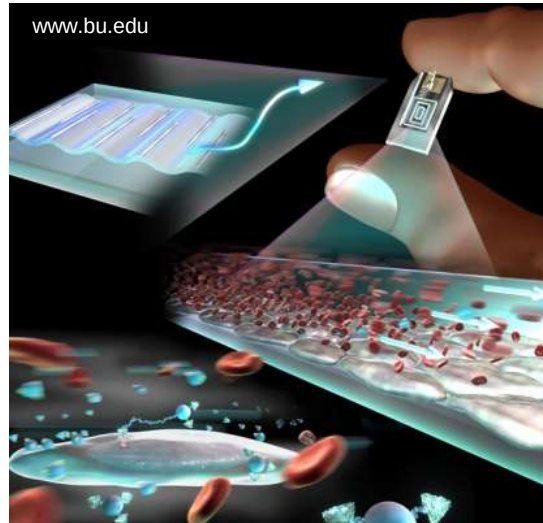




Nanoanalytics / Interfaces II

Lecture: Nanoanalytics and Biophysics

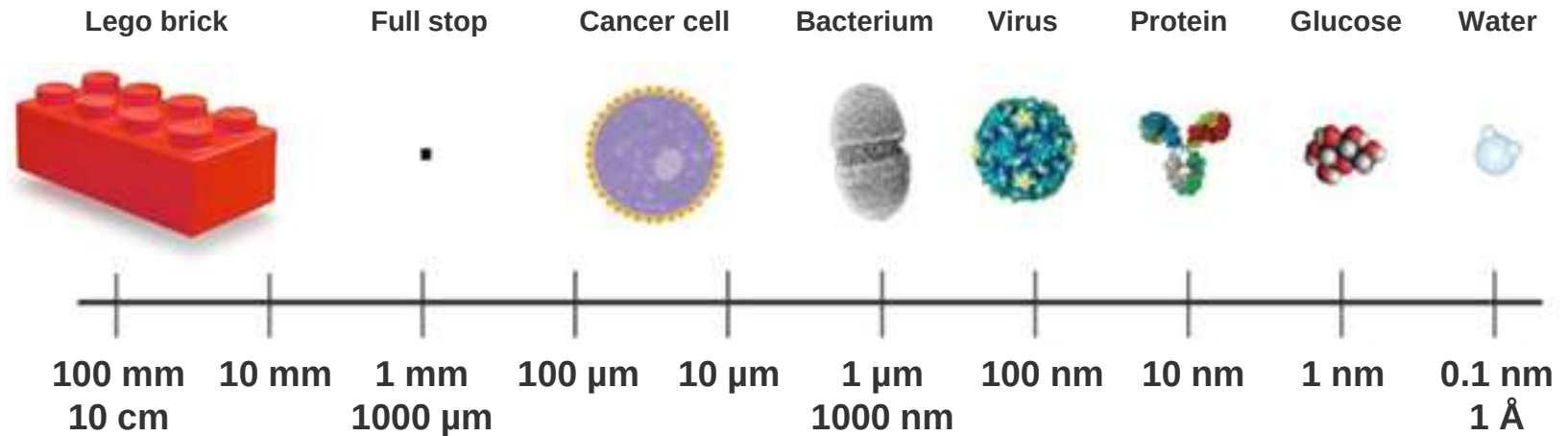
Dr. Johannes Rheinlaender & Prof. Dr. Tilman Schäffer ≠ Prof. Erik Schäffer

johannes.rheinlaender@uni-tuebingen.de

Institute of Applied Physics

University of Tübingen

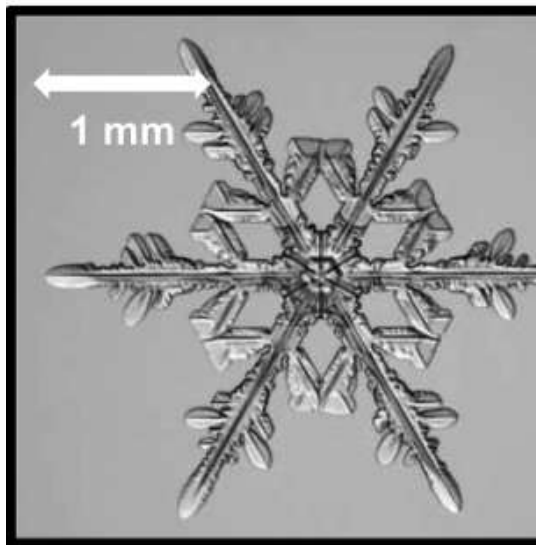
From the macro over the micro to the nano world...



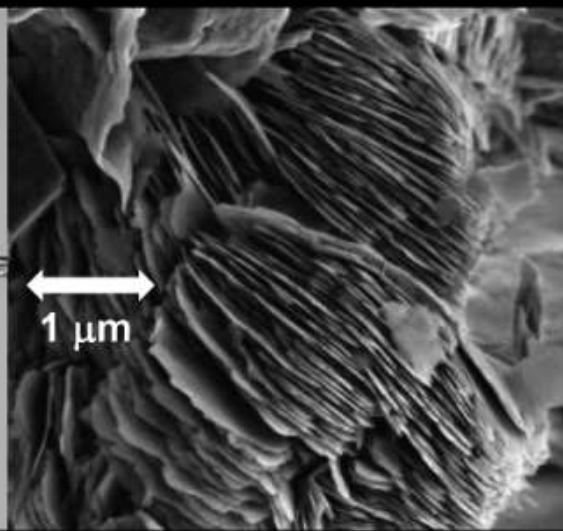


From the macro over the micro to the nano world...

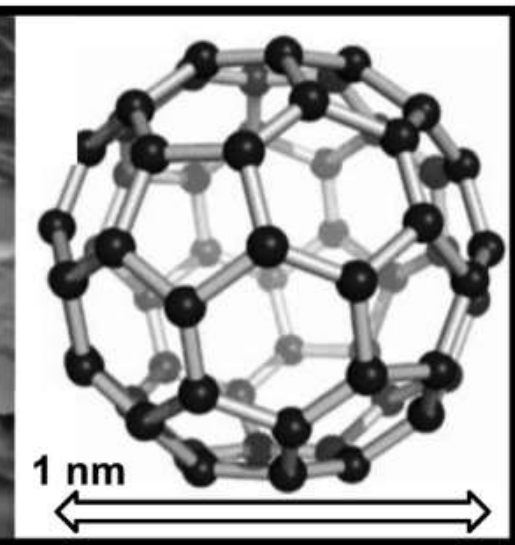
macro (milli)



micro



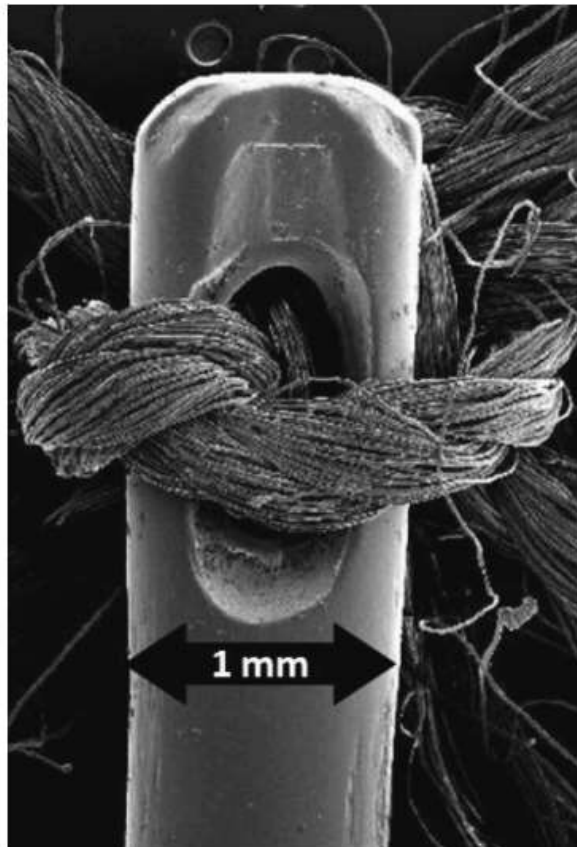
nano



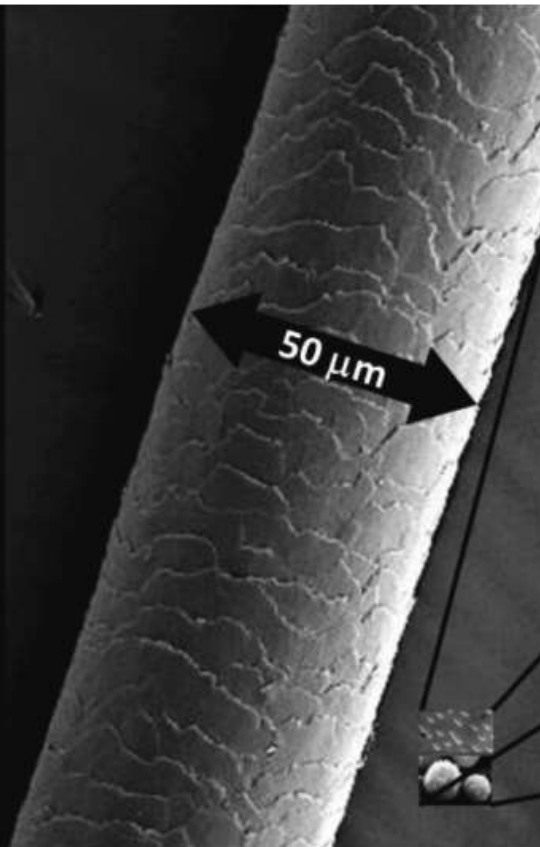


From the macro over the micro to the nano world...

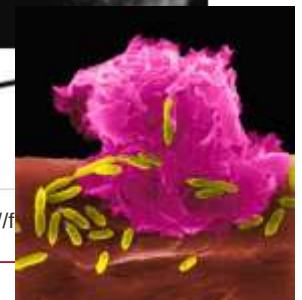
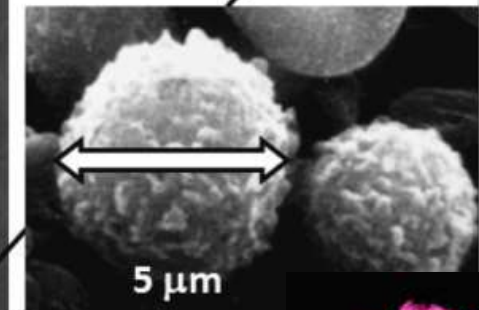
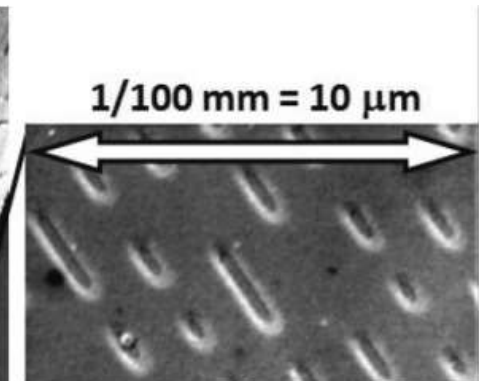
macro (milli)



micro



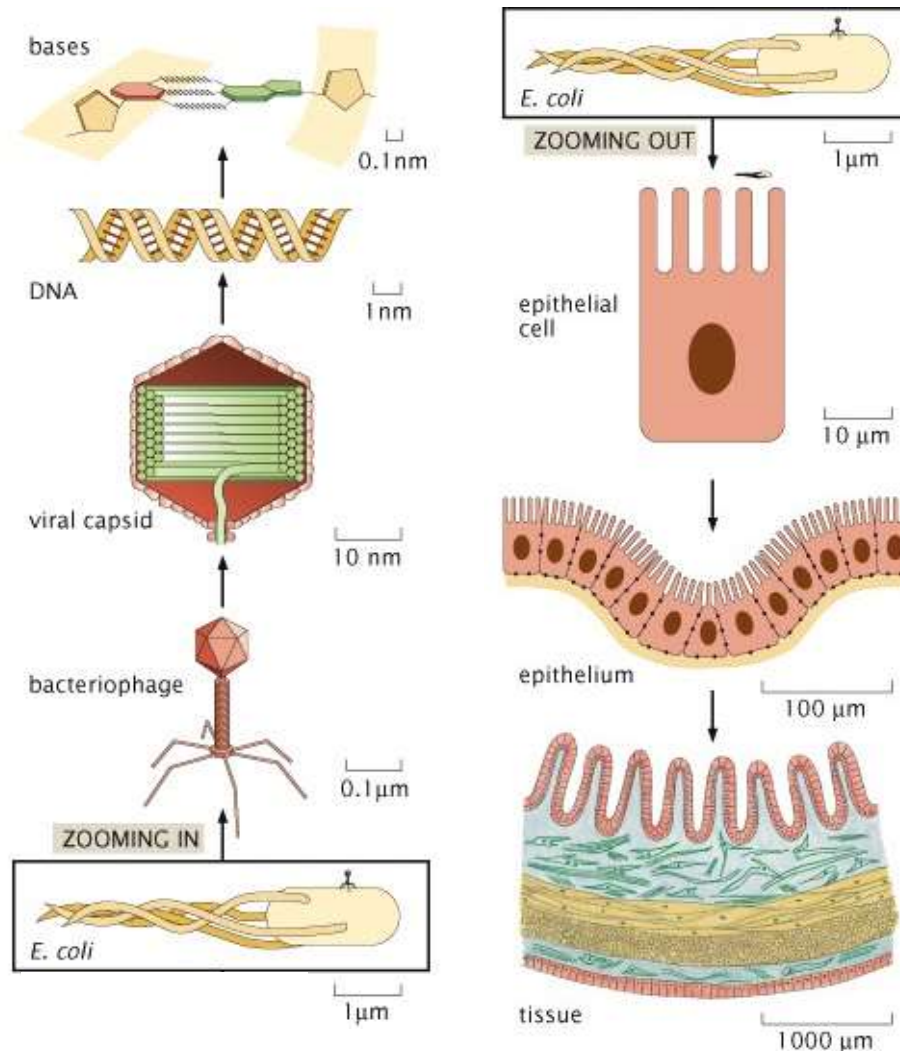
still micro



G. Gateförl [3-5], <http://f>



From the macro over the micro to the nano world...





Why NANO?

What is so cool in making things smaller?

Technological motivation:

R. Feynman in 1956:

“There’s plenty of room at the bottom.”

100 atoms per bit (~nucleotide)

→ All books of the world in 0.1 mm cube

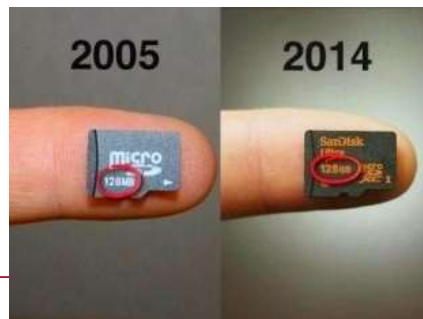


<http://wonderfulengineering.com>

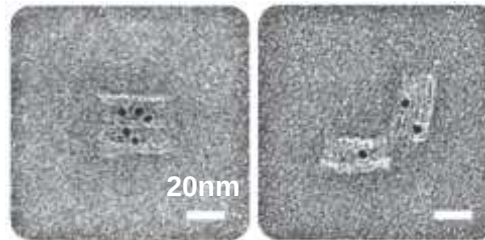
<http://www.123rf.com>

Moore’s Law:

Transistor density
doubles in 1-2 years



Medical motivation:



Douglas *et al.* Science **335** (2012)

DOI: 10.1126/science.1214081



Bath University. <http://people.bath.ac.uk>



Nano = new ?

No! Some examples for old techniques, utilizing nanotechnology intuitively:



Paint



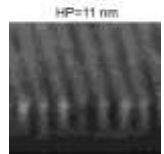
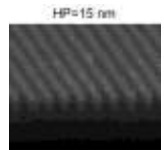
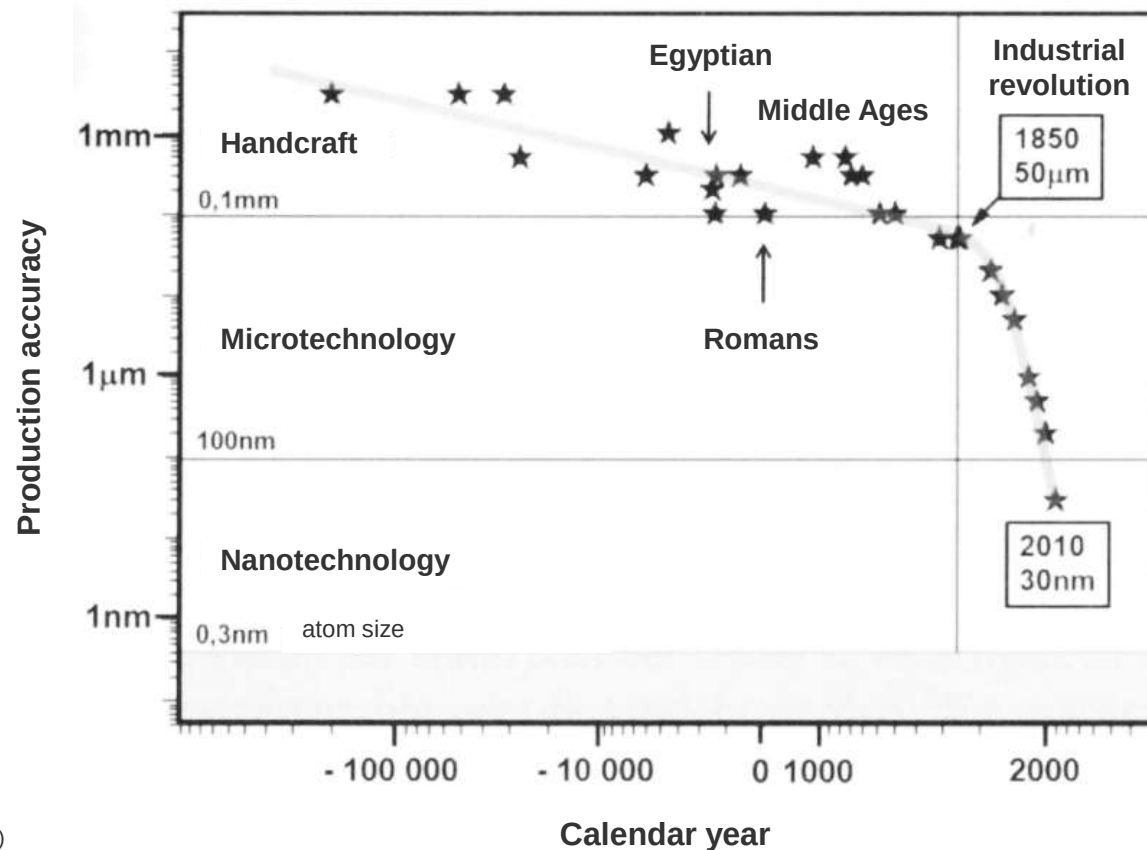
Gold leaf
approx. 100 nm thickness

Cranberry or gold ruby glass with gold nanoparticles having ~500 nm plasmon resonance





But new to fabricate nanotechnology!

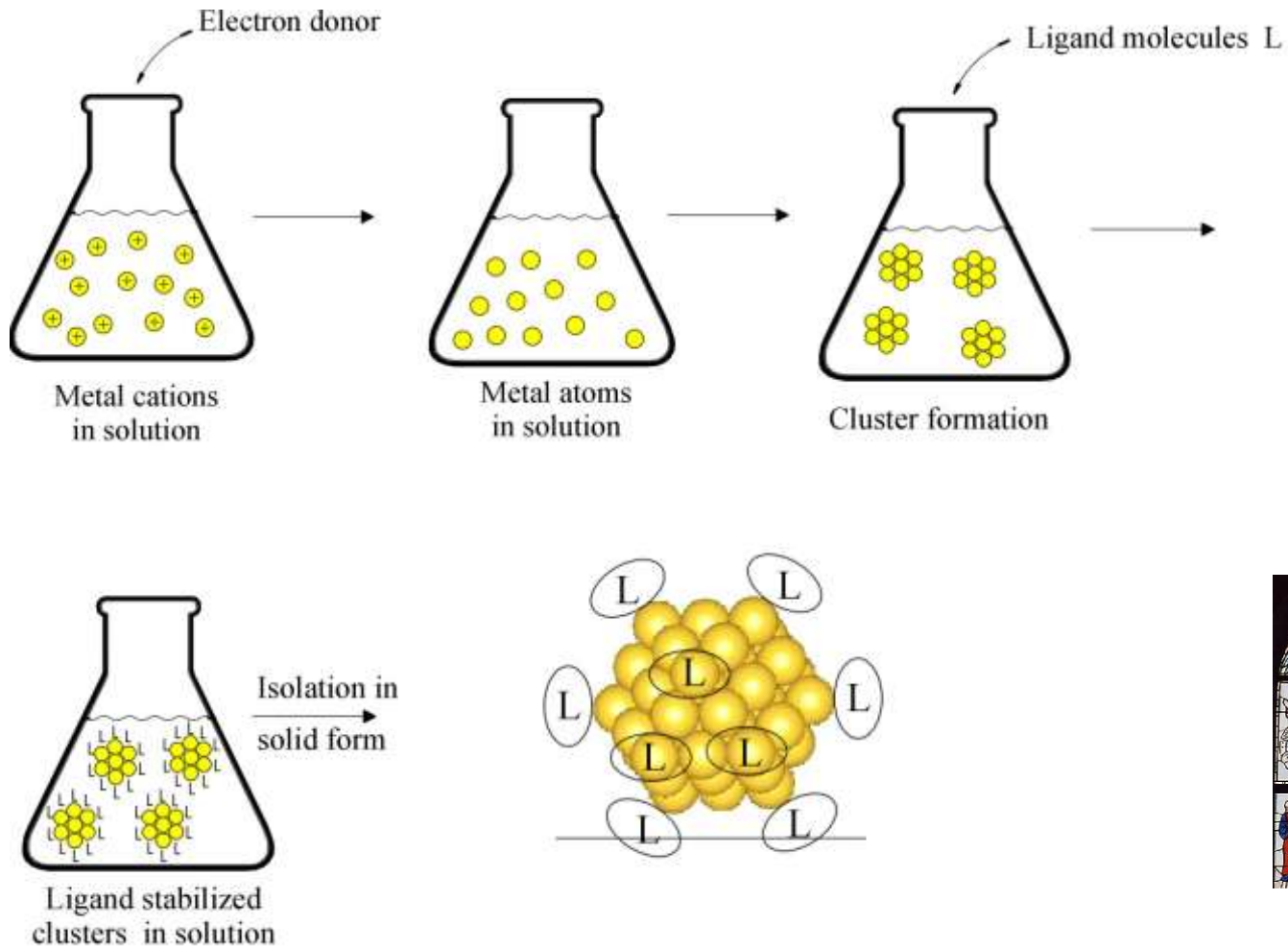


G. Gatefö
Museum Jülich
<http://www.nhm-wien.ac.at>
<http://img.welt.de>
<https://en.wikipedia.org>
<http://mtb-news.de>
Mojarad *et al.* Nanoscale 7 (2015)

(EUV) lithography
($\lambda = 13.5$ nm)



Synthesis of metal cluster nanoparticles



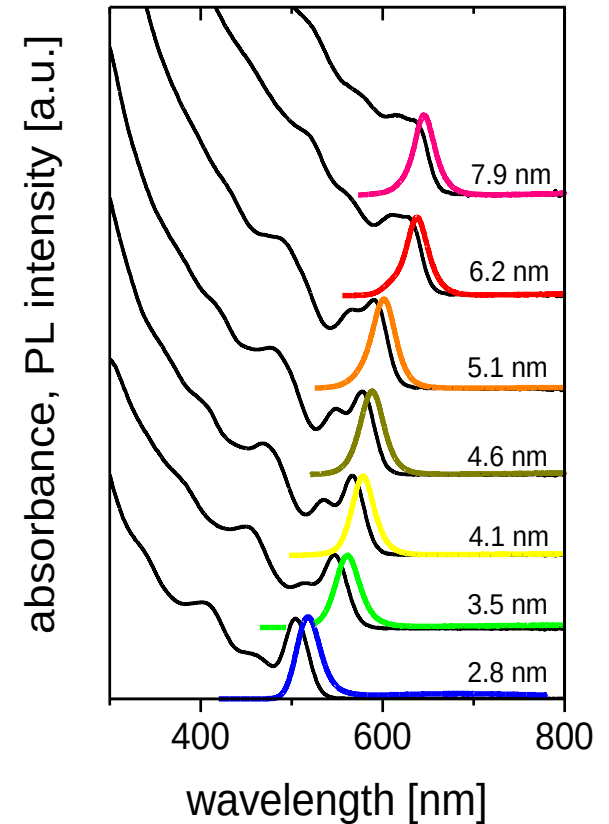


Fluorescent nanoparticles (“quantum dots”)



Fluorescence quantum yield (Efficiency) **85%**

High photo-stability (don't “bleach”)



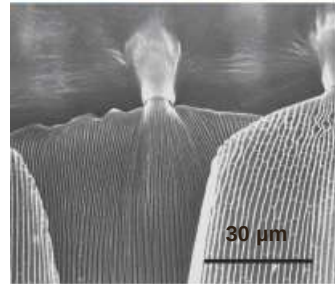
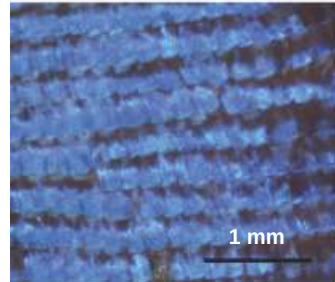
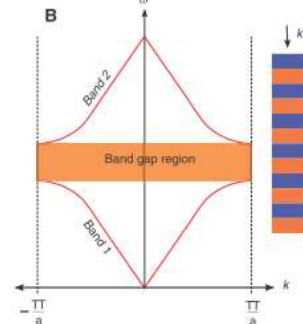
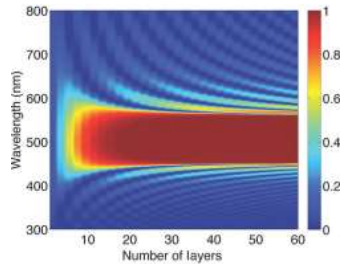
Horst Weller, University Hamburg



Butterfly



Photonic crystal:



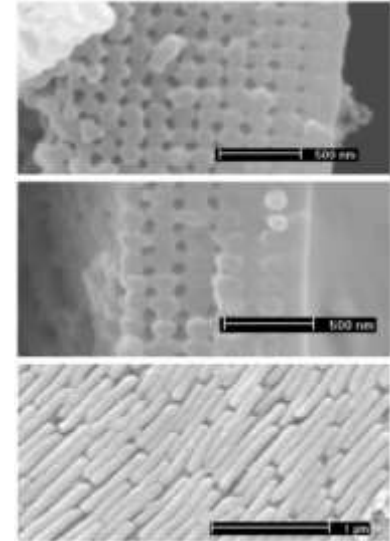
Review:

Starkey & Vukusic
Nanophotonics **2** (2013)
DOI: 10.1515/nanoph-2013-0015

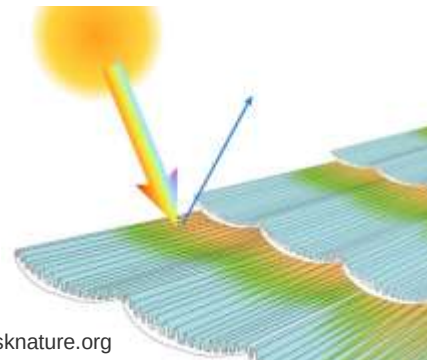
Peacock



<https://i.pinimg.com>



Zi *et al.* PNAS **100** (2003)
DOI: 10.1073/pnas.2133313100



www.asknature.org

Digital Object Identifier
<http://dx.doi.org/10. ...>





Beetle

150 years old Three-Colored Juwel Beetle

Oxford University Museum of Natural History
 (collection by Darwin etc.)
<http://microsculpture.net/>



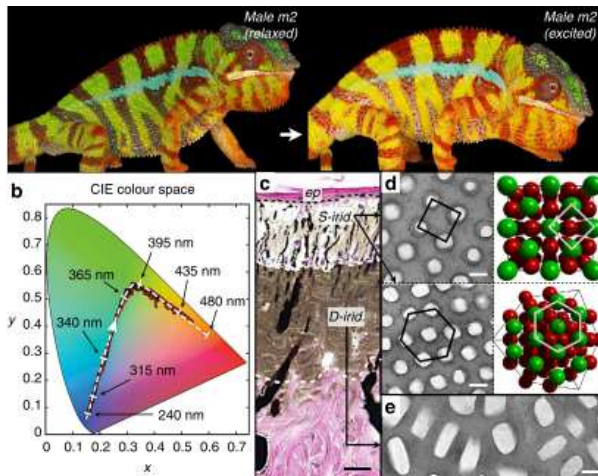
150 years old uniform



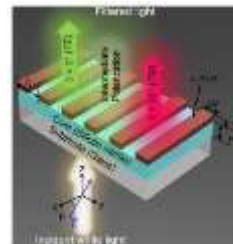
<https://i.pinimg.com>



Chameleon



Multicolor Pixel



L'Oréal (www.loreal.com)

Koirala *et al.* Sci. Rep. **7** (2017)
 DOI: 10.1038/s41598-017-14093-6

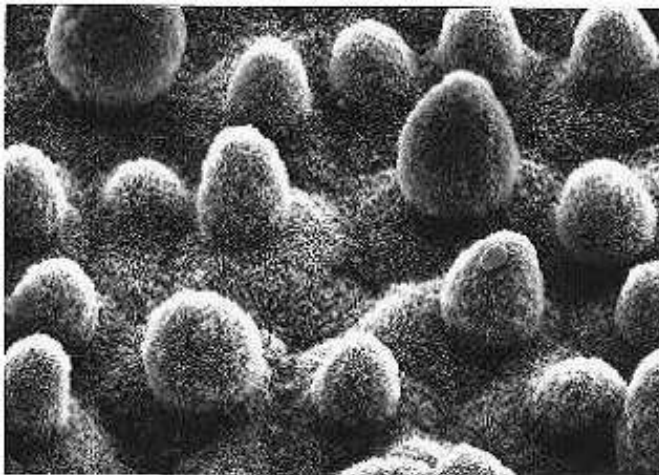
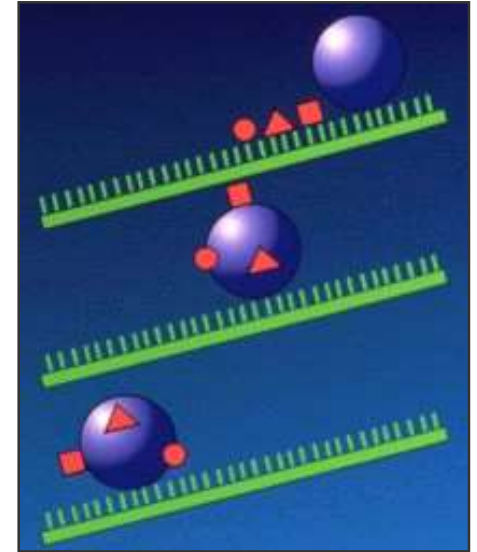
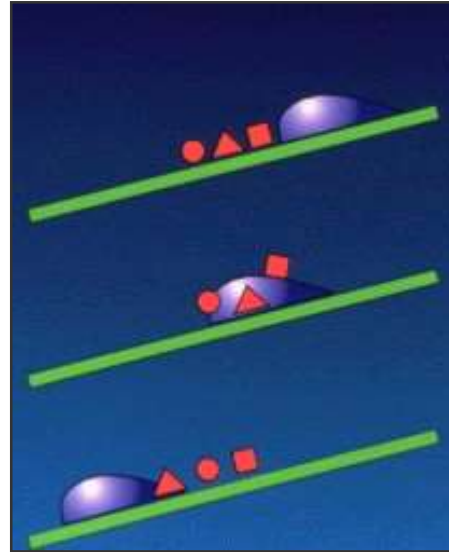
Teyssier *et al.* Nature Comm. **6** (2015)
 DOI: 10.1038/ncomms7368



McMaster University
<http://cranstongroup.mcmaster.ca/>



Self-cleaning – Lotus effect



Prof. Barthlott,
Univ. Bonn



Self-cleaning – Lotus effect



Prof. Barthlott, Univ. Bonn

Technical application:



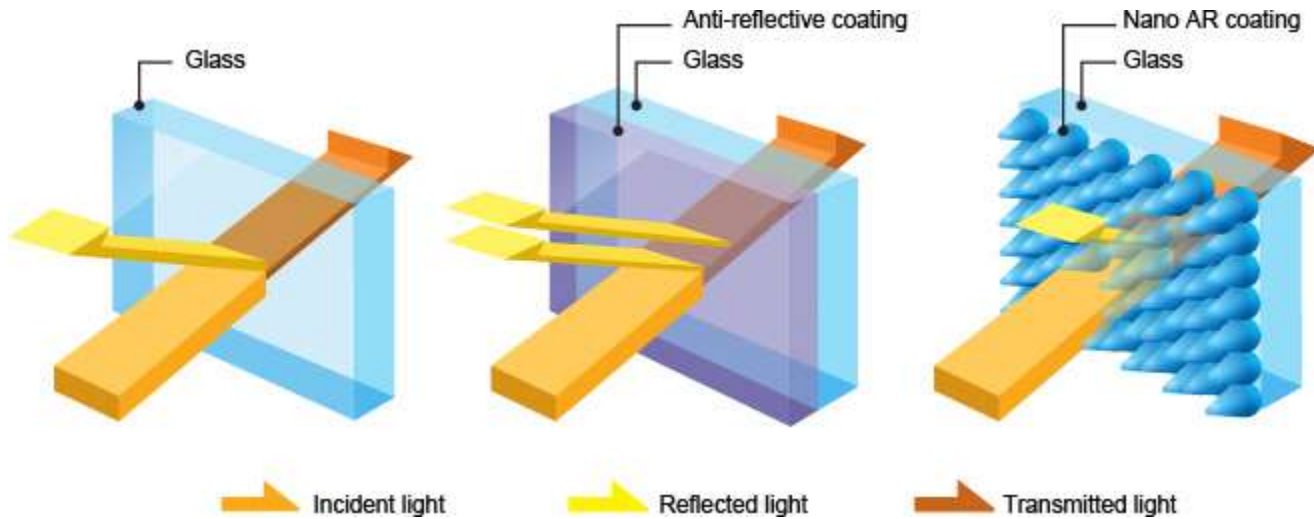
<https://www.youtube.com/watch?v=7is6r6zXFDc>



Paven *et al.* Nat. Comm. **4** (2013)



Nanostructured AR Coatings



www.sony.com.au



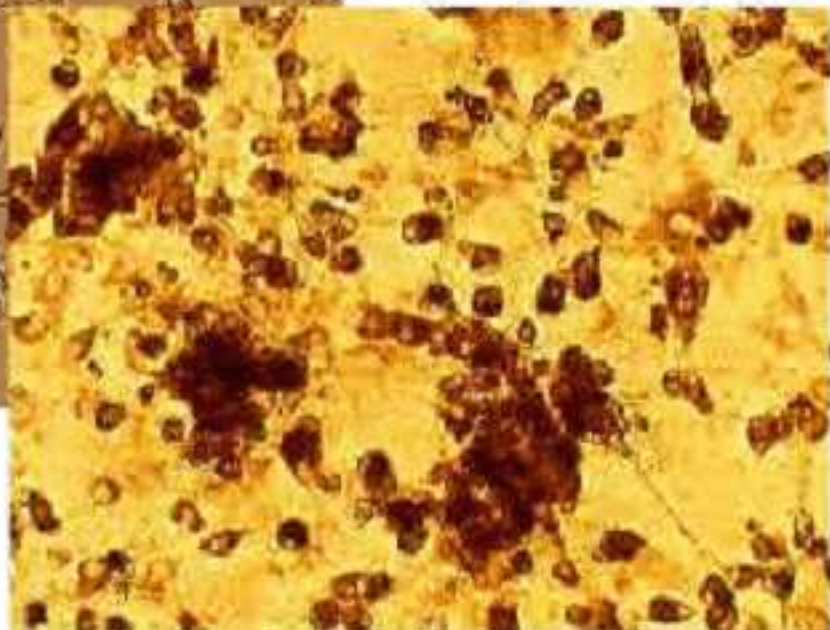
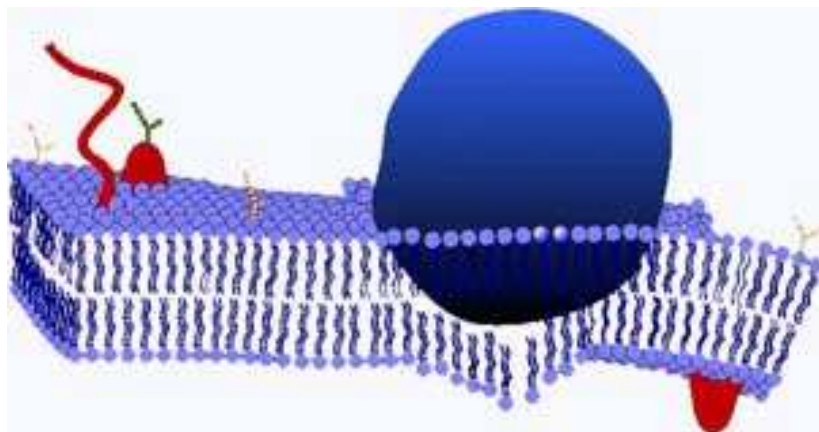
www.aliexpress.com



www.cleantechnica.com



Application in Medicine: Fe_3O_4 nanoparticles for cancer therapy

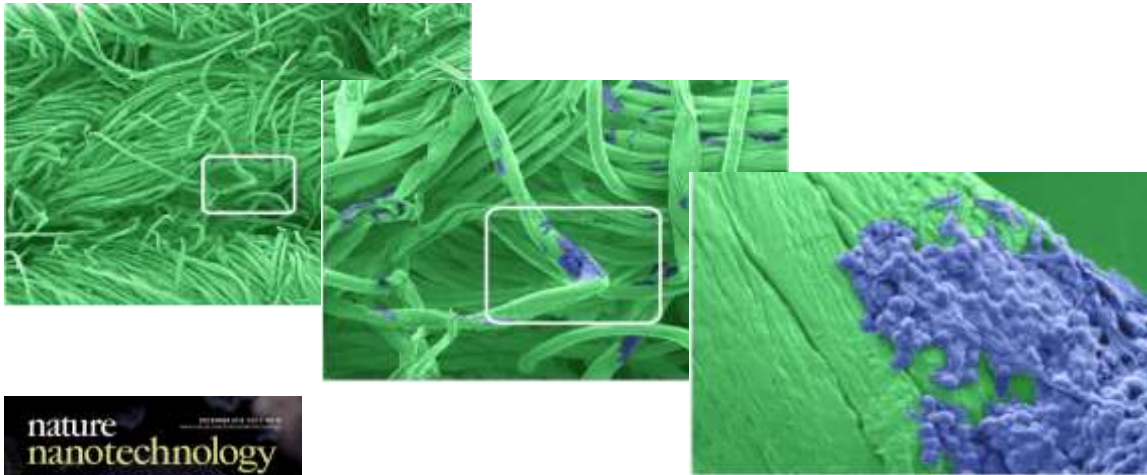


Cancer cells after uptake
of modified Fe_3O_4 -
nanoparticles



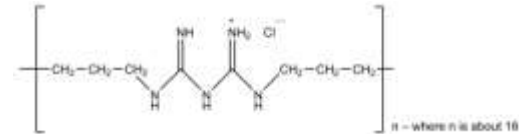
Nanotoxicity

“Nanotechnology and Smelly Socks” Biofilm on t-shirt fibers

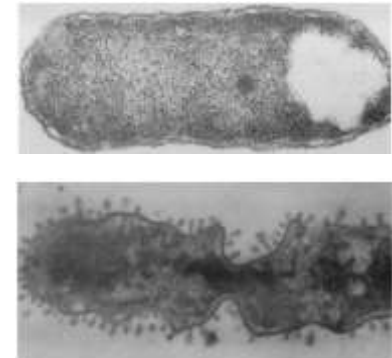


<http://www1.chem.umn.edu/groups/haynes/research.html>

Polyhexanid (PHMB)



Bacterium before and after treatment with PHMB

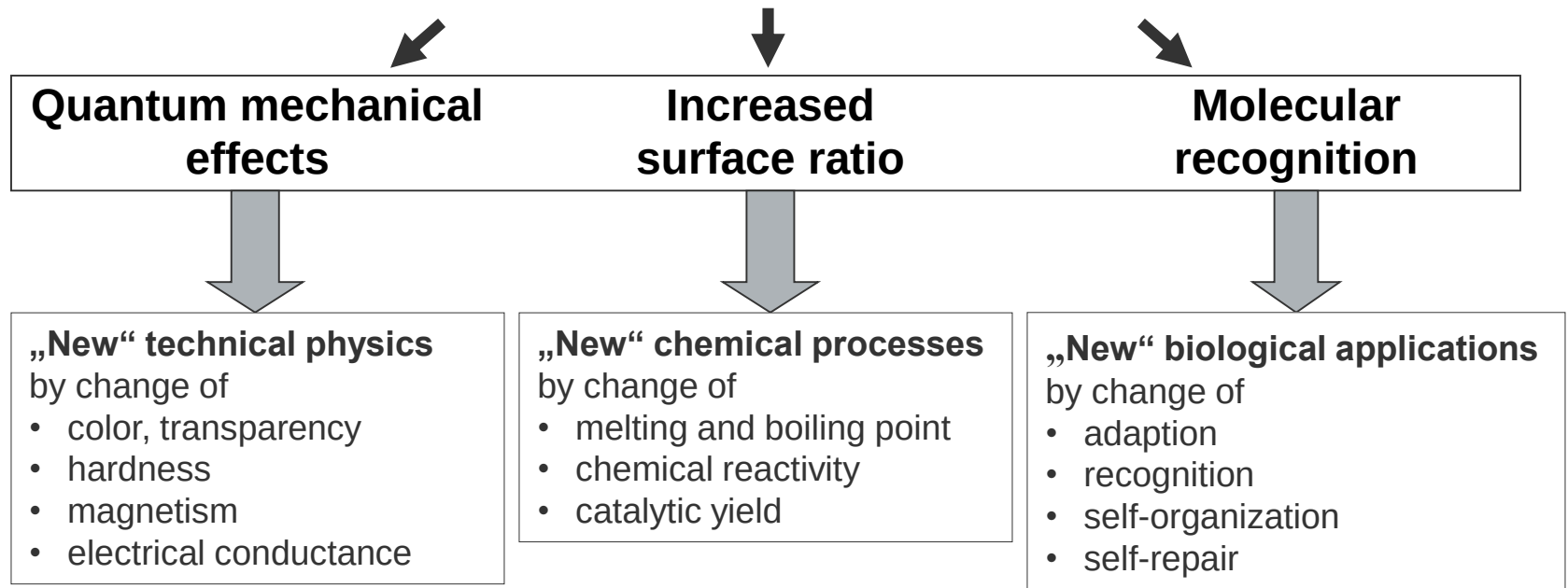


- Physical/chemical process, e.g. against multi-resistant pathogens (MRSA)
- Recently, identified to cause cell death in certain issues, possibly cancerogenic

<http://www.rsc.org/Education/Teachers/Resources/Inspirational/resources/5.2.2.pdf>

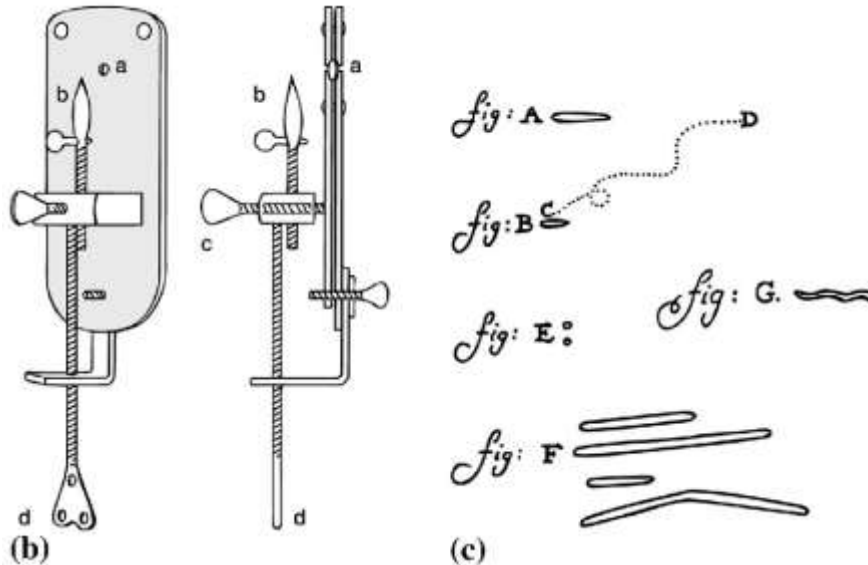


The three fundamental new properties in the nano world





Beginning of Nanoanalytics: First optical Microscope



Antony van Leeuwenhoek (1632-1723)

Modern optical
research microscope

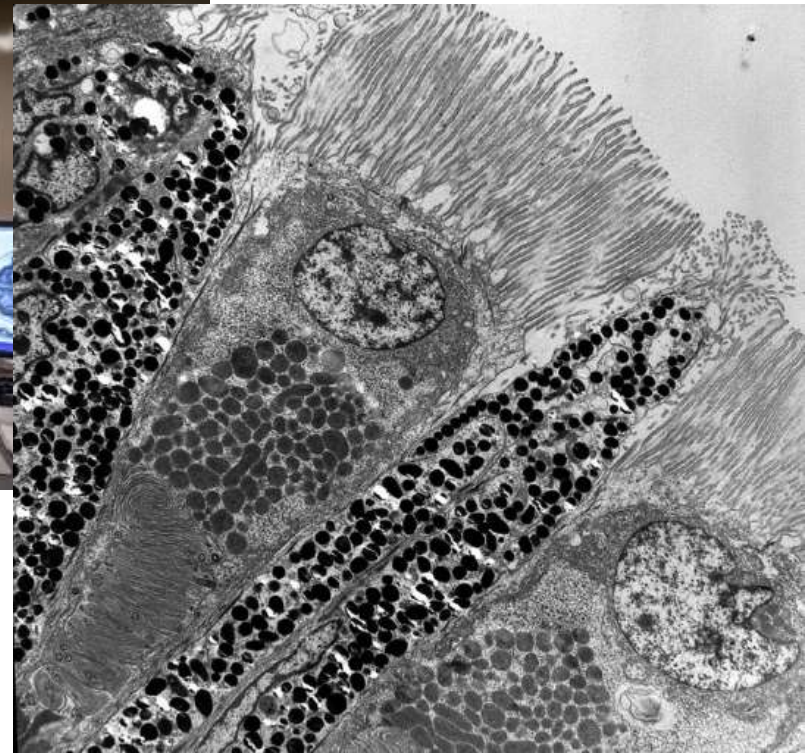




Transmission Electron Microscope (TEM)

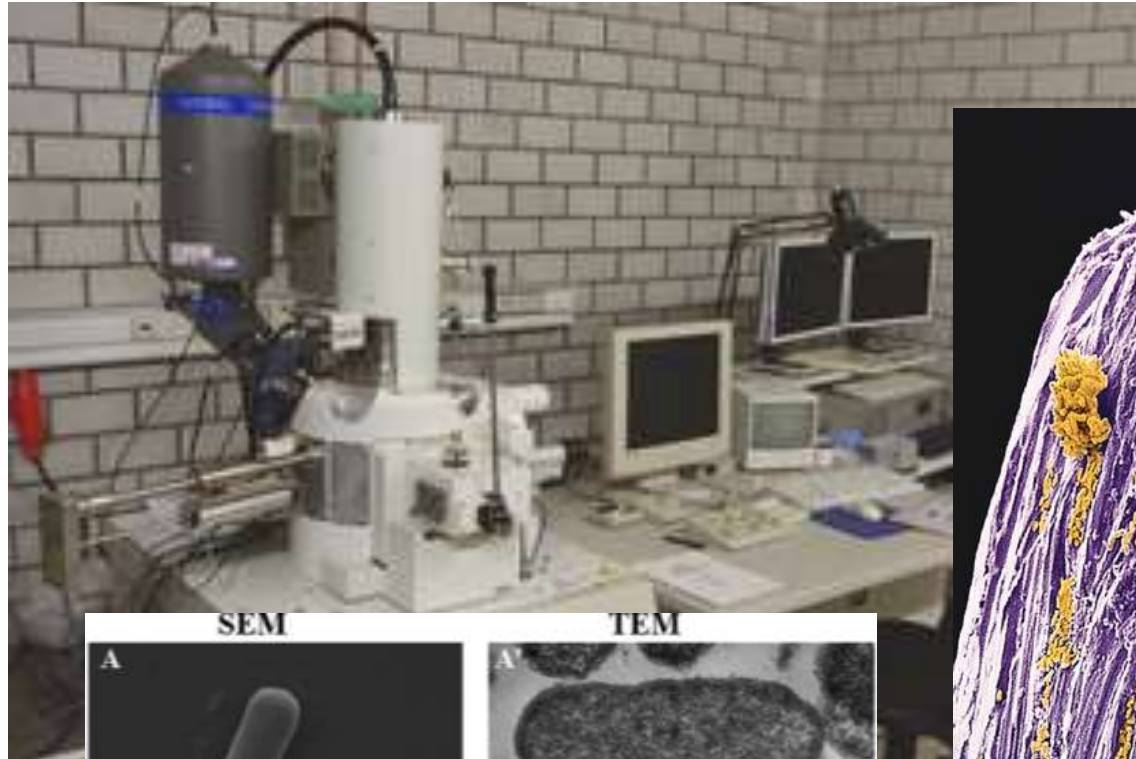


Bacteria on a pin

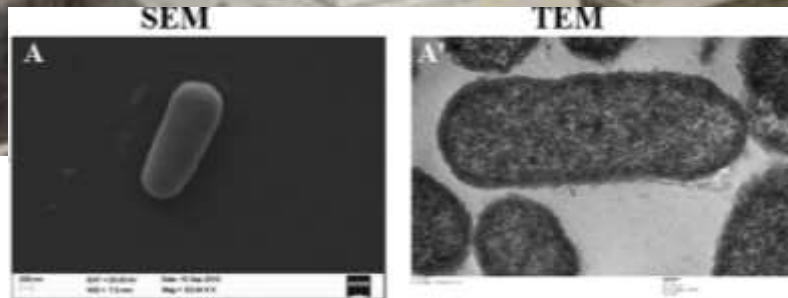
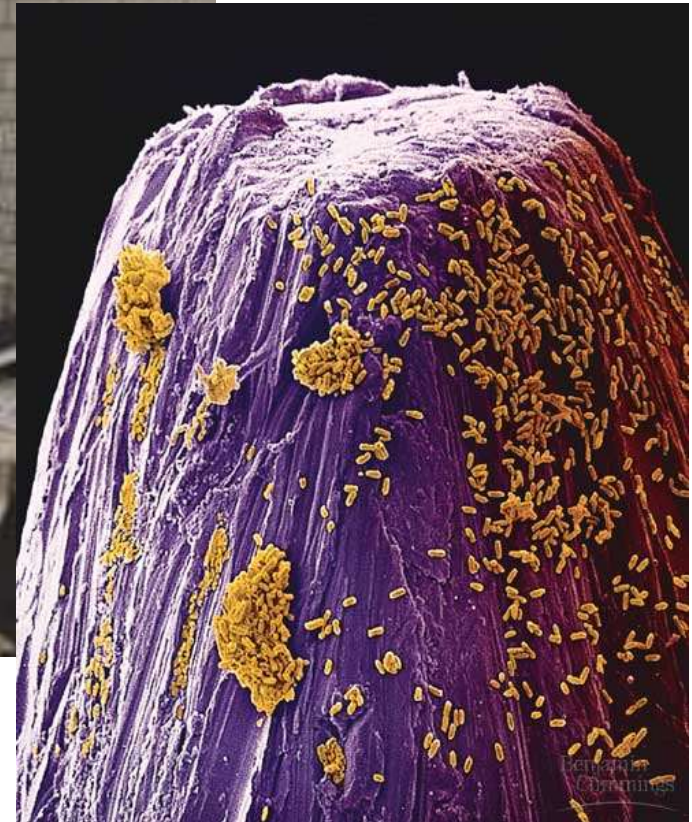




Scanning electron microscope (SEM)



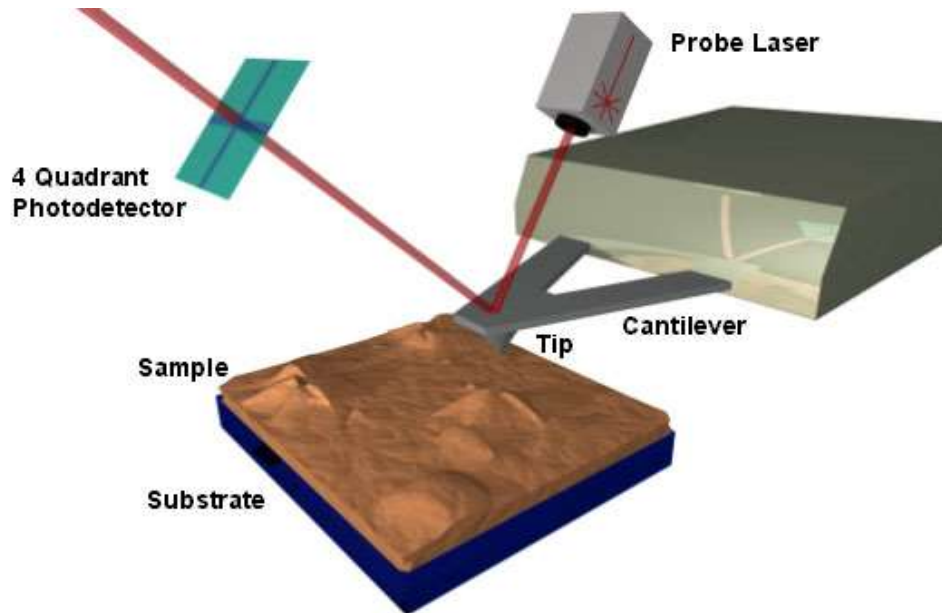
Bacteria on a pin



Sharma *et al.* Antimicrob. Agents Chemother. **55** (2011)



Atomic Force Microscope (AFM)

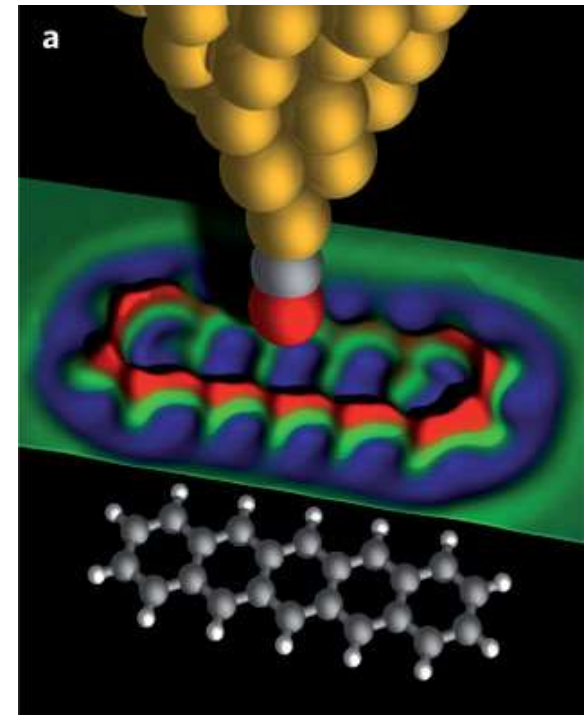


www.education.mrsec.wisc.edu

DNA on mica



Pentacene molecule



Gross. Nature Chemistry **3**, 273–278 (2011)



Atomic Force Microscope (AFM)

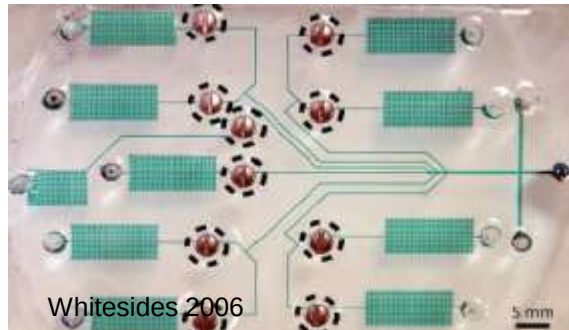




Where Nano meets Bio/Medicine:

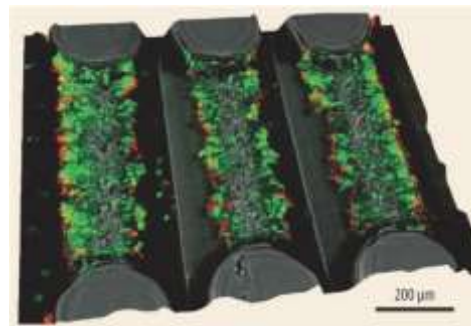
“Lab on a Chip”

Micro- and Nanofluidics



<http://www.gene-quantification.de/lab-on-chip.html>

“Organ on a Chip”



Hagmeyer *et al.*
Physik Journal **15** (2016)



“The impact of nanotechnology is expected to exceed the impact that the electronics revolution has had on our lives.”

Richard Schwartz

(Professor of electrical and computer engineering, Purdue University)



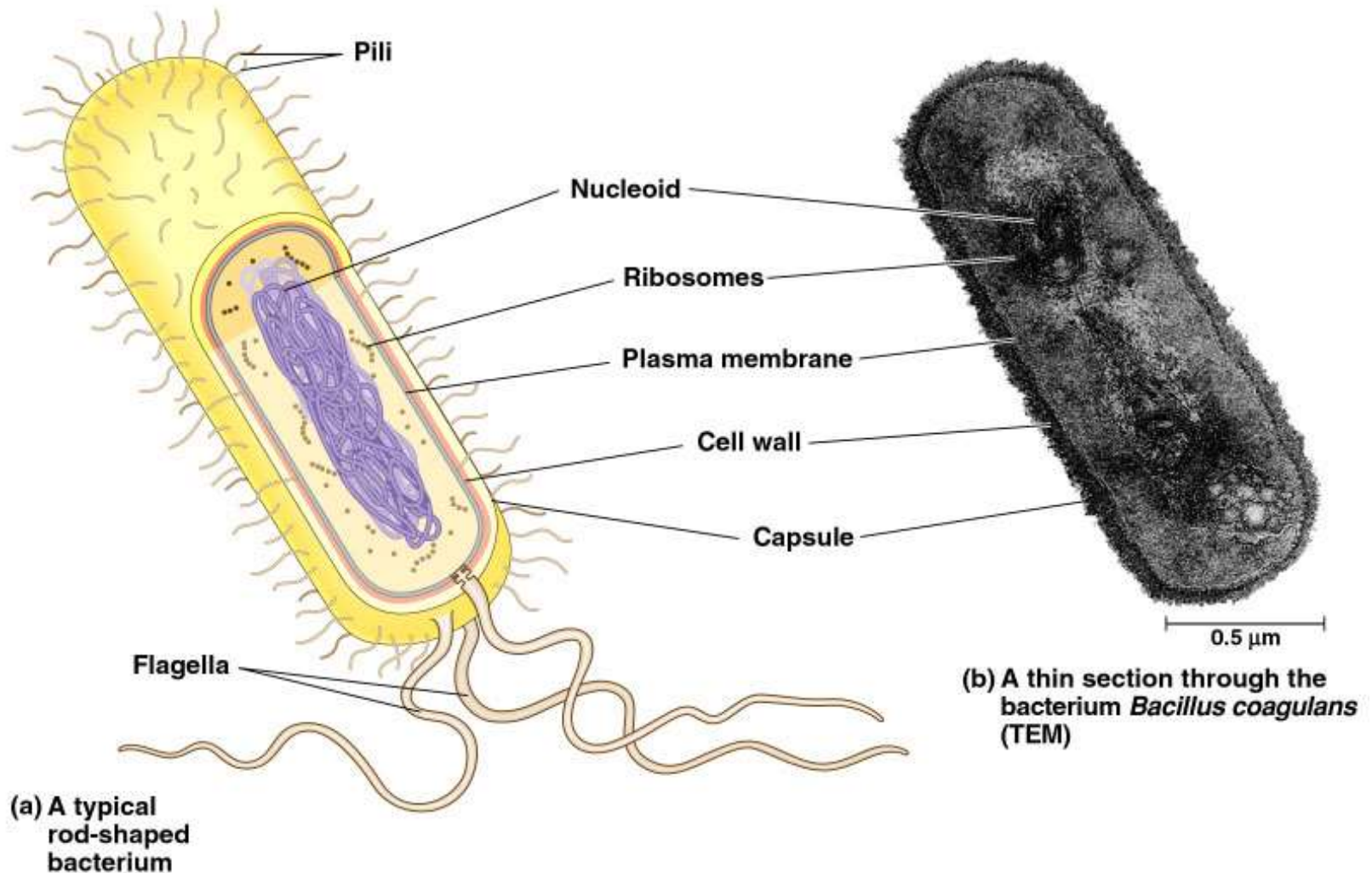
Biophysics: physics of biological systems



www.ib3.eps.hw.ac.uk

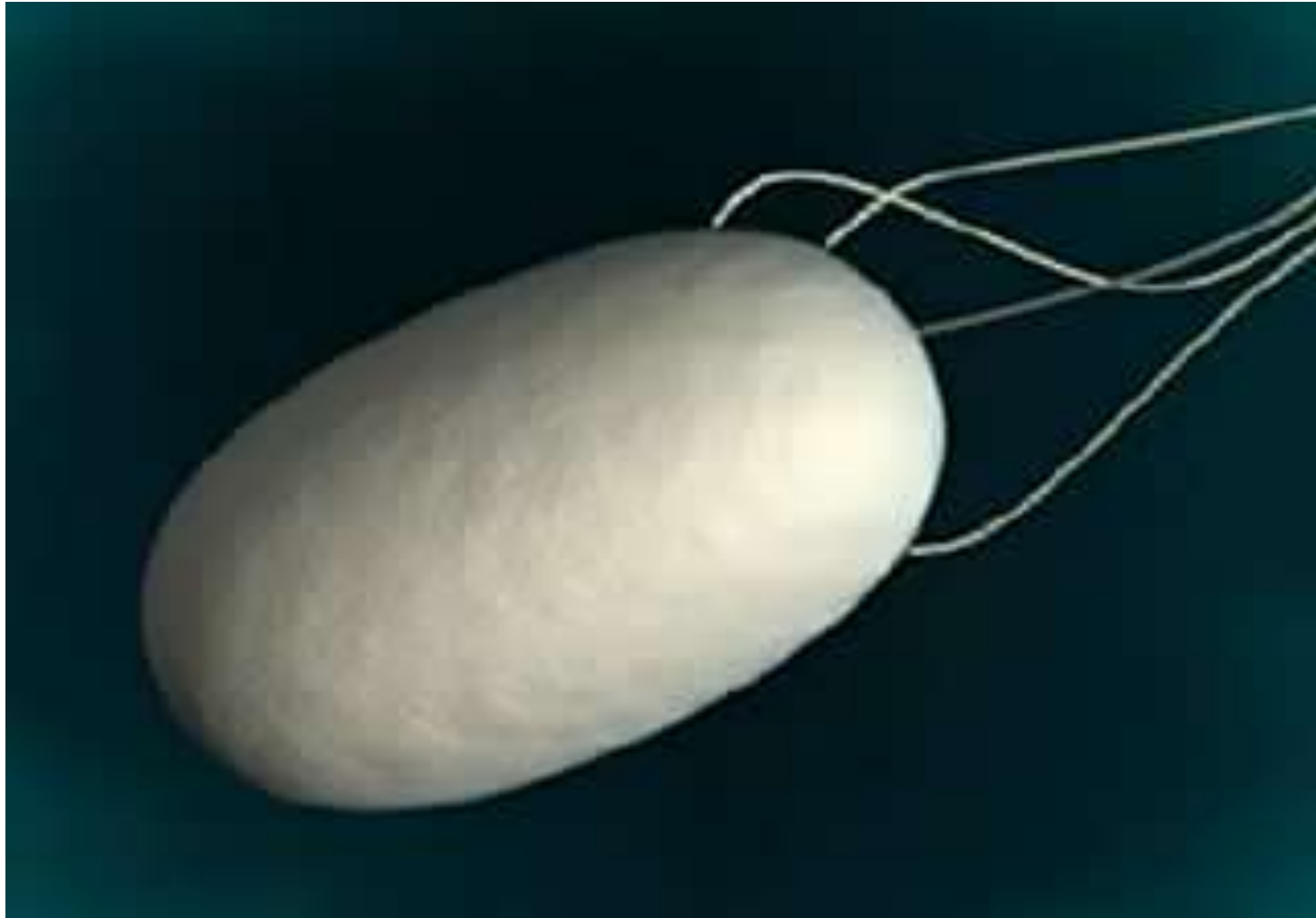


Prokaryotic cell (bacterium)



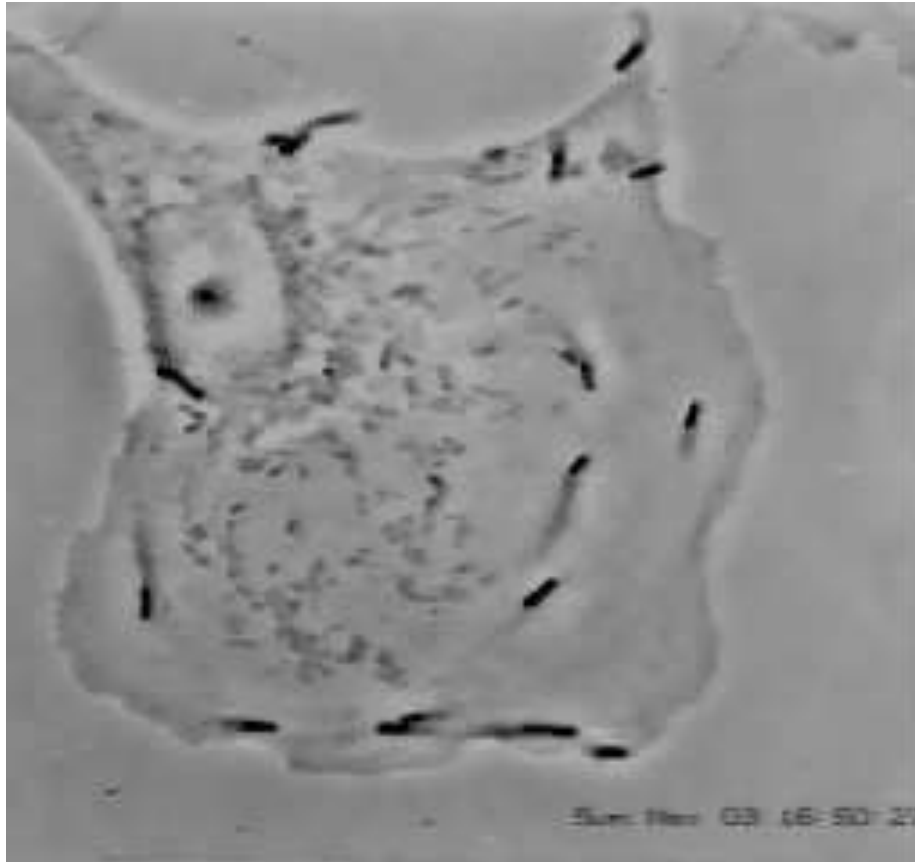


Bacterium = nano-machine

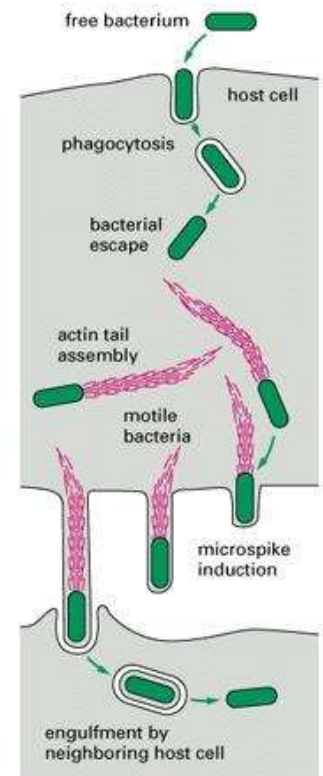
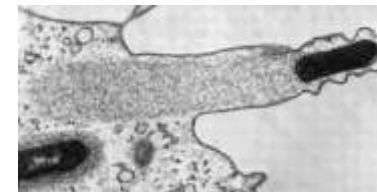
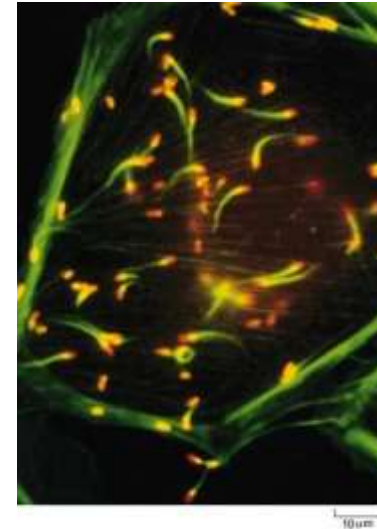




Listeria monocytogenes bacteria moving in host cell



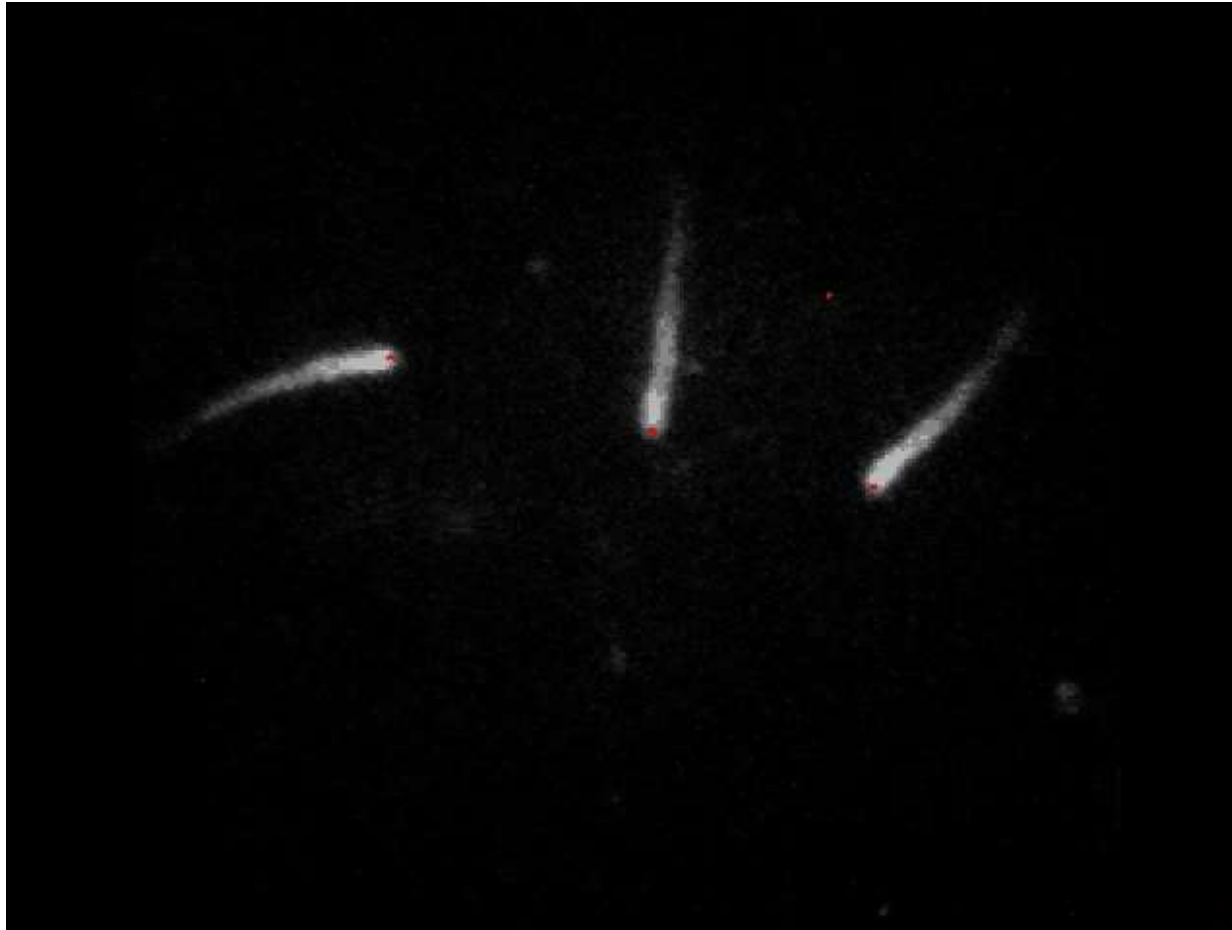
Julie Theriot, Stanford University



<http://labrat.fieldofscience.com/2010/11/bacterial-comet-tails.html>



“Artificial” *Listeria monocytogenes* bacteria

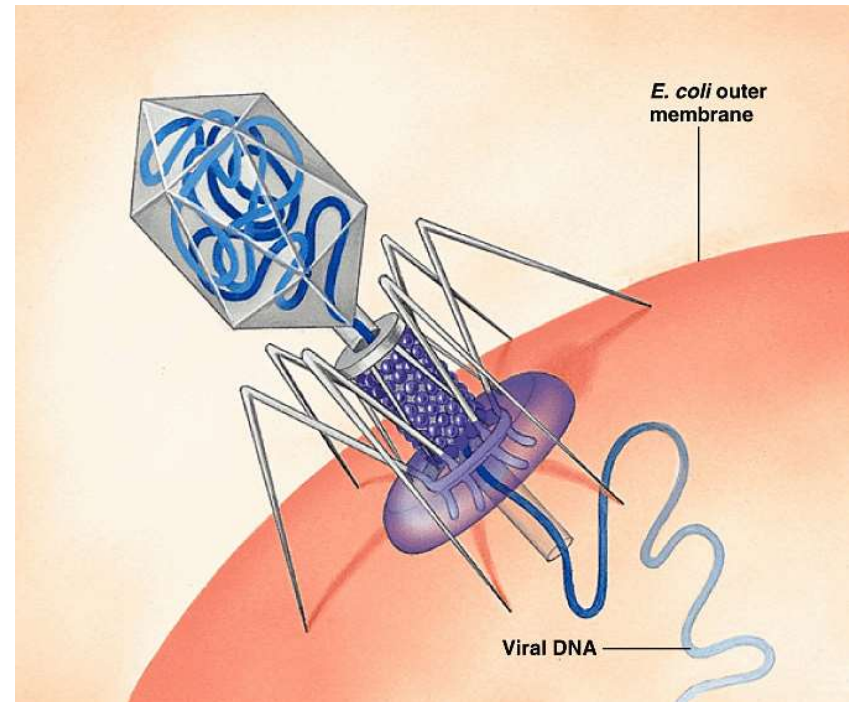
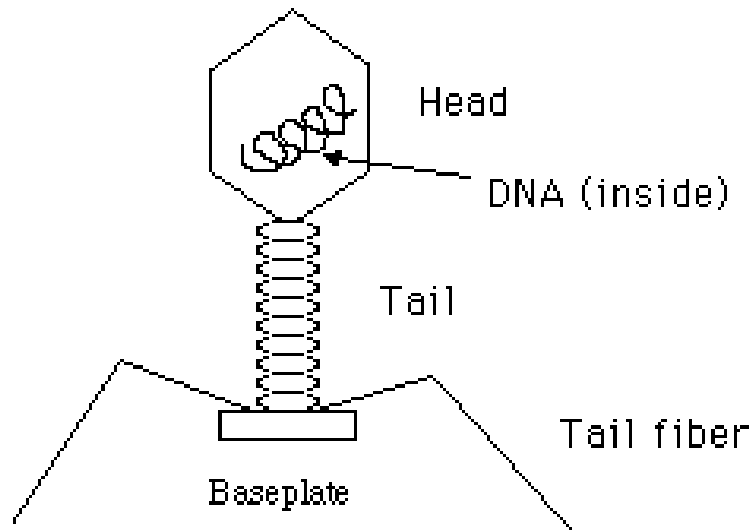


Cameron *et al.*
Curr. Biol. 11 (2001)

0.5 μm bead coated with the ActA protein of *Listeria monocytogenes*

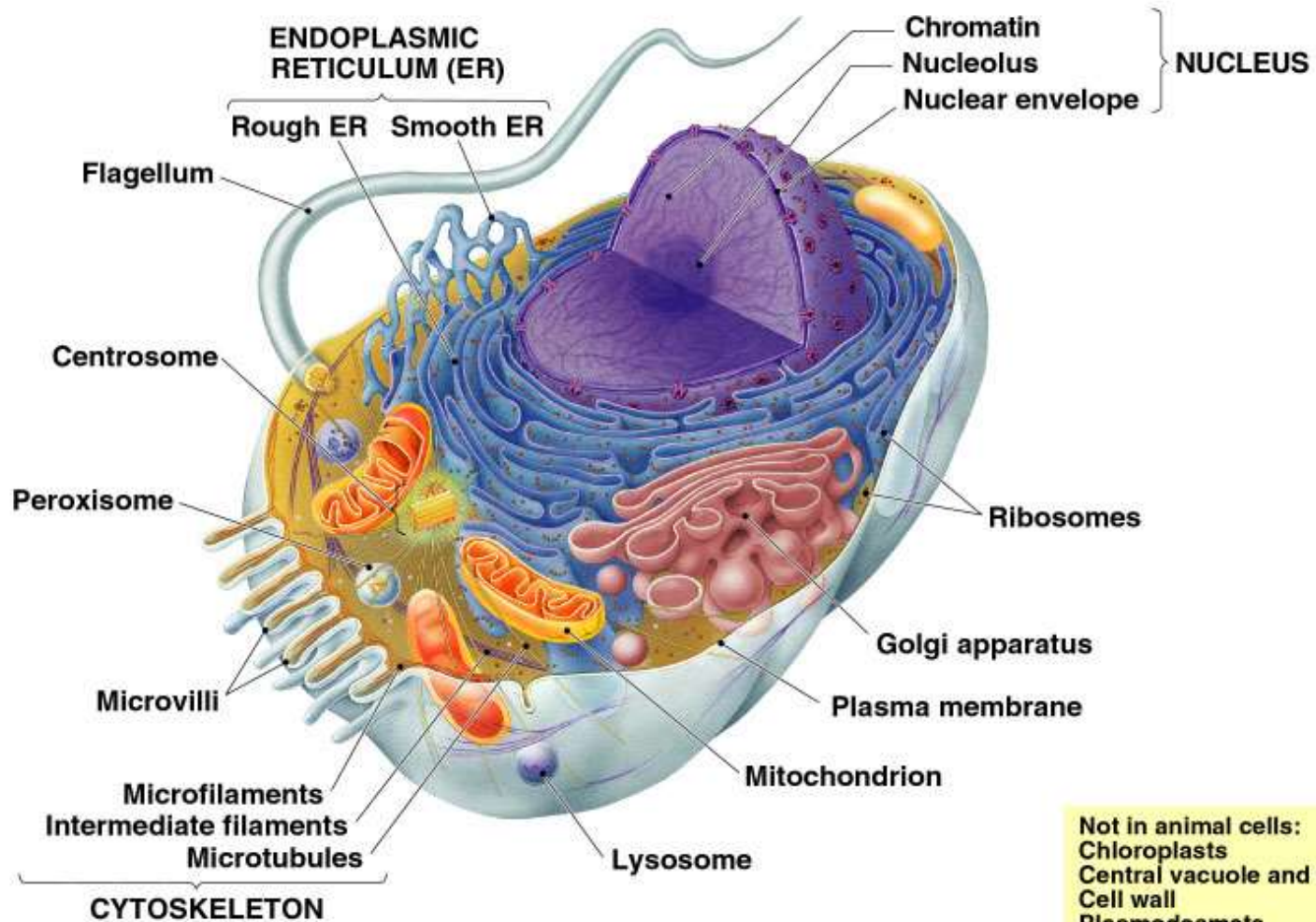


Bacterial viruses (“bacteriophages”)



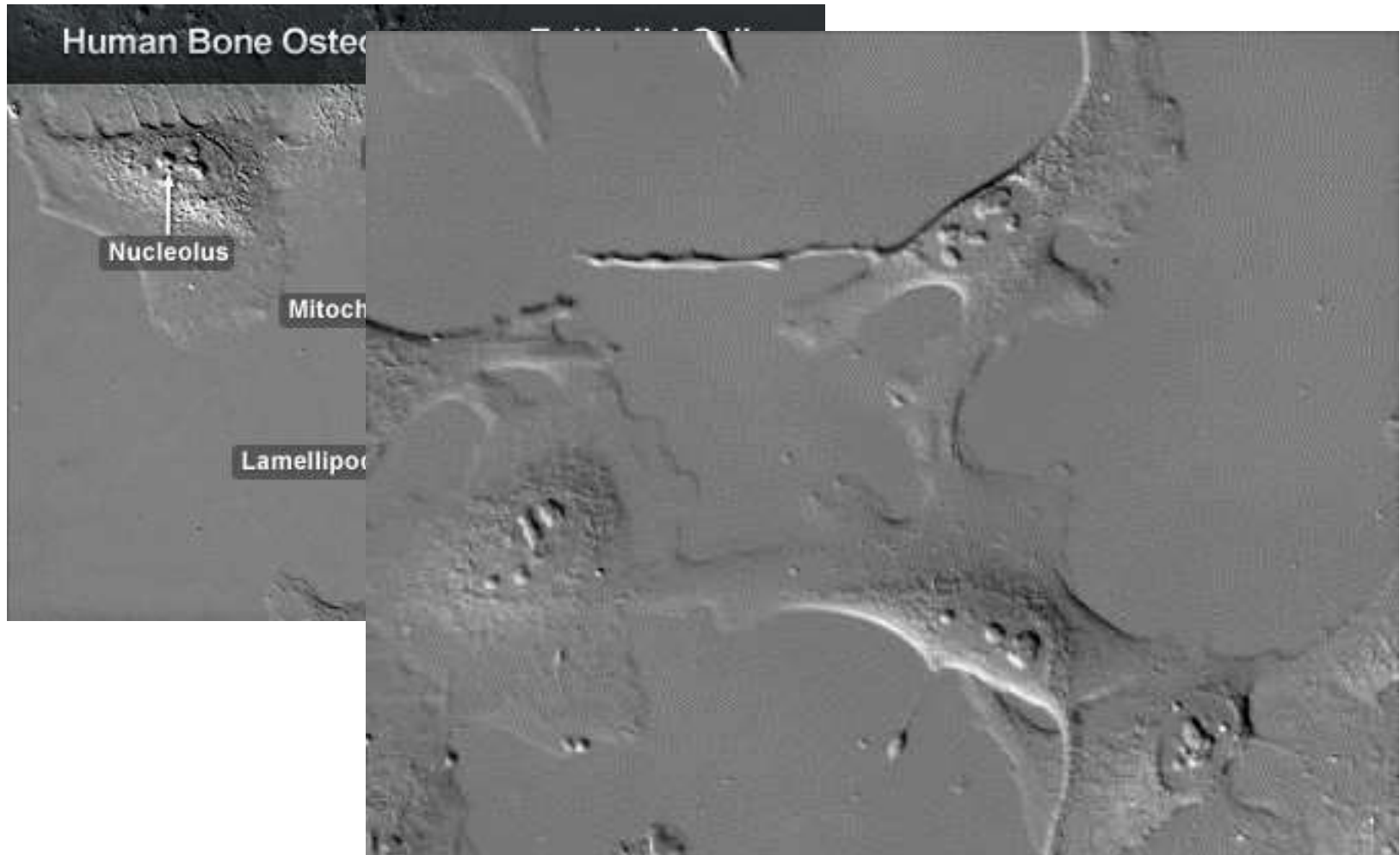


Eukaryotic cell



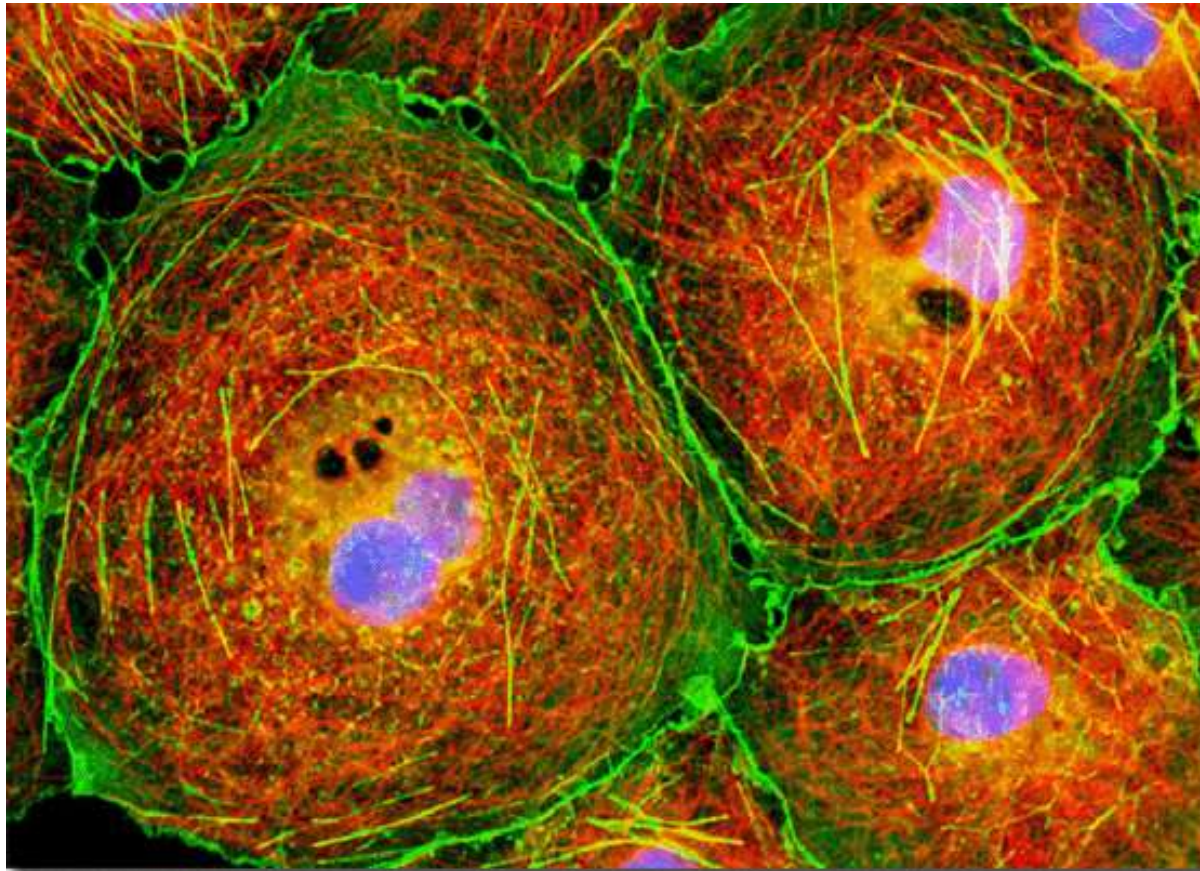


Migration of Human Bone Osteosarcoma Epithelial Cells (U2OS Line)





The Cytoskeleton: Fluorescence Microscopy

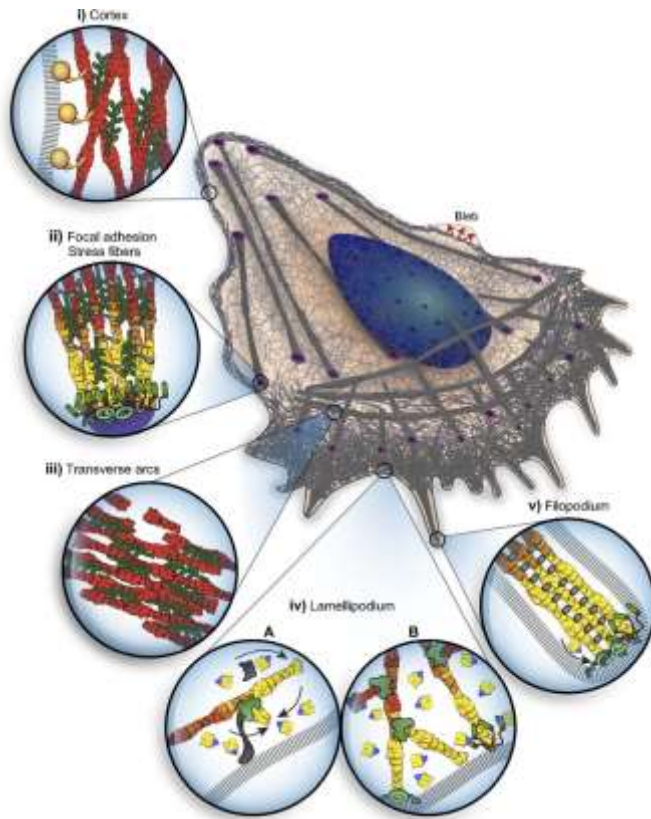


microtubules
actin
DNA

African Green Monkey Kidney Fibroblast Cells (COS-7)



The Cytoskeleton



Blanchoin *et al.* Actin Dynamics, Architecture, and Mechanics in Cell Motility. *Physiological Reviews* (2014)

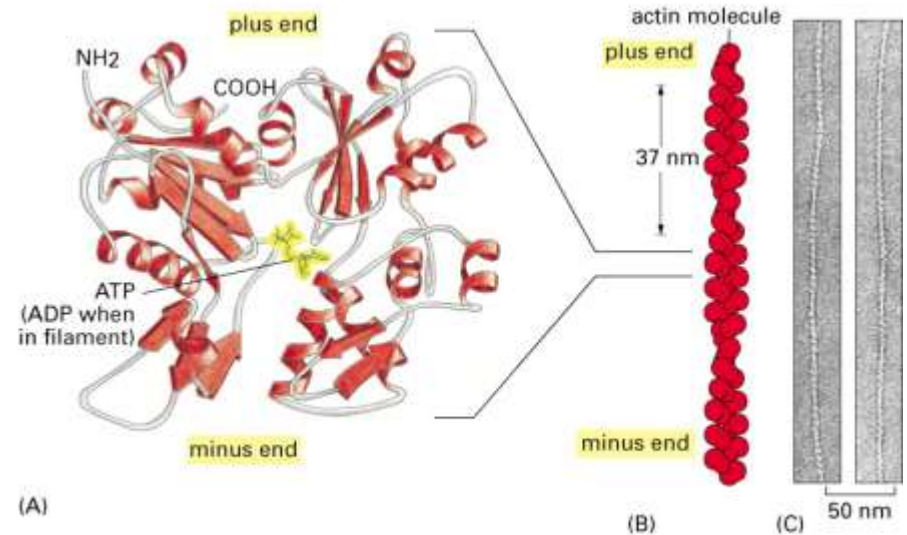
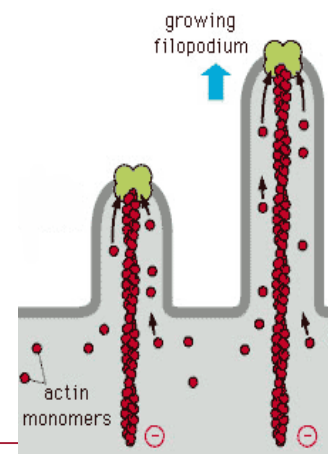
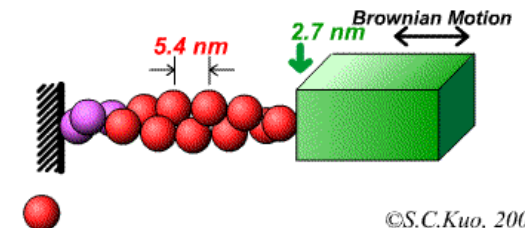


Figure 16-7. *Molecular Biology of the Cell*, 4th Edition.



Actin polymerization “Brownian ratchet”



©S.C.Kuo, 2002
Johns Hopkins University



Leucocyte chasing a bacterium



Vanderbilt University



Bath University

Directed migration

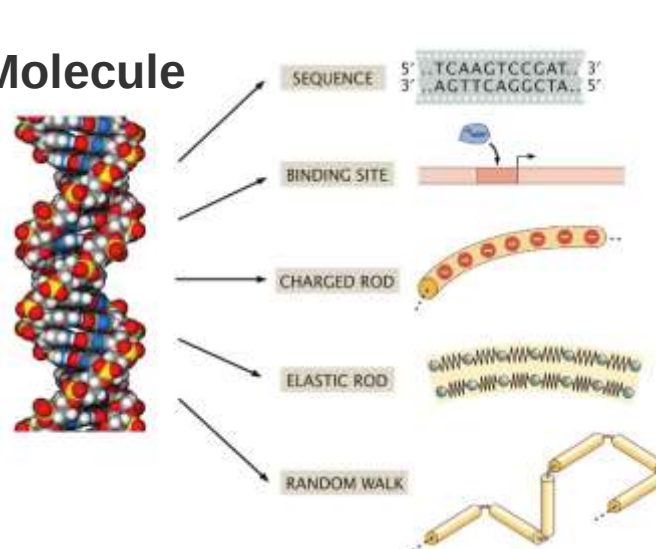


<http://www.youtube.com/watch?v=4bvskwAnIXU>

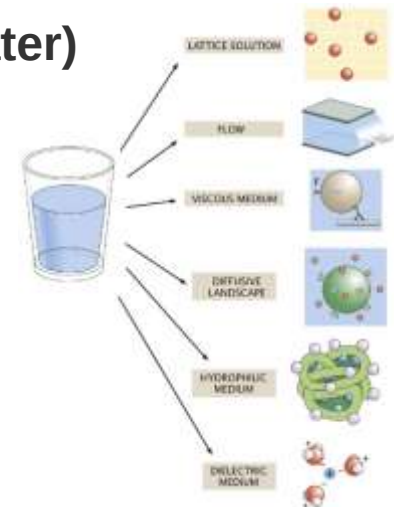


Idealizing Biological Stuff by Physical Models

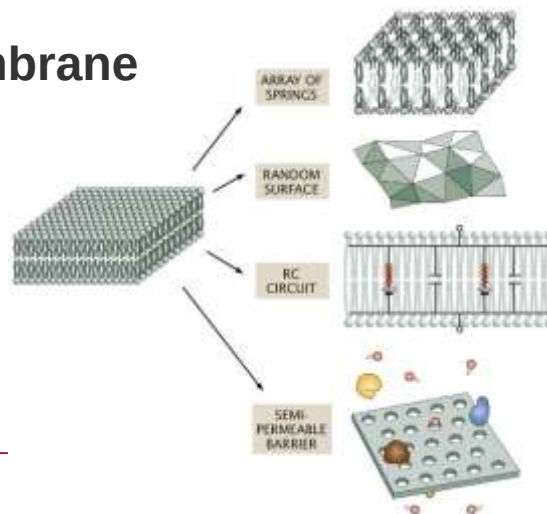
Protein Molecule



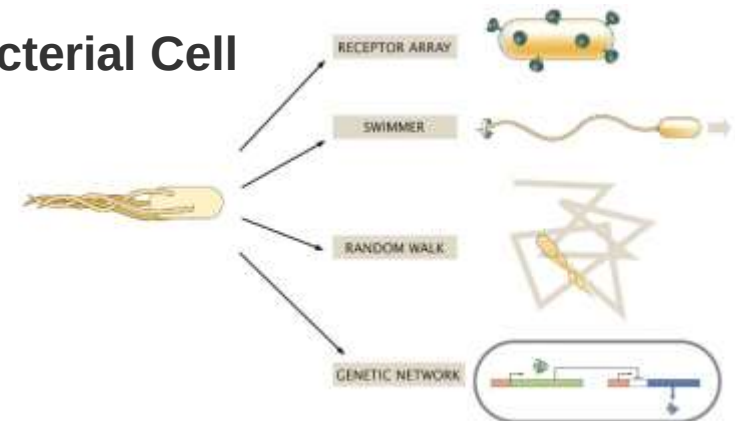
Fluid (Water)



Lipid Membrane



Bacterial Cell





View of a Physicist:

“You can recognize truth by its beauty and simplicity. When you get it right, it is obvious that it is right – at least if you have any experience – because usually what happens is that more comes out than goes in.”

Richard Feynman

(physicist and Nobel laureate)

Something simple can make complex pattern:
Fractal *Barnsley Fern*



<http://media.istockphoto.com>
M. Borrello

K.C. Cole: Sympathetic Vibrations:
Reflections on Physics as a Way of Life (1985)



But: Biology is usually not simple!

Platelet activation pathway:



Harry G. Frankfurt:
On Bullshit (2005)



[https://en.wikipedia.org/wiki/Jigsaw_puzzle#/medi
a/File:2013-11-23_WikiCon_2013_1420.JPG](https://en.wikipedia.org/wiki/Jigsaw_puzzle#/media/File:2013-11-23_WikiCon_2013_1420.JPG)

Calling Bullshit

<http://callingbullshit.org/index.html>

“That is not only not right; it is not even wrong!”

“Das ist nicht nur nicht richtig; es ist nicht einmal falsch!”

Wolfgang Pauli
(physicist and Nobel laureate)



[https://www.rndsystems.com/pathways/
blood-coagulation-signaling-pathways](https://www.rndsystems.com/pathways/blood-coagulation-signaling-pathways)



Topics

Introduction

Physics from micro to nano scale

Micro- and nanofluidics

Micro- and nanomanipulation

Entropic effects and free energy

Diffusion

Polymers physics

Physics of the cytoskeleton

Mechanics of cells and tissues

Cellular forces and motor proteins

Interface and membrane physics

Nano meets bio: Lab-on-a-chip technology

Analytical and microscopy techniques → seminar + practical

Extra: Lab tour



ILIAS

Repository

- > Sommersemester 2019
- > 4 Medizinische Fakultät
- > Master Biomedical Technologies
- > AS9.2 Nanoanalytics and Biophysics

Password: BMT2019

Additional Literature

Gerd Ganteför: Nanotechnology für Neugierige

Edward L. Wolf: Nanophysics and Nanotechnology

Horst-Günter Rubahn: Nanophysik und Nanotechnologie

Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl: Physics and Chemistry of Interfaces

Philip Nelson: Biological Physics - Energy, Information, Life

Jonathon Howard: Mechanics of Motor Proteins and the Cytoskeleton

Rob Phillips, Jane Kondev, Julie Theriot, Hernan Garcia: Physical Biology of the Cell

Henrik Bruus: Theoretical Microfluidics

And see references...

But: Not mandatory!

Parts of Nanoanalytics / Interfaces 2

- Lecture
 - Tuesdays 10 – 12h (e.g. 10:15 – 11:45), Morgenstelle C9A42
 - written test **Tuesday 09 July 2019 (10-12h)**
- Seminar
 - Tuesdays 8 – 10h (e.g. 8:30 – 10:00), C9A42
 - **first date 23 April (9-10h)** for introduction, topics, dates
- Labwork
 - Part 1: Block practical 1 – 12 April 2019 (9-17h)
 - Part 2: Tuesdays 13:30 – 18:00, initial meeting **today** 13:30 C9A03

Attendance is mandatory!