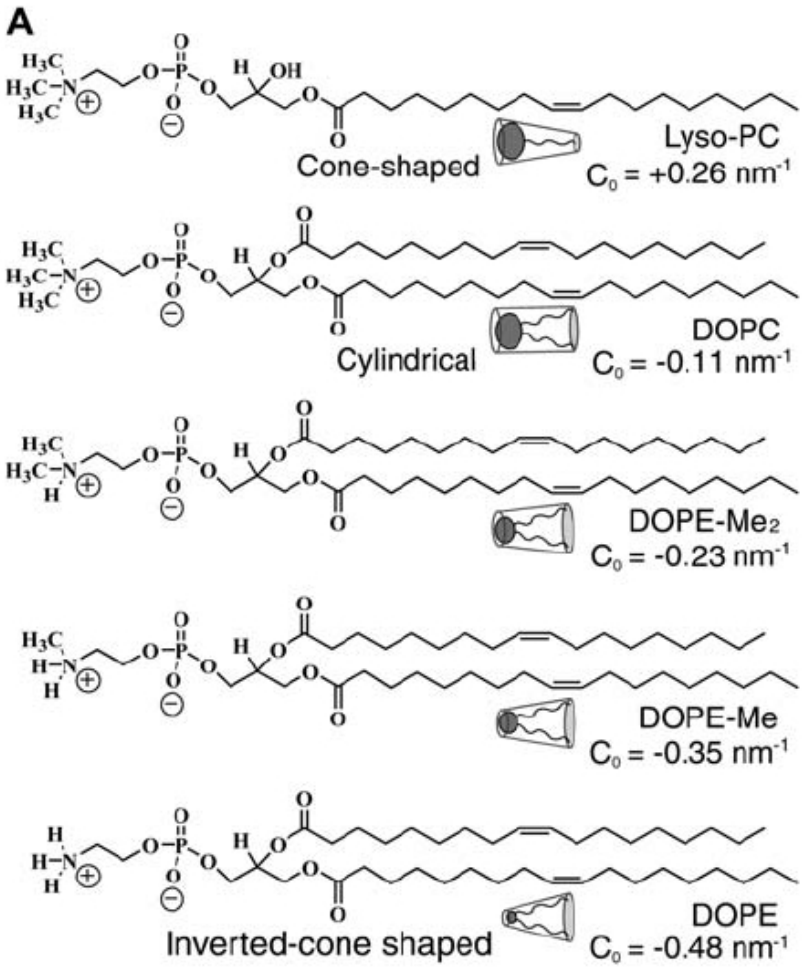


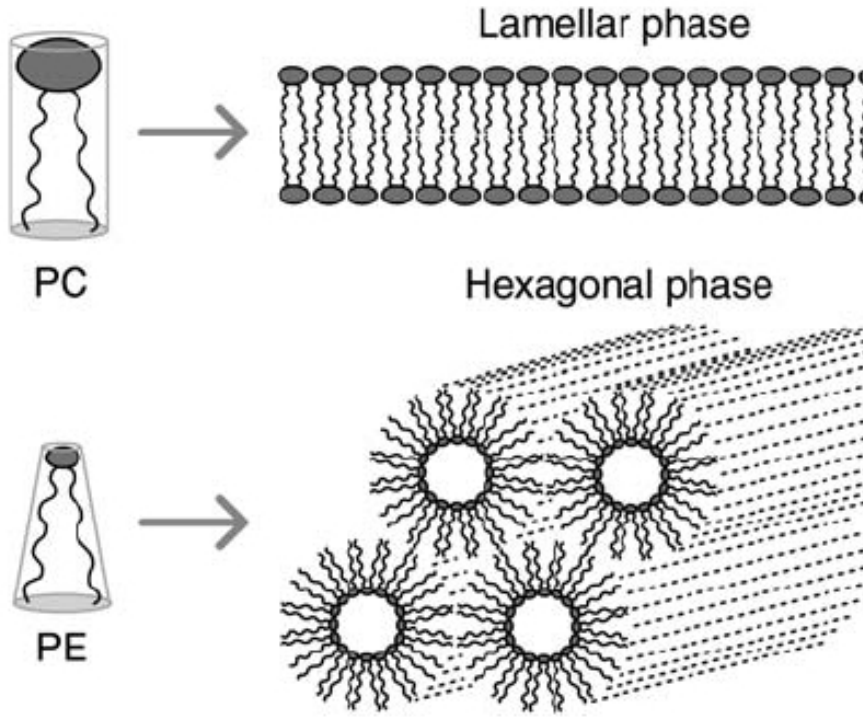
Figure 1

Phospholipids



Types of Phosholipids





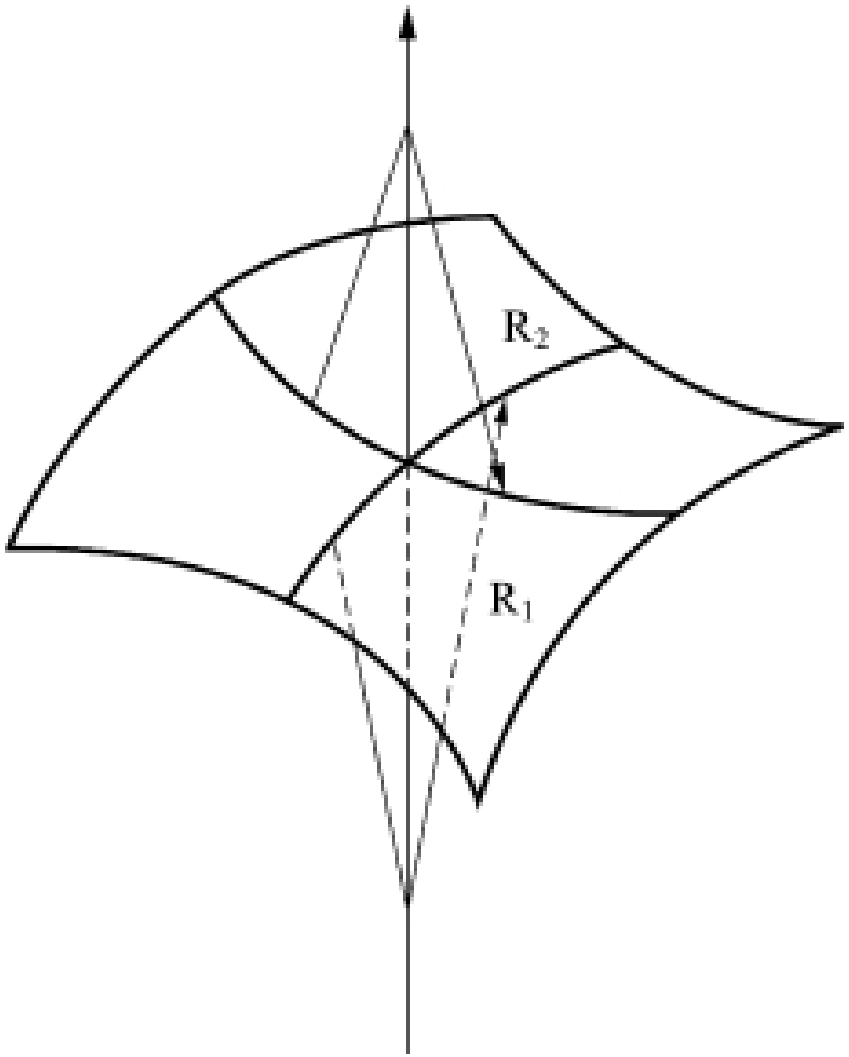
Helfrichs Theory

In 1973 W. Helfrich published his work about "*Elastic Properties of Lipid Bilayers: Theory and Possible Experiments*"

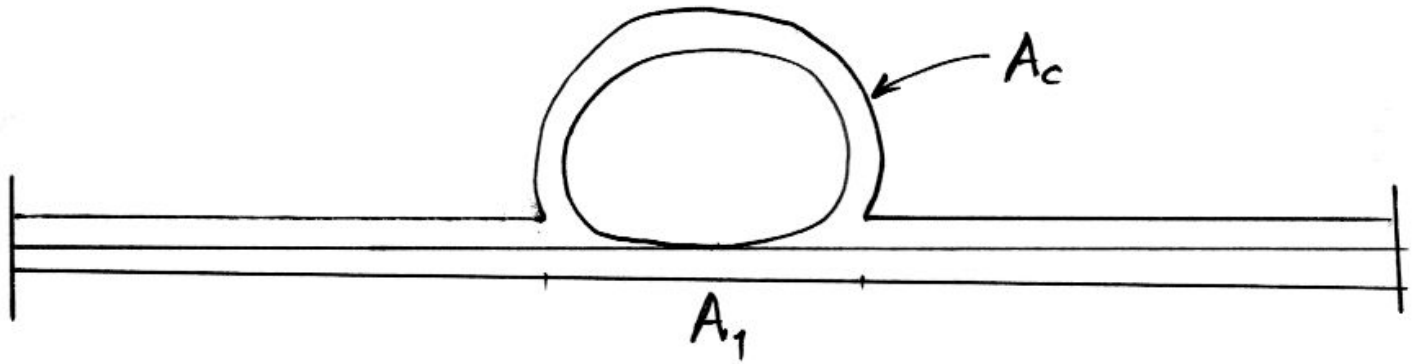
$$G = \underbrace{k_c \int dA(c - c_o)^2}_{Curvature\ \ Energy} + \underbrace{\gamma \int dA}_{Surface\ \ Energy}$$

where $c := \frac{1}{R_1} + \frac{1}{R_2}$ is the **Mean Curvature**
and c_o is the **Spontanous Curvature**

Mean Curvatures



The Lipid Droplet in Terms of Helfrichs Theory



→ *see blackboard*

Our Problem

Is it possible that the Lipid Droplet detach from the ER?
$\longrightarrow$ *see blackboard*

Minimizing the Energy

- Analytically (by solving the corresponding Euler-Lagrange Equations)
- Surface Evolver (by internally optimizing (Gradient Method))
- via own Program (by nummerical minimizing the energy)

Differential Geometry of Surfaces

With the help of differential geometry one gets the **Mean Curvatures**:

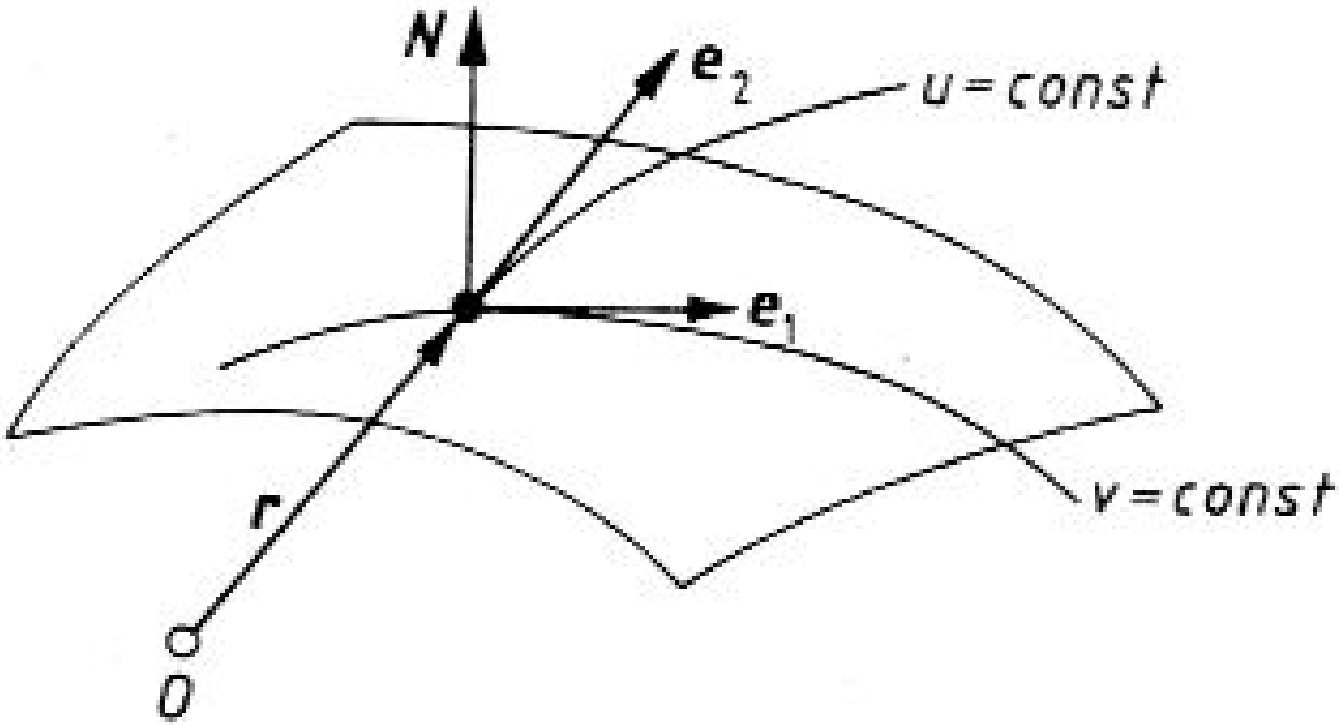


Abb. 3.55

Explizit gilt

Differential Geometry of Surfaces

Curvature Tensor

$$\mathbf{b} = \begin{pmatrix} \frac{\partial \mathbf{N}}{\partial u} \cdot \frac{\partial \mathbf{r}}{\partial u} & \frac{\partial \mathbf{N}}{\partial u} \cdot \frac{\partial \mathbf{r}}{\partial v} \\ \frac{\partial \mathbf{N}}{\partial v} \cdot \frac{\partial \mathbf{r}}{\partial u} & \frac{\partial \mathbf{N}}{\partial v} \cdot \frac{\partial \mathbf{r}}{\partial v} \end{pmatrix}$$

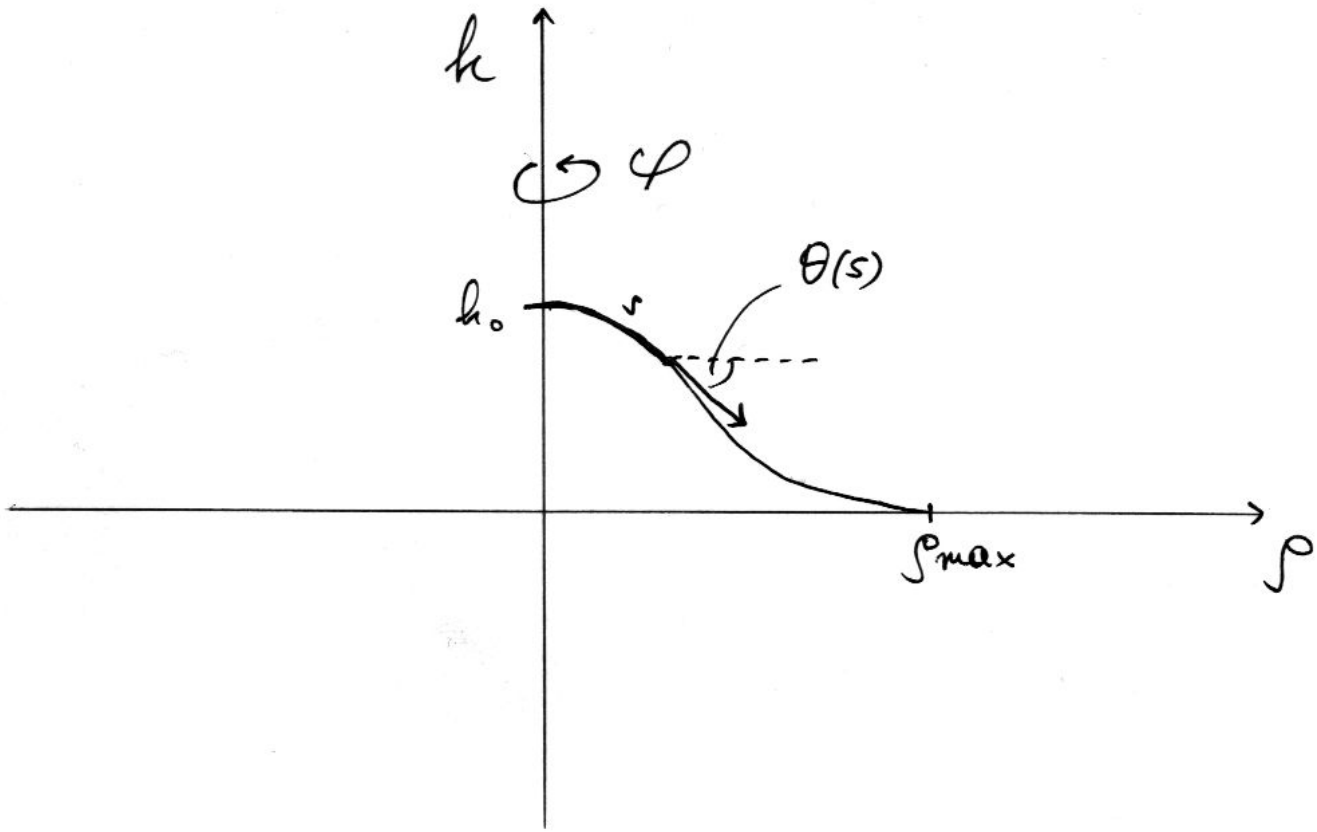
And than the Mean Curvature is:

$$c = b_{ij} g^{ij} = tr\mathbf{b}$$

where g^{ij} is the Metric Tensor:

$$\mathbf{g} = \begin{pmatrix} \frac{\partial \mathbf{r}}{\partial u} \cdot \frac{\partial \mathbf{r}}{\partial u} & \frac{\partial \mathbf{r}}{\partial u} \cdot \frac{\partial \mathbf{r}}{\partial v} \\ \frac{\partial \mathbf{r}}{\partial v} \cdot \frac{\partial \mathbf{r}}{\partial u} & \frac{\partial \mathbf{r}}{\partial v} \cdot \frac{\partial \mathbf{r}}{\partial v} \end{pmatrix}$$

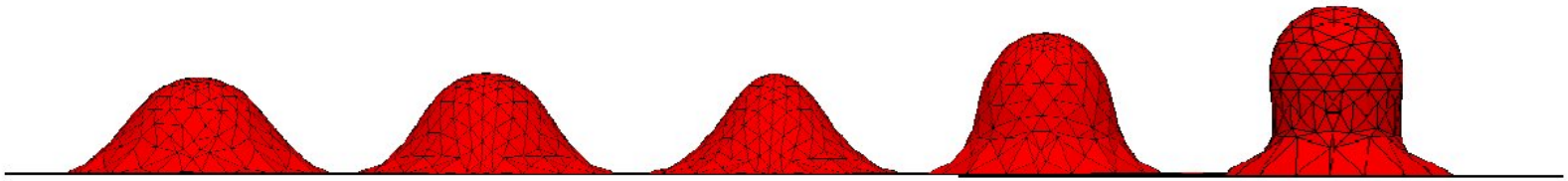
A good Parametrization



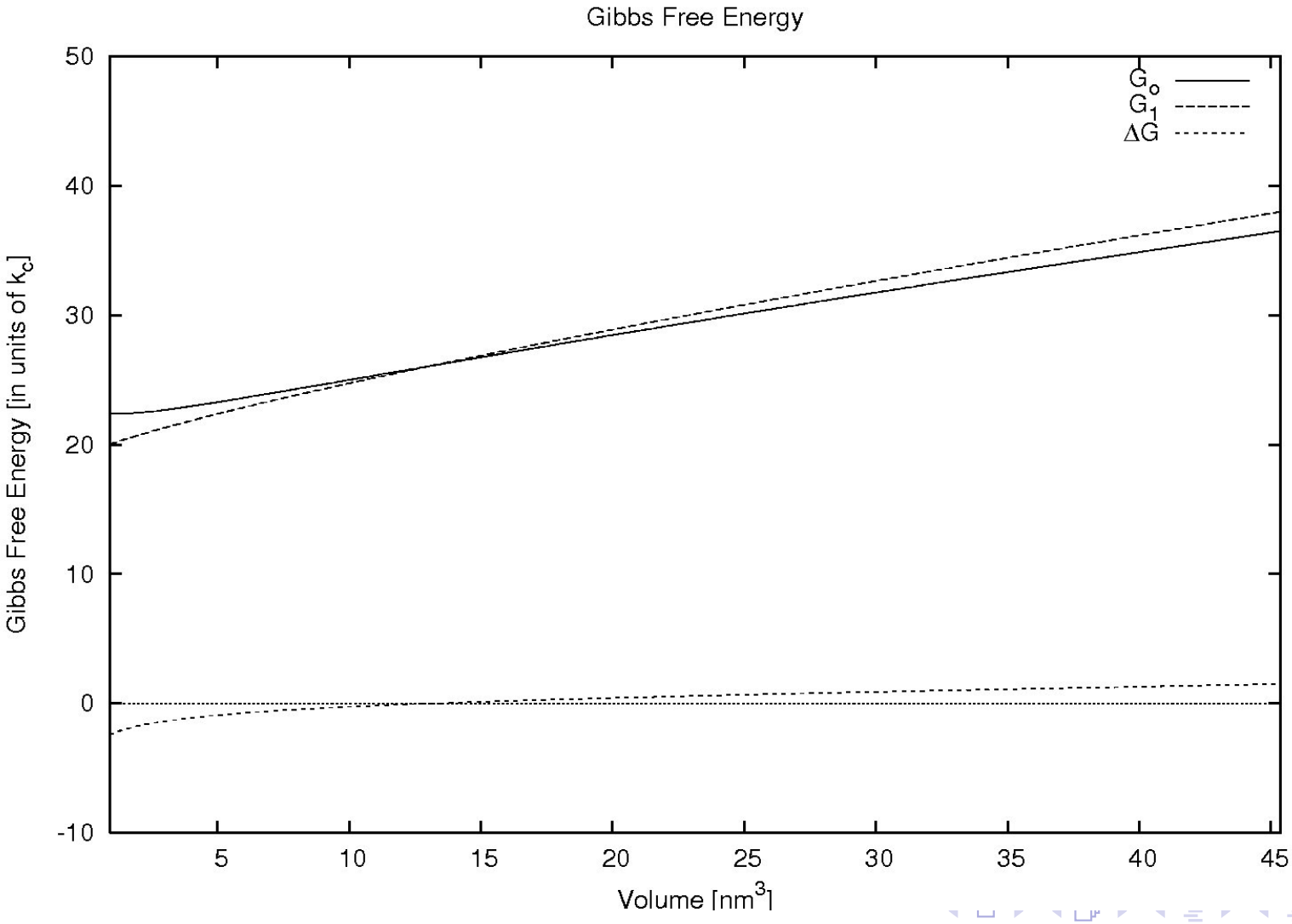
→ *see blackboard*

Surface Evolver

Surface Evolver (by Ken Brakke)



Is the Process of Detaching Energetically Favorable?



Aim of the Thesis

- Is it possible that Lipid Droplets detach from ER?
- If yes, what is the obtained volume?
- If no, how must the parameters be adjusted, that it detaches.
- Generate a Phase Diagram