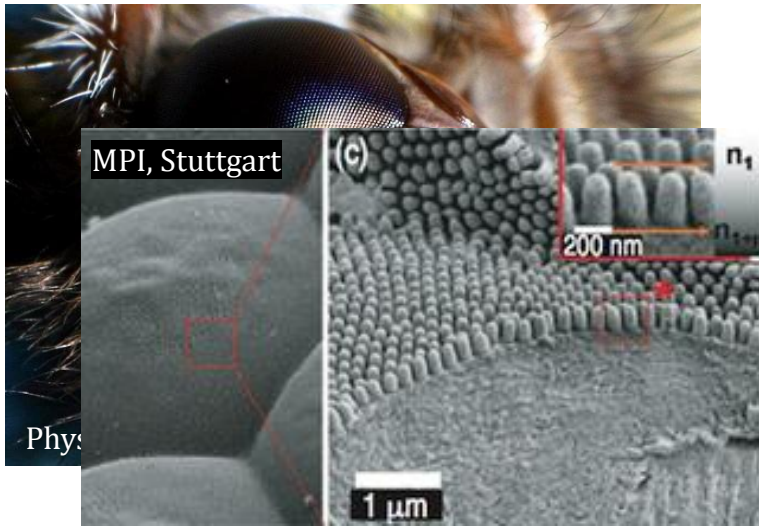
Functional Micropatterned Surfaces in Nature und Technology

Part 1: Self-cleaning Surfaces

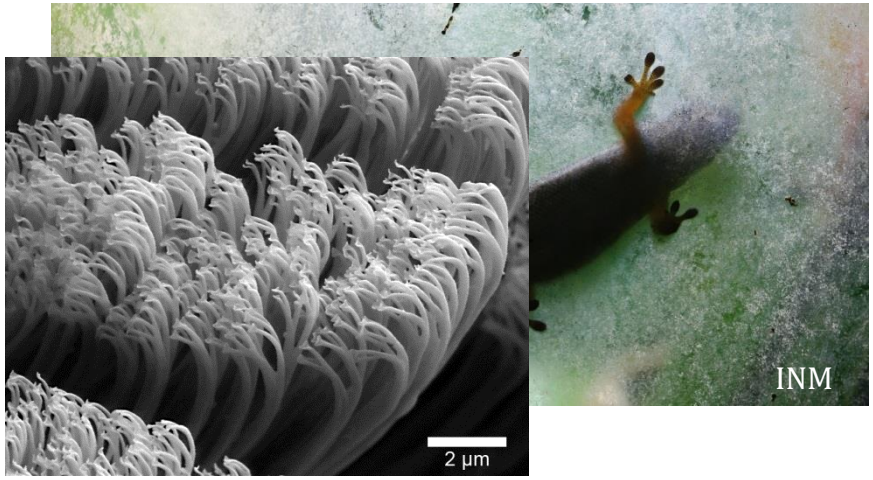
Nanobiomaterialien, Sommersemester 2019

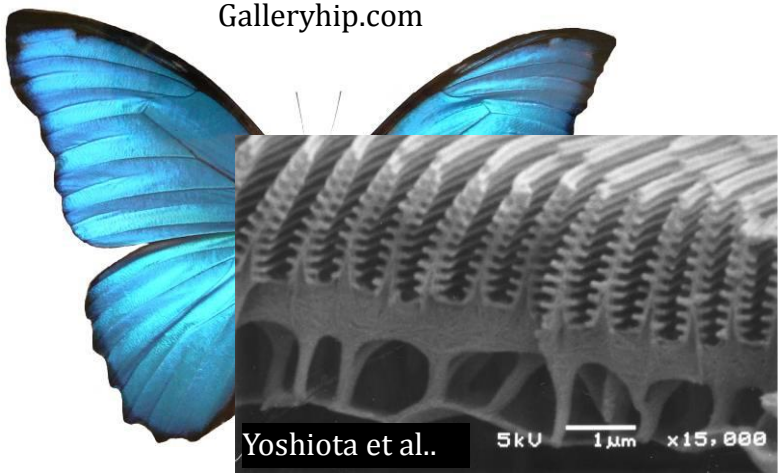
Dr. René Hensel

Functional Surfaces in Nature



Galleryhip.com





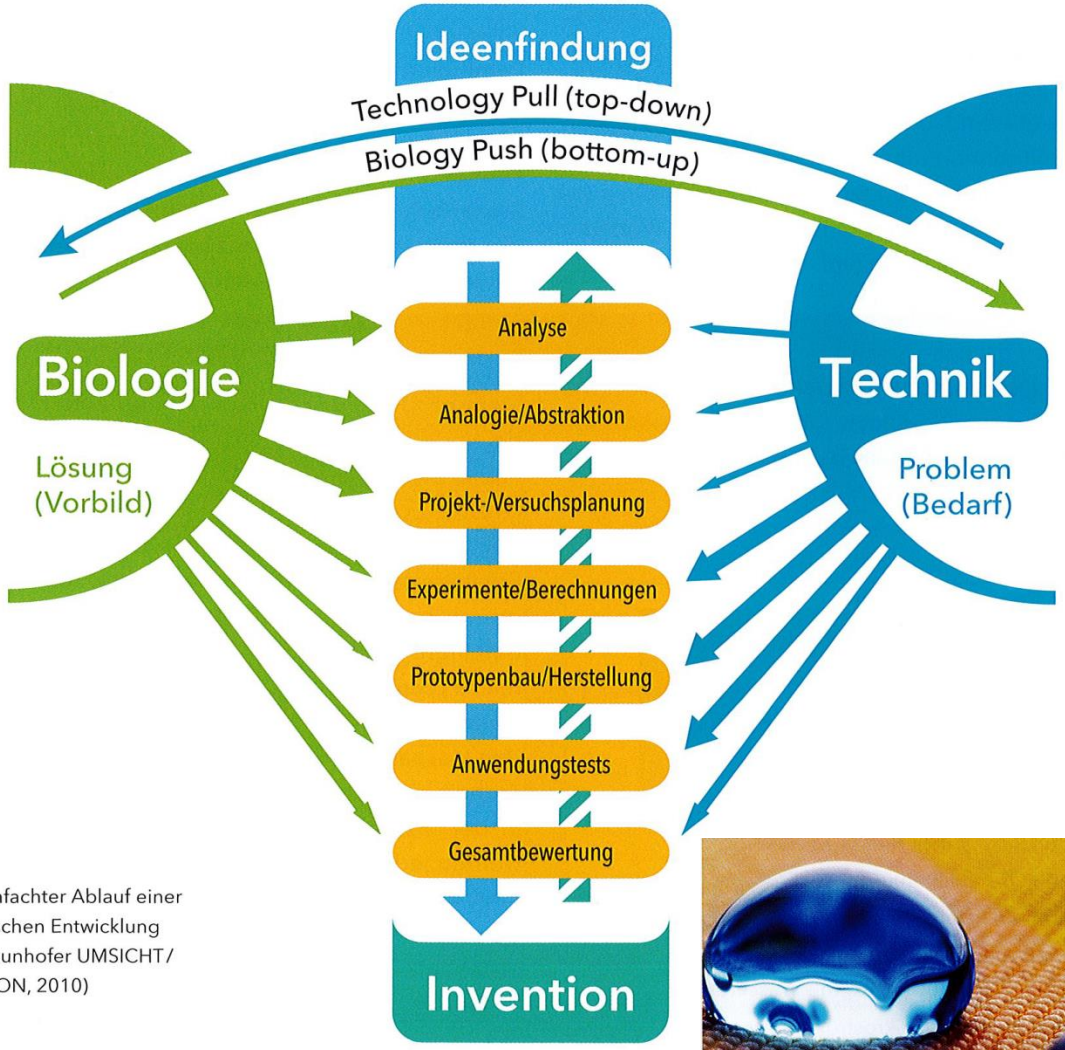
Biomimetics/*Bionik*

”Biomimetics is an interdisciplinary approach combining biology and technology to solve technical problems. The approach includes the understanding gained from biological models, abstraction of underlying principles, and transfer knowledge into applications.”

VDI Richtlinie 6223

Phenomenon → Understanding → Abstraction → Transfer

Biomimetics/*Bionik*

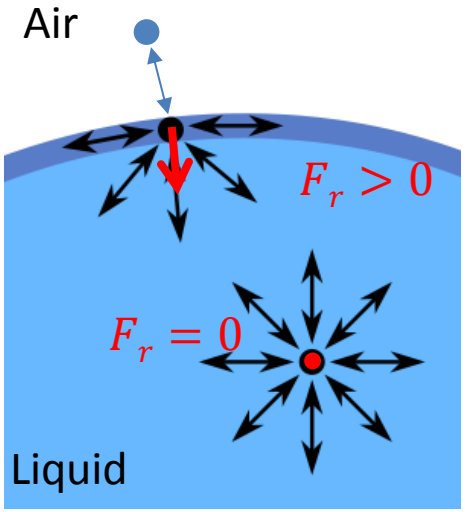


Vereinfachter Ablauf einer bionischen Entwicklung (© Fraunhofer UMSICHT/ BIOKON, 2010)

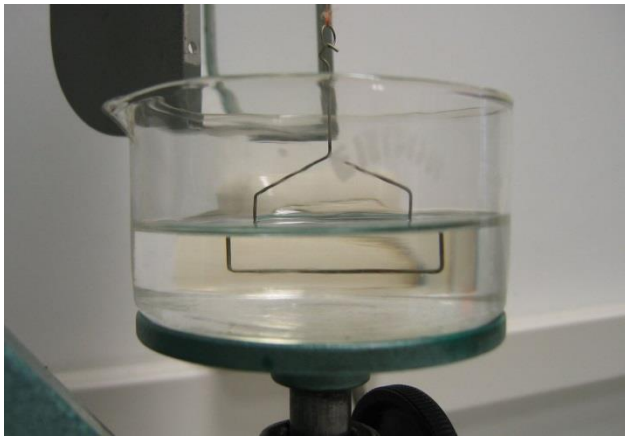
Self-cleaning surfaces

Surface Tension/ Surface Free Energy

Interaction between atoms or molecules



Tensiometer



Wikipedia

$$\gamma = \frac{F}{2L} = \frac{dW}{dA}$$

Surface tension [N/m]

Surface free energy [J/m²]

Surface Tension/ Surface Free Energy

Overview (Popov, V.L.)

Liquid	Surface tension (mN/m)
Diethyl ether	17.00
n-Hexane	18.40
Isopropanol	21.70
n-Octane	21.80
Ethanol	22.27
Acetone	23.70
Toluene	27.73
Glycerol	63.00
Water	71.97
Mercury	487.00

Solid	Surface free energy (mJ/m^2)
PTFE (Teflon)	18.30
Silicon rubber	21
Paraffin	25
Polystyrene	33
NaCl	160
Al_2O_3	640
Si	1280
Ag	1440
Fe	2400
W	4500

Surface to Volume Ratio

Size ratio

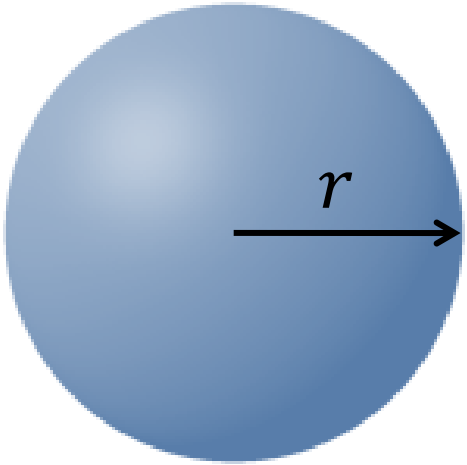
Diameter of Earth = 1

Micro = 10^{-6}

Nano = 10^{-9}

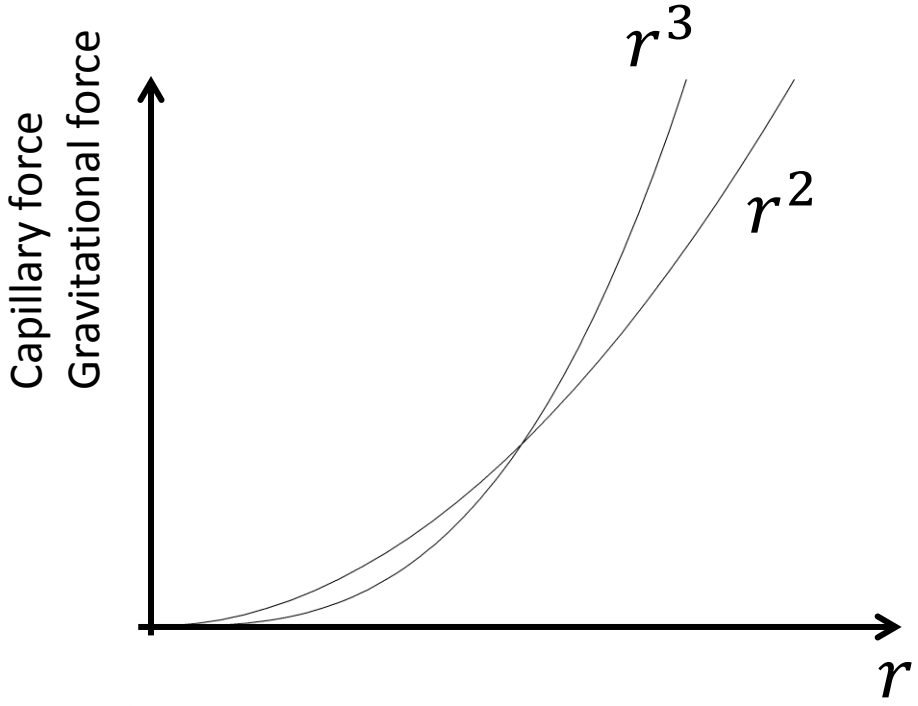
Surface to Volume Ratio

Liquid droplet



$A_0 \sim r^2$

$V \sim r^3$



Examples:

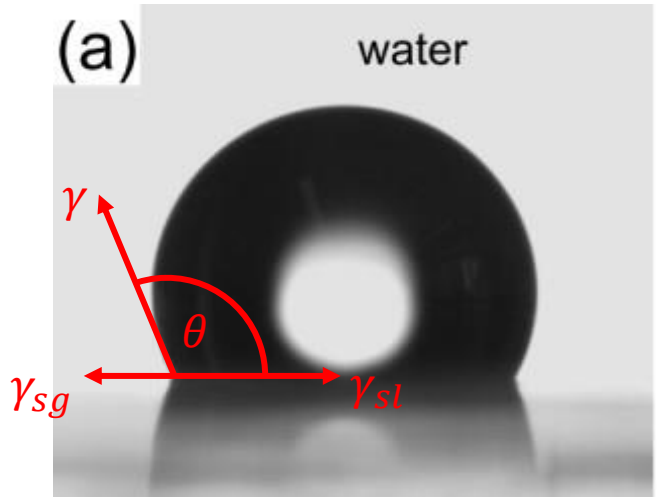
- Capillary length, Capillary rise

Surface Wetting

Wetting of Smooth Surfaces

Three-phase contact angle:

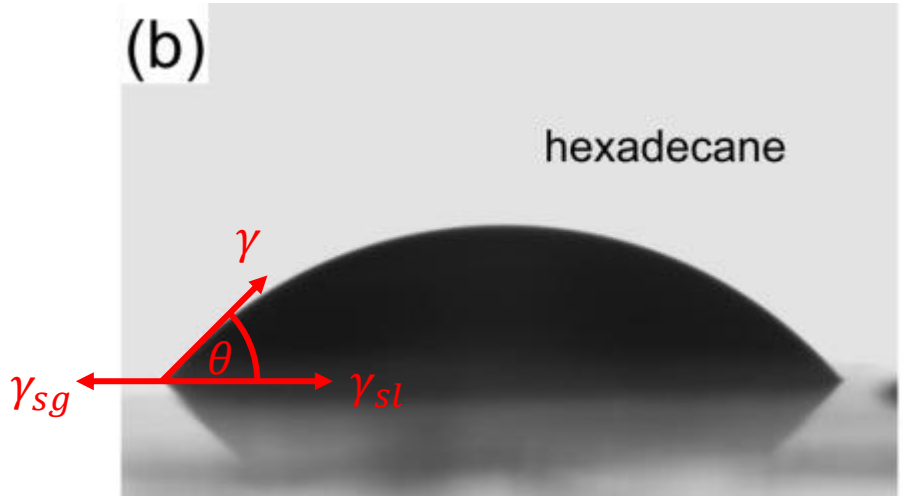
$$\cos\theta = \frac{\gamma_{sg} - \gamma_{sl}}{\gamma}$$



Capillary force:

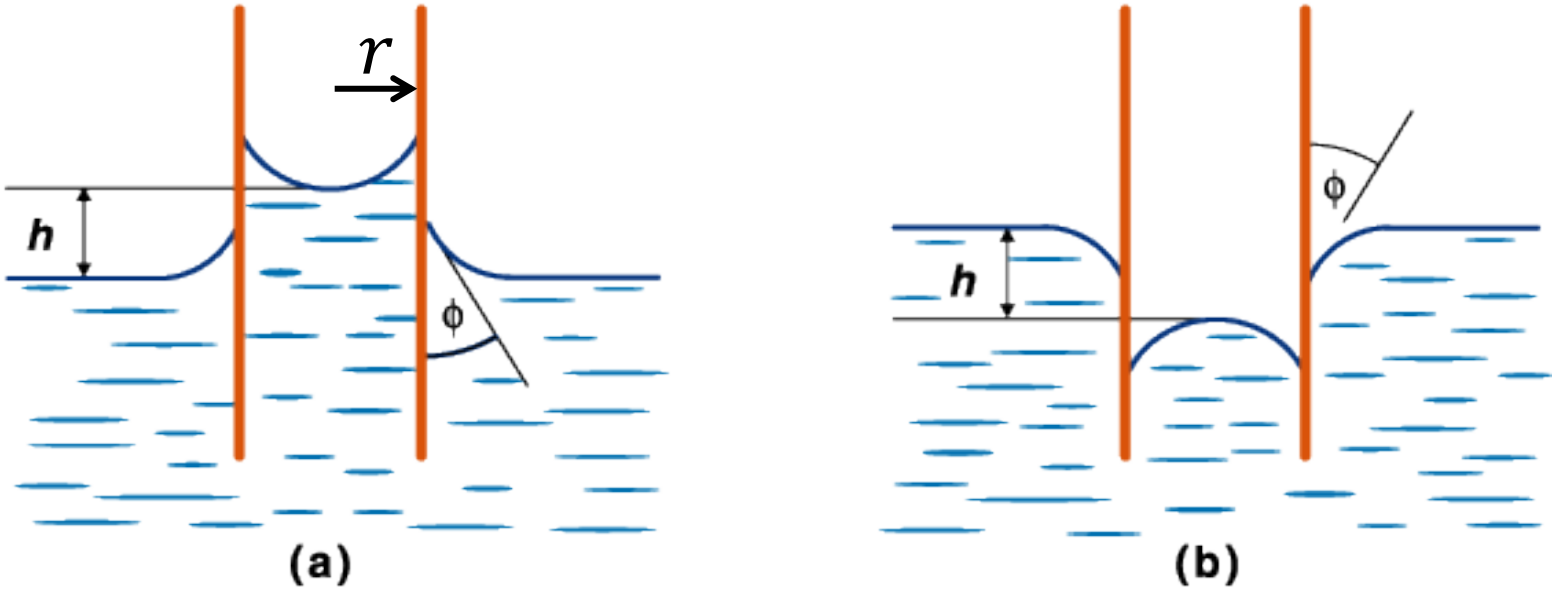
$$F_c = l\gamma\cos\theta$$

Force acting at
the three-phase contact line.



Capillary Rise

Height of the meniscus: $h = \dfrac{2\gamma \cos\theta}{\rho g r}$



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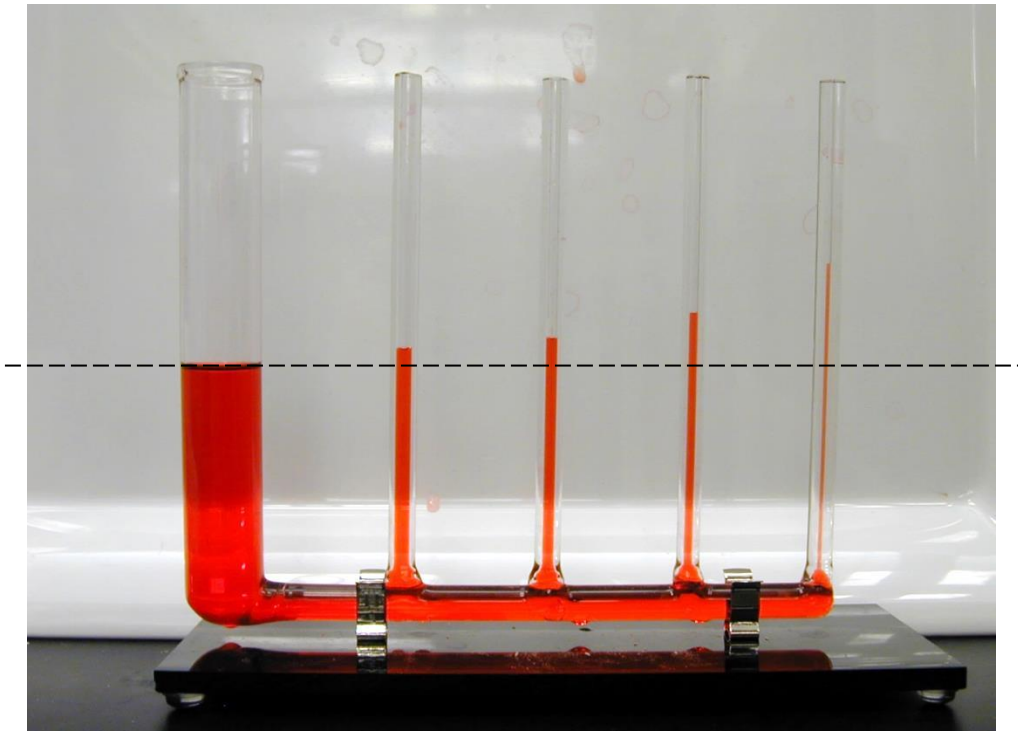
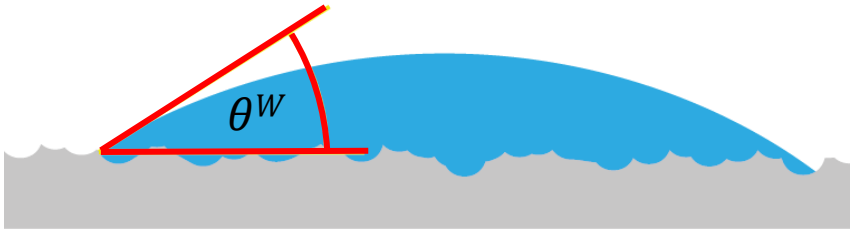


Wetting of Rough Surfaces

Wenzel‘s model



smooth: $\frac{A_{real}}{A_{proj}} = 1$

rough: $\frac{A_{real}}{A_{proj}} > 1$

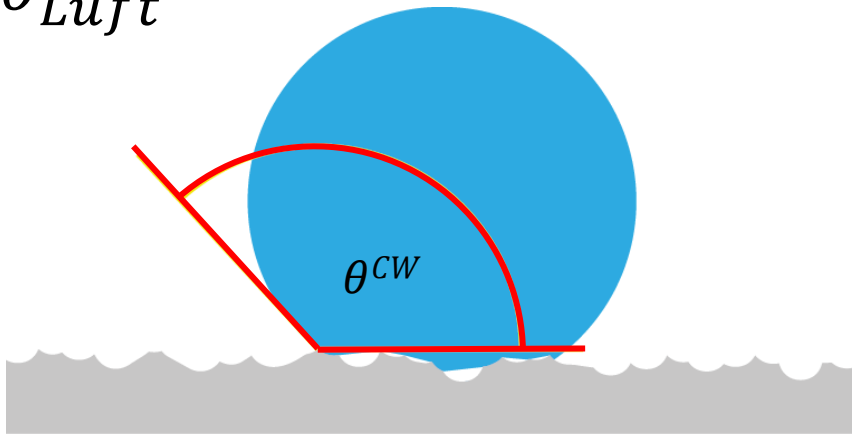
$$\cos\theta^W = \frac{A_{real}}{A_{proj}}\cos\theta$$

Wetting of Rough Surfaces

Cassie und Baxter‘s model

$$\cos\theta^{CB} = f_1 \cos\theta + f_2 \cos\theta_{Luft}$$

$$\cos\theta^{CB} = f_1 \cos\theta + f_1 - 1$$

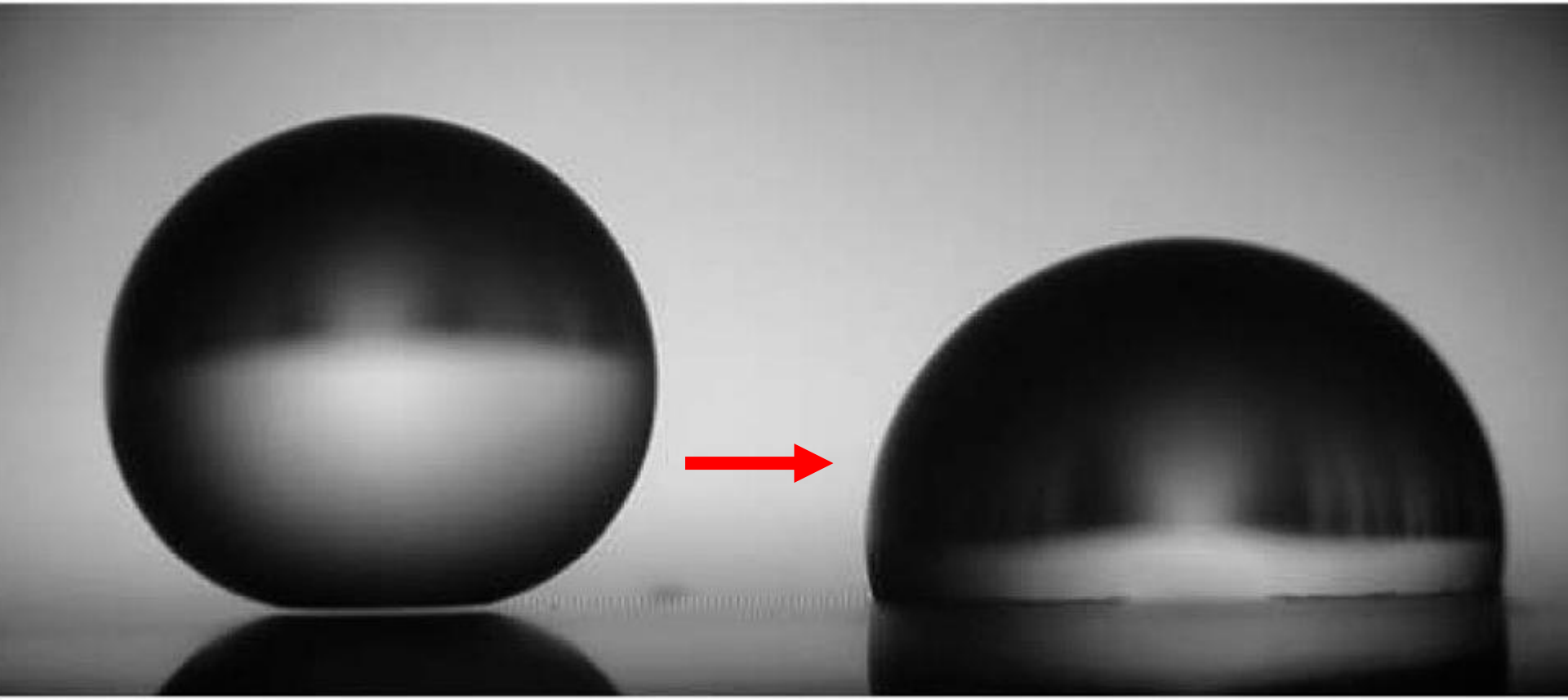


$f1$ fraction of liquid-solid interface

f_2 fraction of liquid-air interface

θ_{Luft} = 180°

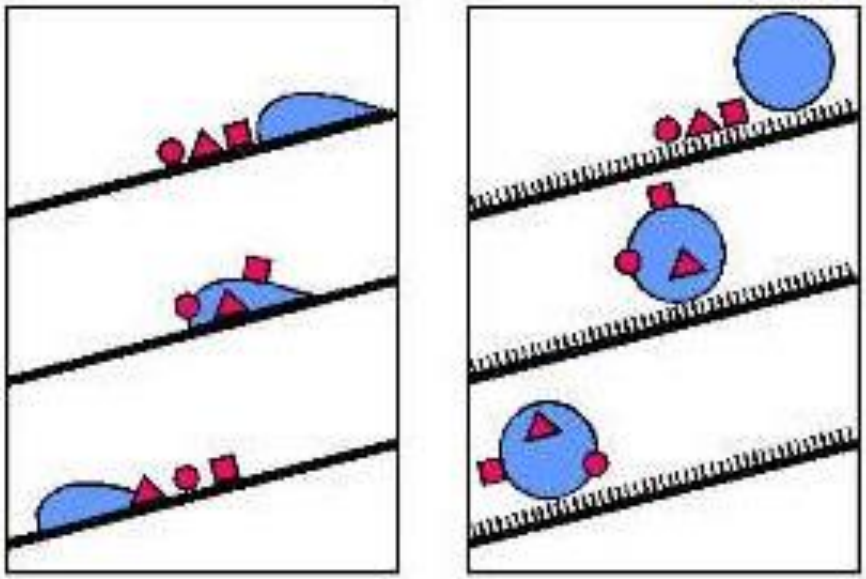
Wetting of Rough Surfaces



Cassie und Baxter state is metastable and can be transferred to stable Wenzel state.

Self-cleaning Surfaces

Adhesion of dust and particles is lower to rough surfaces compared to the interaction with water-air interface of a droplet.



Neinhuis, C., Barthlott, W. *Planta* 1997

http://www.pw-internet.de/images/cms/ispo1.jpg

Current Research Topics

- Self-cleaning surfaces for liquids with low surface tension such as oils, solvents and water with tensides
- Integration of additional functionalities such as optical properties, antifouling, …
- Mechanical resistance, scratch resistance, …

Fragen zur Vorlesung

- Was ist Bionik? Welche Beispiele gibt es?
- Wie kann die Oberflächenenergie von Festkörpern bestimmt werden?
- Warum besitzt Wasser eine höhere Oberflächenspannung als Dodekan?
- Was beschreibt die Kapillarlänge?
- Wie wird das Benetzungsverhalten bestimmt? Welchen Einfluss hat die Oberflächenrauigkeit auf das Benetzungsverhalten?
- Was sind die strukturellen und chemischen Voraussetzungen um eine selbstreinigende Oberfläche herzustellen.
- Existieren selbstreinigende Oberflächen für ölige Flüssigkeiten? Wenn ja, wie unterscheidet sich deren Oberflächenstruktur?