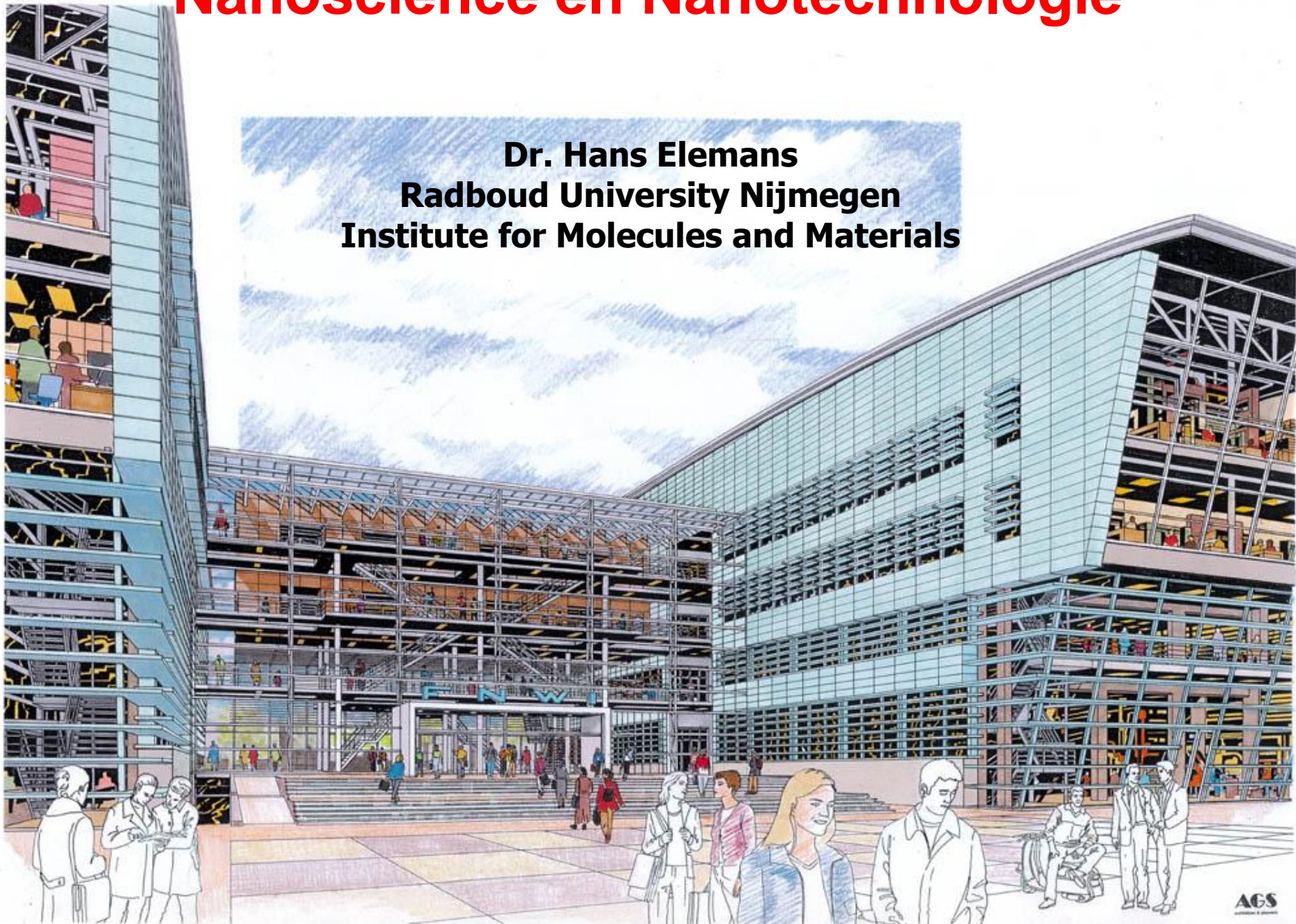
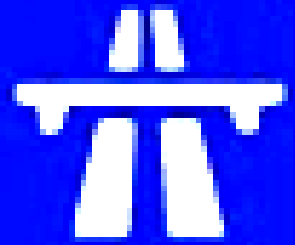


# Nanoscience en Nanotechnologie

**Dr. Hans Elemans**  
**Radboud University Nijmegen**  
**Institute for Molecules and Materials**



# Nanotechnology



Science  
Fiction

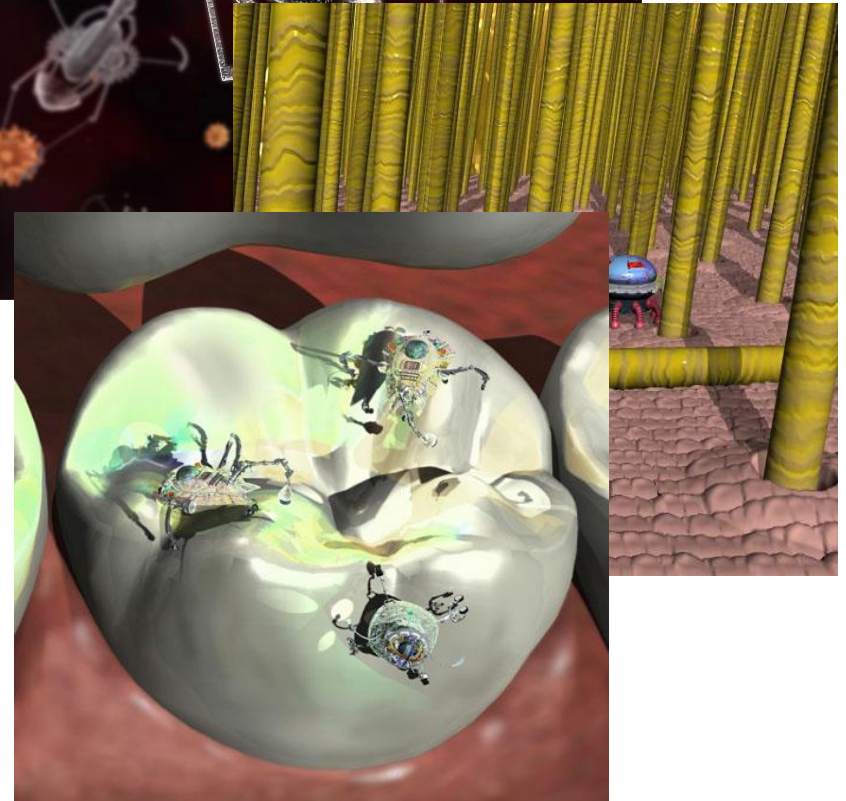
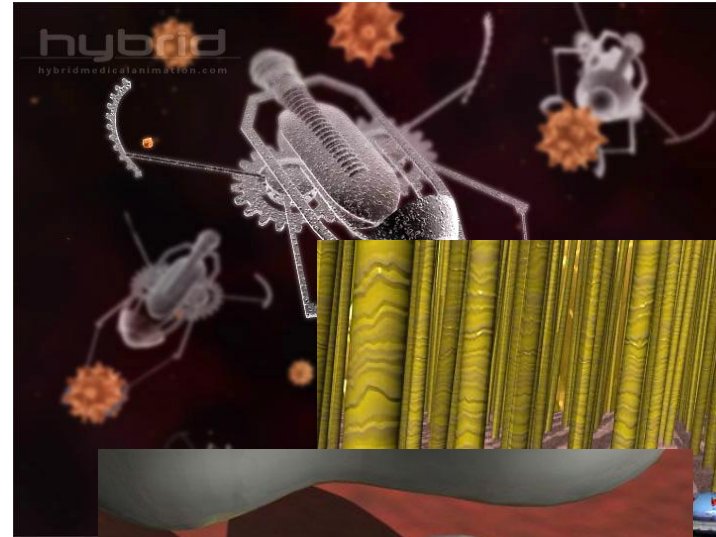
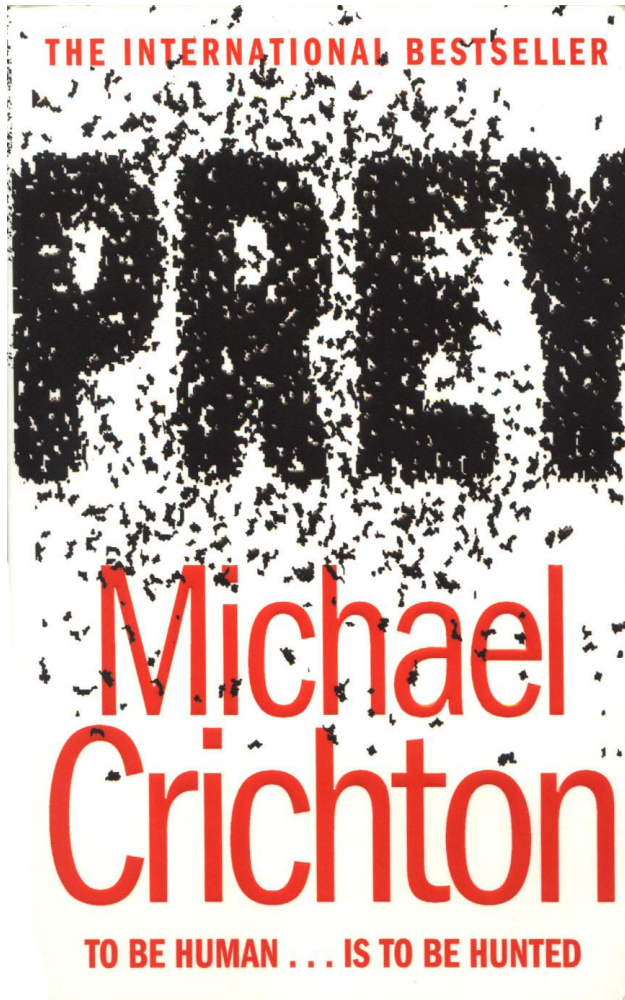
Hype

Science  
Project





# Nano & Sciencefiction



*“The best way to predict the future is to invent it.”*

Alan Kay (1971)

**NanoScience:** de studie van fundamentele principes van structuren met op zijn minst één dimensie tussen de 1 en 100 nanometer

**NanoTechnologie:** toepassing van deze kennis om nieuwe materialen en apparaten te maken

# Hoe klein is 'Nano'?

**Zon**

1,390,000,000



**Aarde**

36,000,000



**Voetbal**

0.3



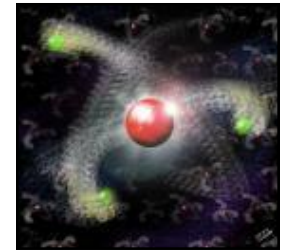
**Buckybal**

0.000000003



**Atoom**

0.0000000001



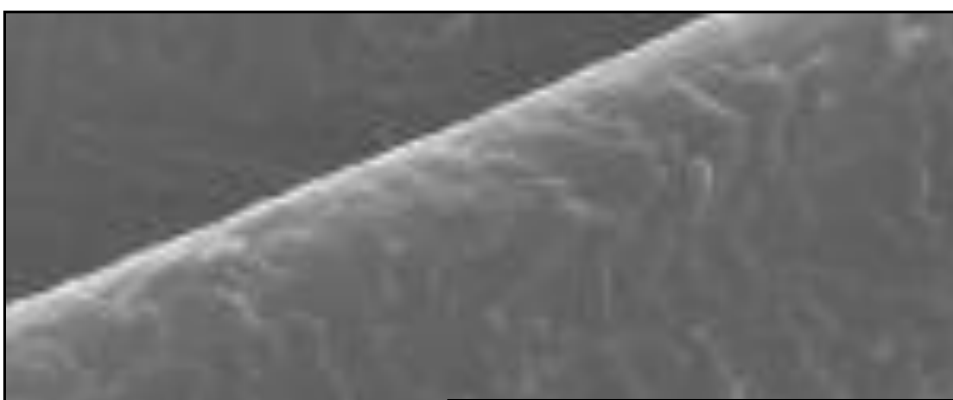
**$1 \times 10^{+9}$  M**

**1 M**

**$1 \times 10^{-9}$  M**

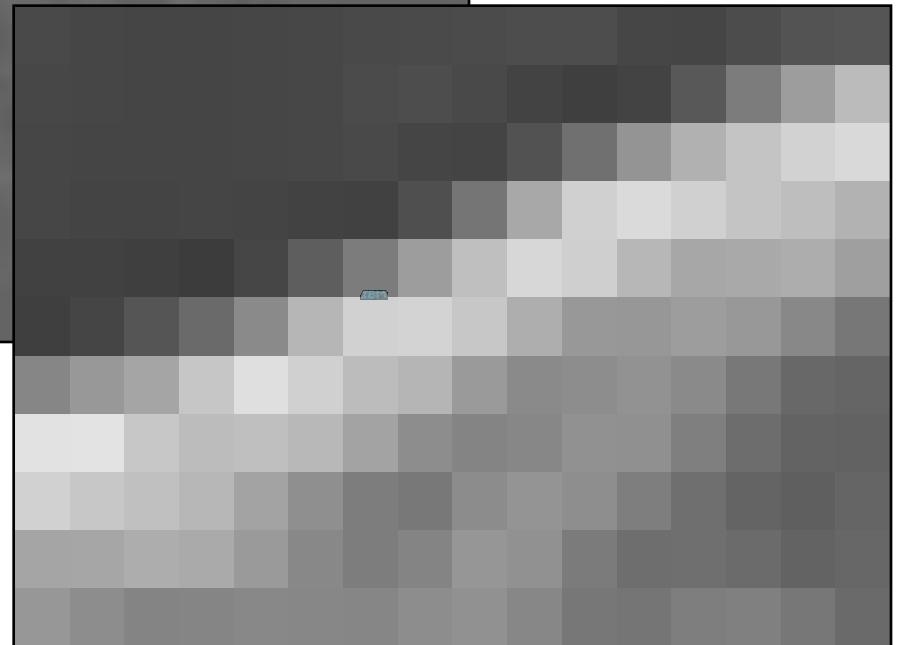
***Hoe dik is een mensenhaar?***

**Een mensenhaar is  
50 micrometer dik...**



....ofwel 50.000 nanometer...

...ofwel 500.000 atomen !



# **Nanoscience-Nanotechnology**

**250 miljoen euro: NanoNed (2005)**

**5 miljard euro komende 4 jaar in de EU**

**20 miljard euro wereldwijd in 2004-2008**

***1000 miljard dollar nanoprodukten / jaar (2010)***

**Nanomedicine**

**Nanomaterials**

**Nanoelectronics**

# Nanotechnologie: Inspiratie uit de Natuur!

**Kunstmatige Robot**



2 m

**Natuurlijke Robot**



24 nm =  
0.00000024 m



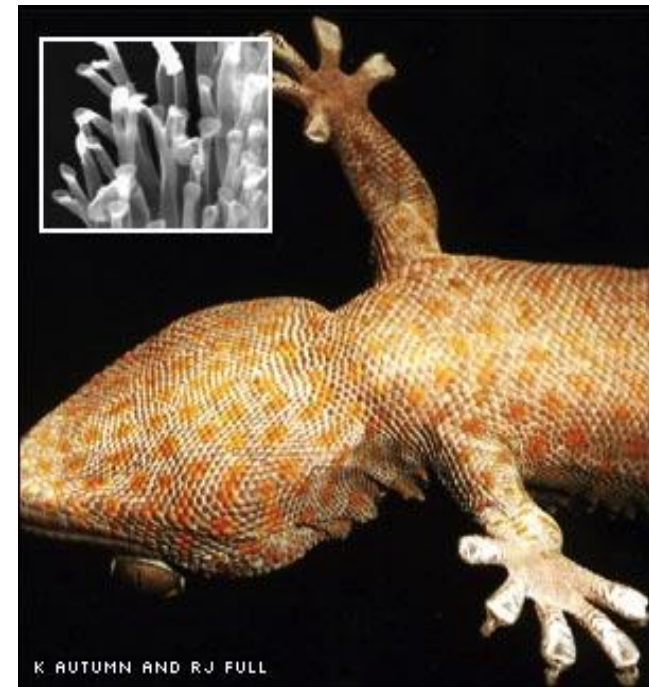
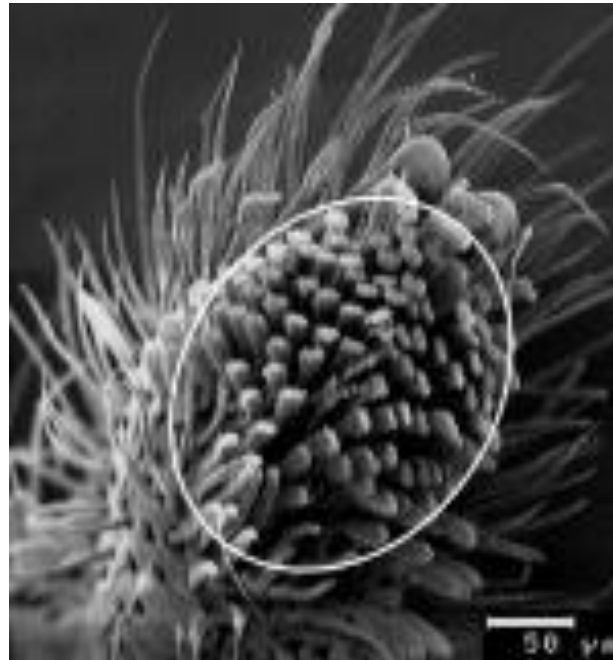
# Nanotechnologie: Inspiratie uit de Natuur



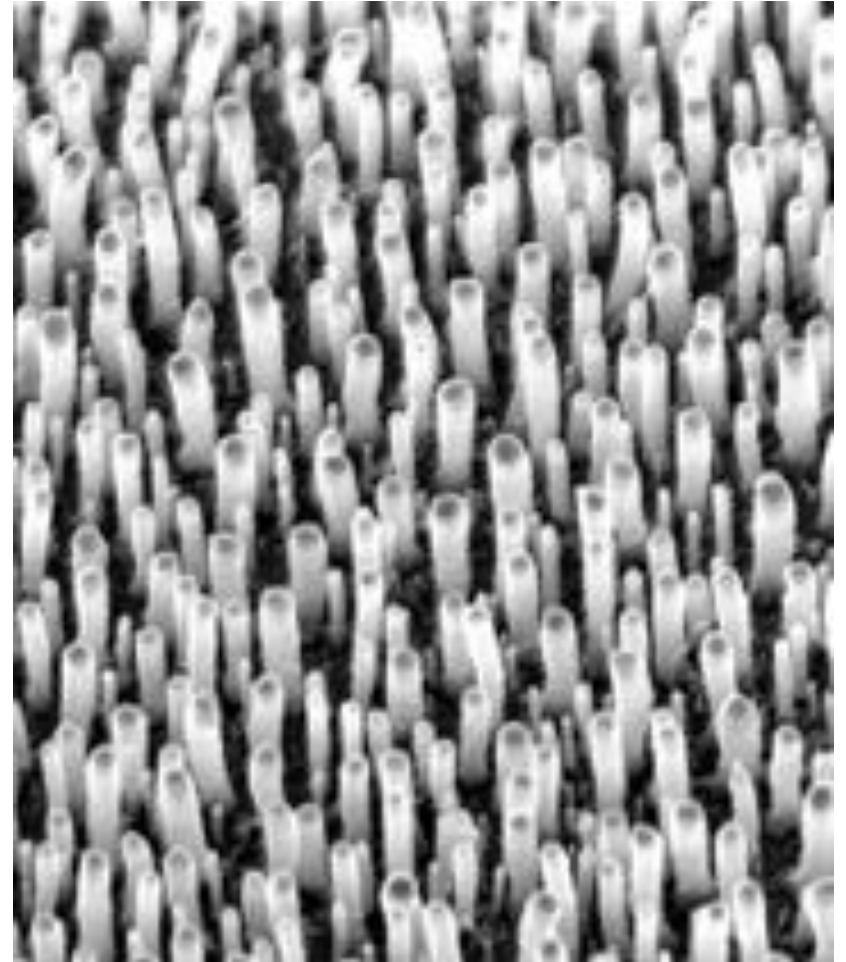
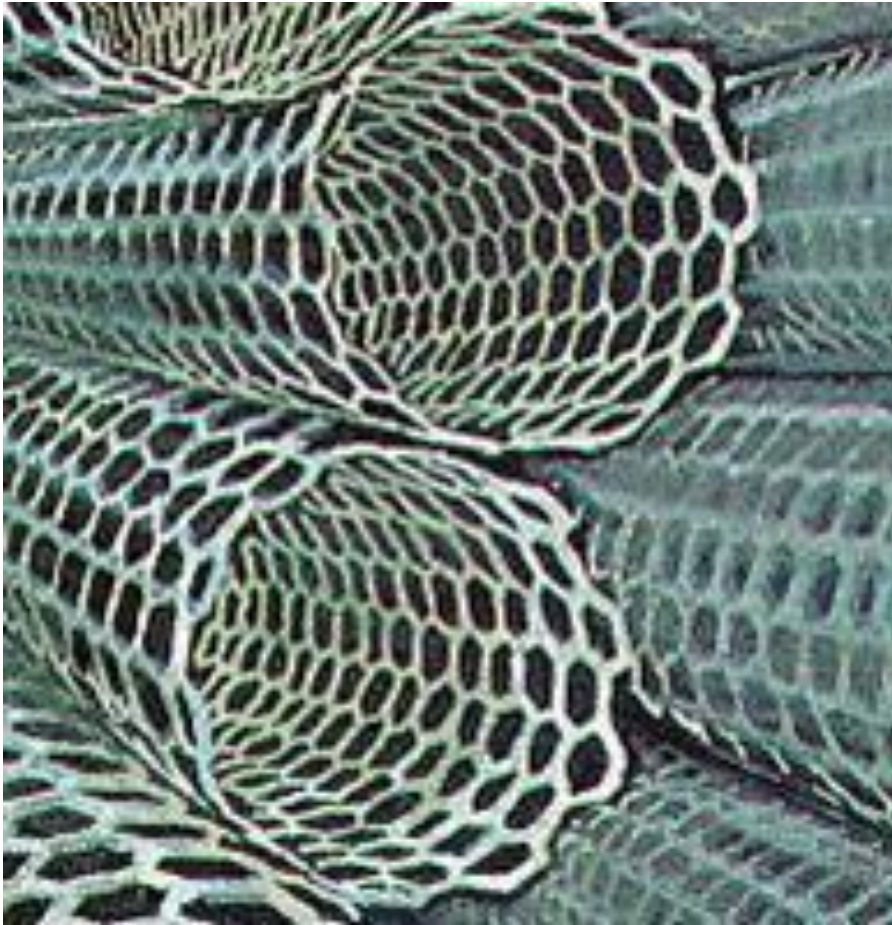
# Nanotechnologie: Inspiratie uit de Natuur



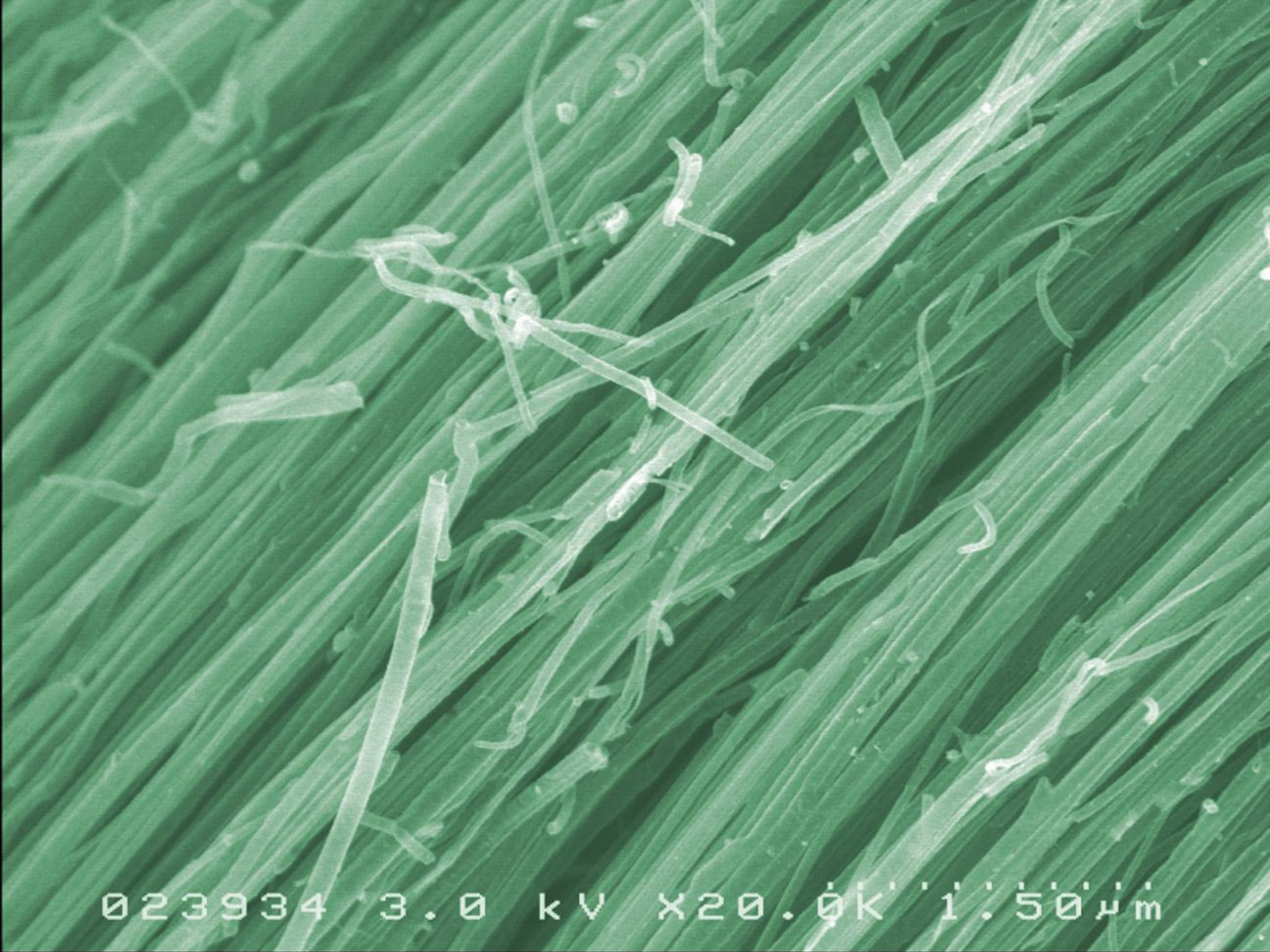
1980



# Koolstof Nanobuisjes







023934 3.0 kV x20.0k 1:50µm



# Nanotechnologie in het Dagelijks Leven

Nanomaterialen: nieuwe eigenschappen, sterker, lange levensduur



**Supersterke Vishengel  
(uitgebracht 7 juli 2005)**

# Nanotechnologie in het Dagelijks Leven

## Samsung 'Silver Nano' wasmachine

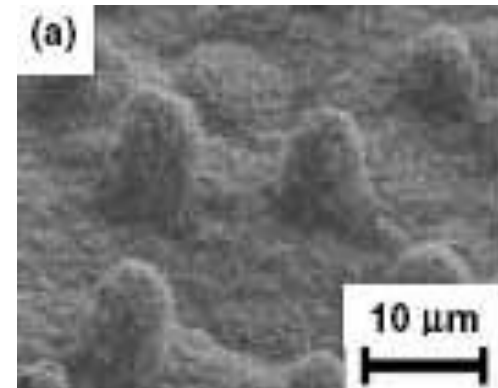


Zilver nanodeeltjes verwijderen >99% van de bacteriën

Inmiddels ook in koelkasten en airco's

# Lotus Leaf Effect: Zelfreiniging in de Natuur

maar 2-3% of water druppels raken het oppervlak aan



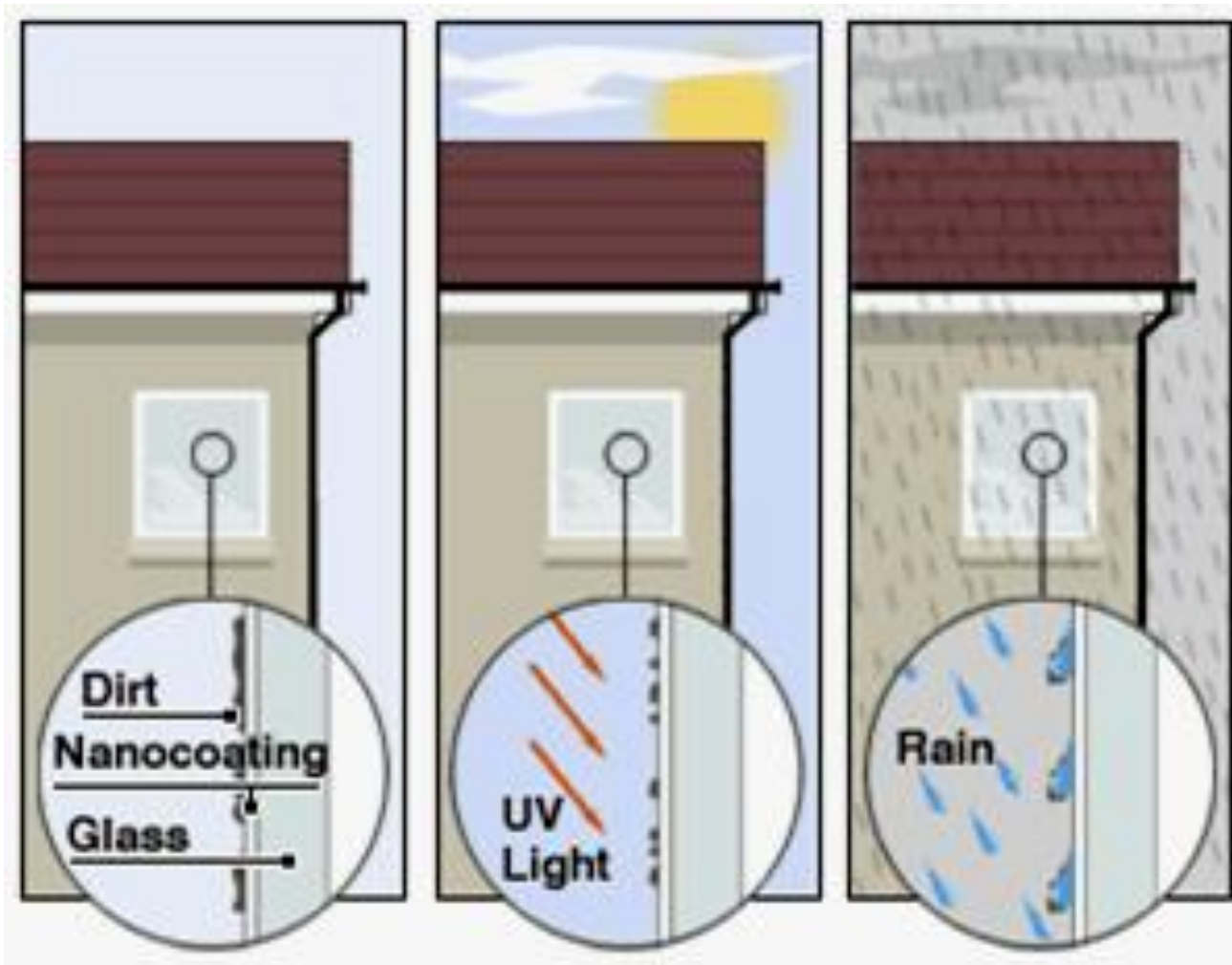
*'nano-haartjes'*

druppels rollen er van af en nemen het vuil mee



# Nanotechnologie in het Dagelijks Leven

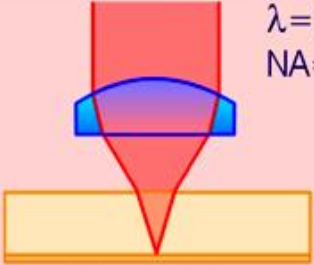
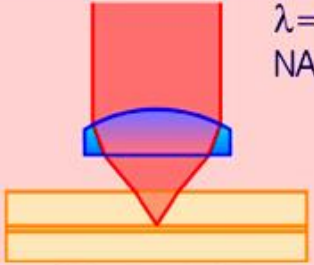
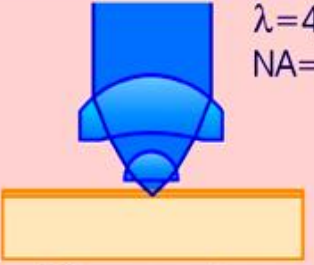
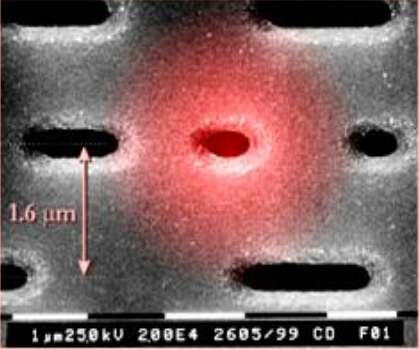
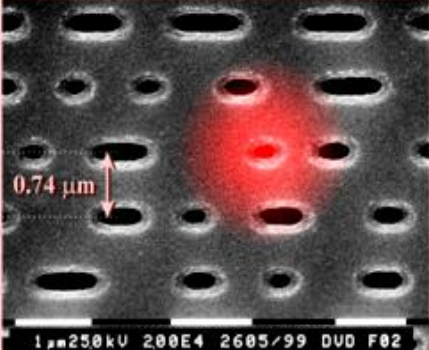
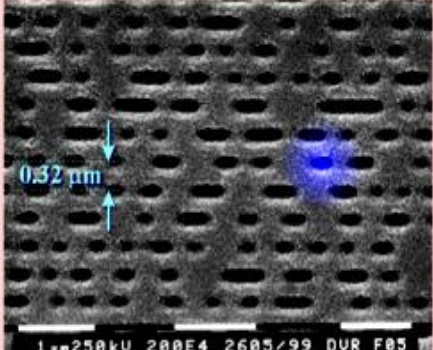
Nanomaterialen: nieuwe eigenschappen, sterker, lange levensduur



Lotus Leaf effect: Zelfreinigende ramen



# Nanotechnologie in het Dagelijks Leven

CD	DVD	DVR
 <p><math>\lambda = 780 \text{ nm}</math> <math>NA = 0.45</math></p> <p>1.2 mm substrate</p>	 <p><math>\lambda = 650 \text{ nm}</math> <math>NA = 0.6</math></p> <p>0.6 mm substrate</p>	 <p><math>\lambda = 400 \text{ nm}</math> <math>NA = 0.85</math></p> <p>0.1 mm cover layer</p>
 <p>1.6 <math>\mu\text{m}</math></p> <p>1 <math>\mu\text{m}</math> 250 kV 200E4 2605/99 CD F01</p>	 <p>0.74 <math>\mu\text{m}</math></p> <p>1 <math>\mu\text{m}</math> 250 kV 200E4 2605/99 DVD F02</p>	 <p>0.32 <math>\mu\text{m}</math></p> <p>1 <math>\mu\text{m}</math> 250 kV 200E4 2605/99 DVR F05</p>

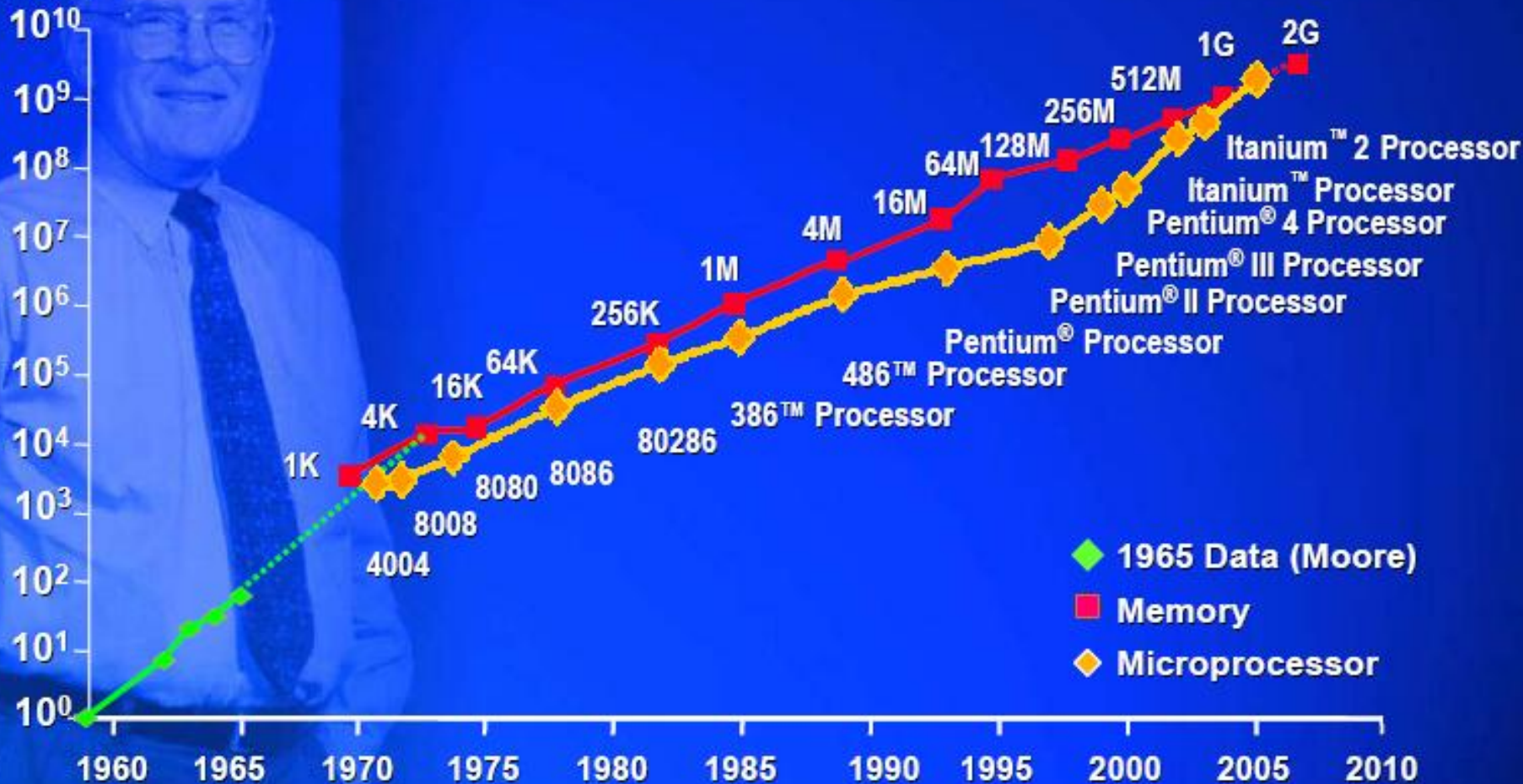
**0.32 micrometer = 320 nanometer !**

# Maar vooral in Computers !



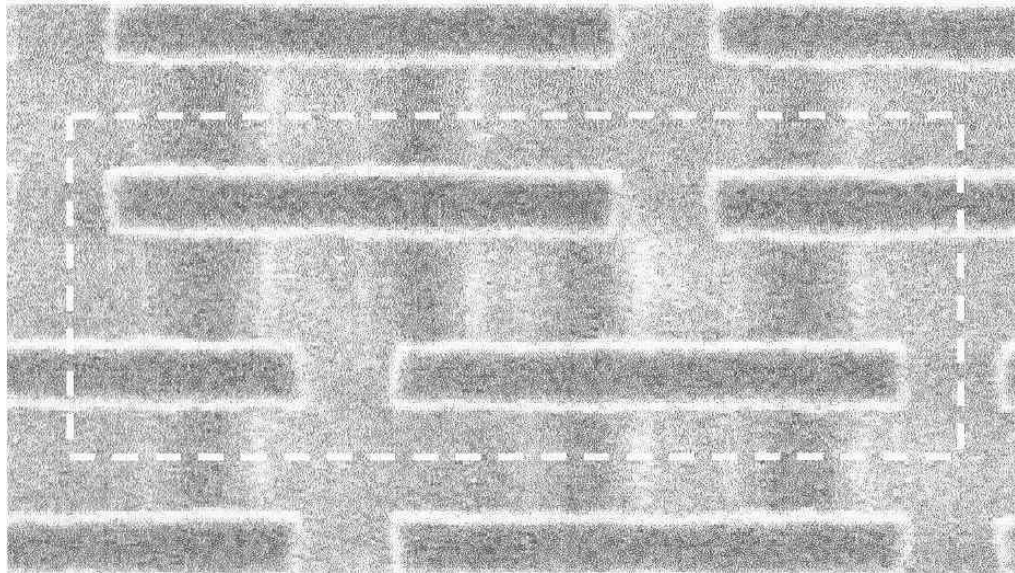
# Moore's Law - 2005

Transistors  
Per Die





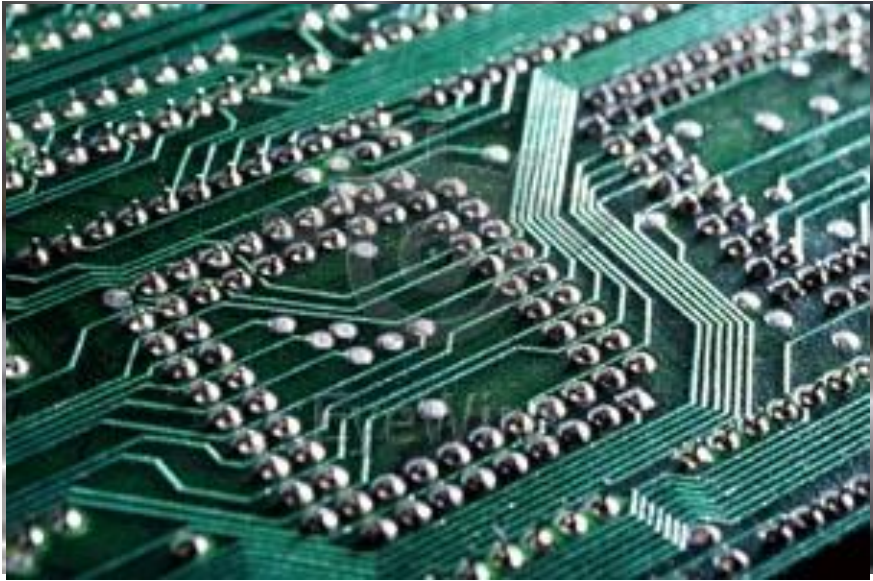
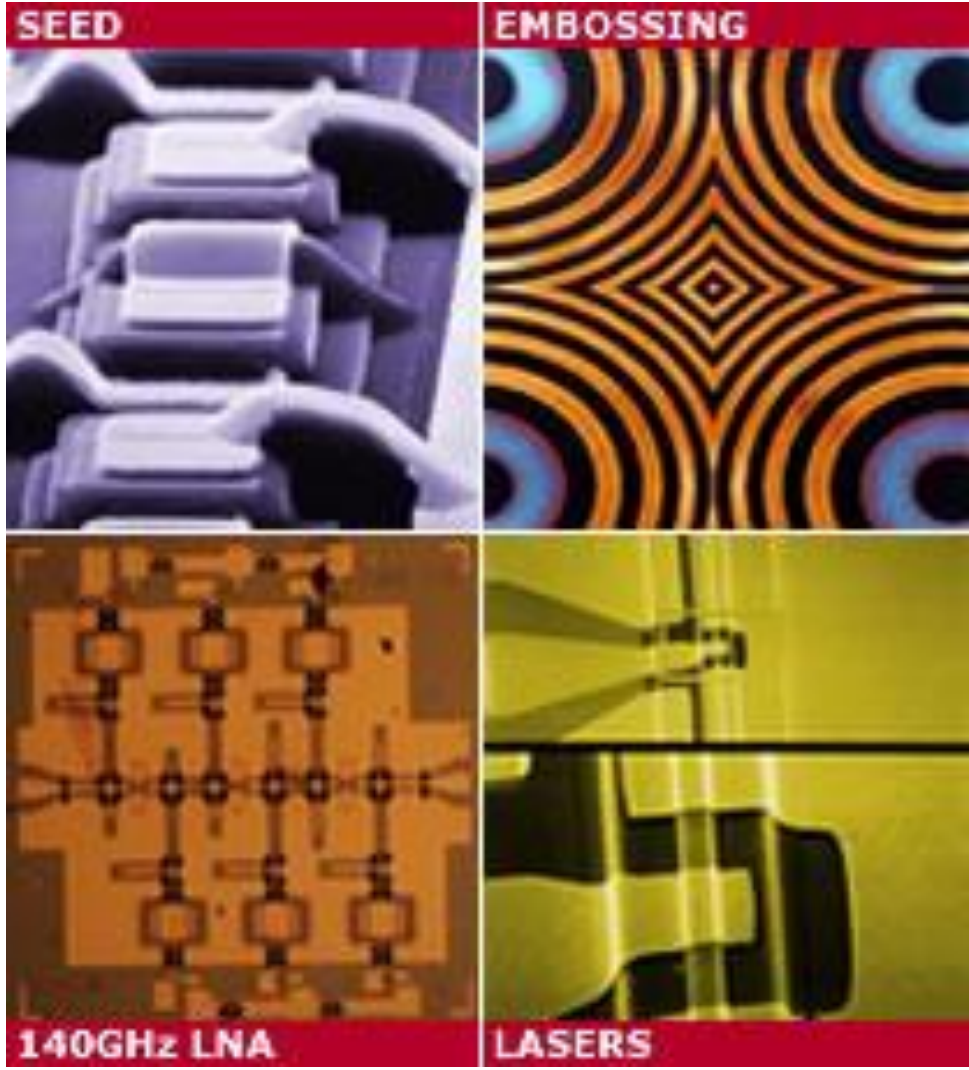
# Intel® Press Release 27-01-2007

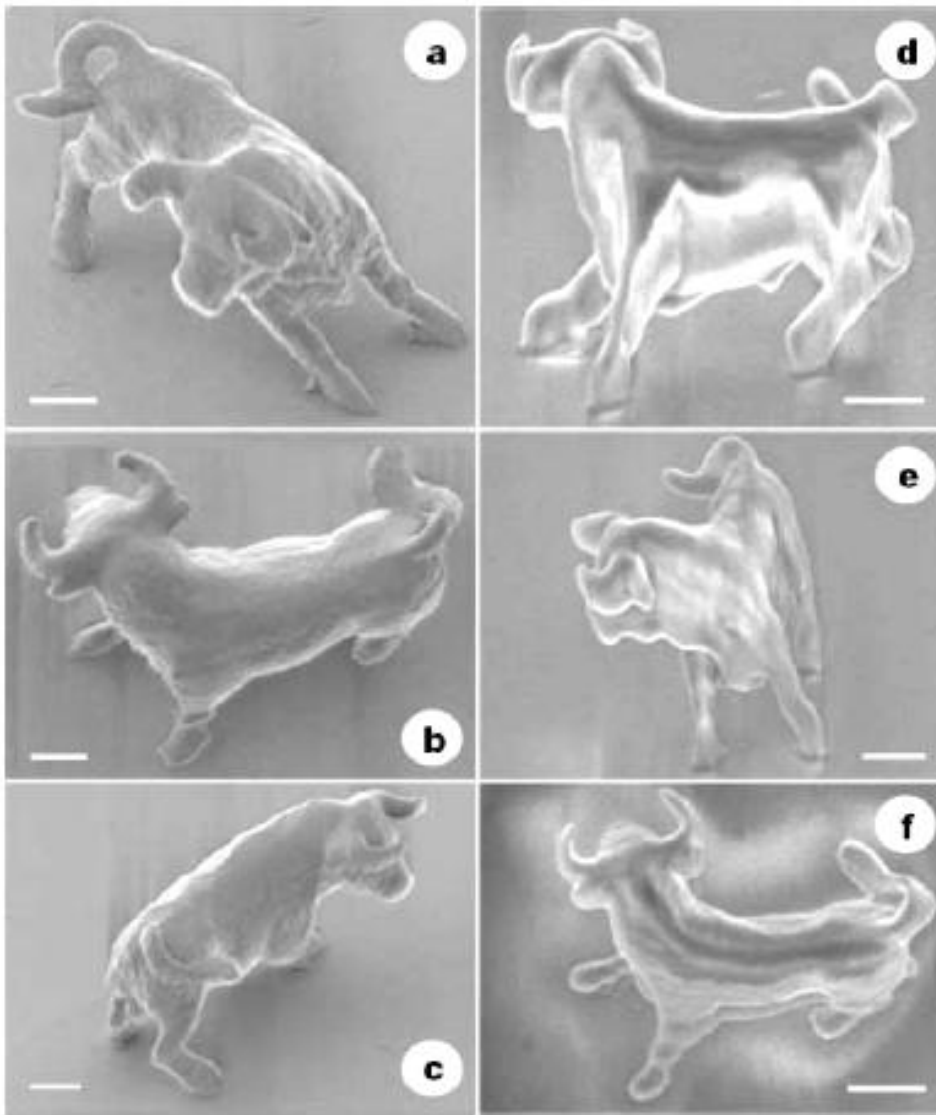


More than 2 million 45 nm transistors can fit on the period at the end of this sentence.



# Lithography

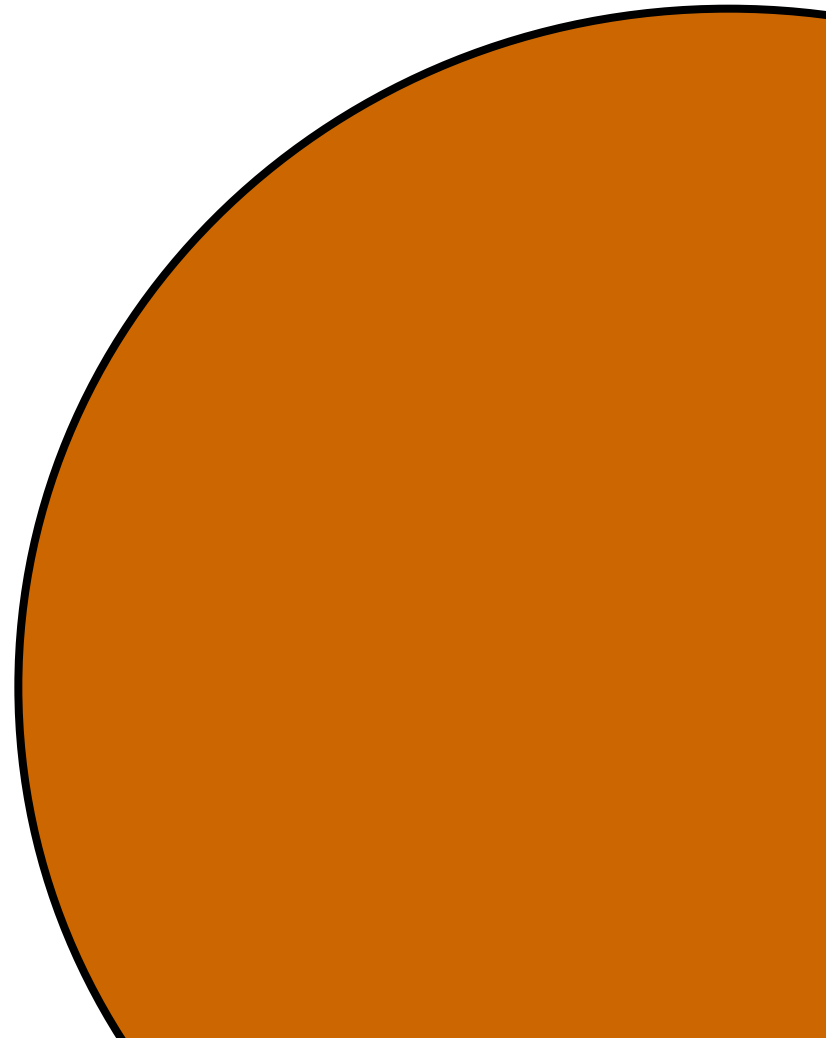




**Fig. 1** Fabrication of a bull sculpture (10  $\mu\text{m}$  long and 7  $\mu\text{m}$  high, about the size of a red blood cell) produced by raster scanning at subdiffraction-limit resolution using a titanium sapphire laser. Scale bars: 2  $\mu\text{m}$ . [Reprinted by permission from Kawata *et al.*, *Nature*, 2001, 412, 697–698. Copyright 2001 Macmillan Publishers Ltd.]

**nano-fabricage ?**

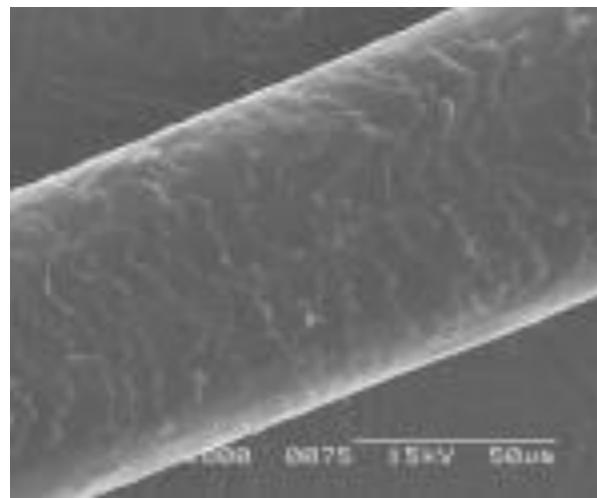
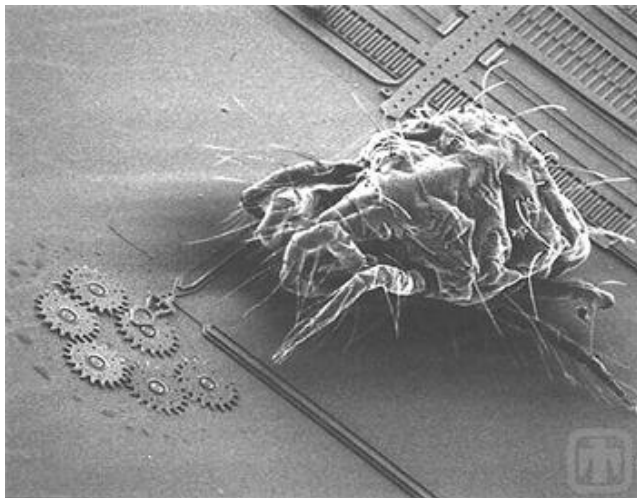
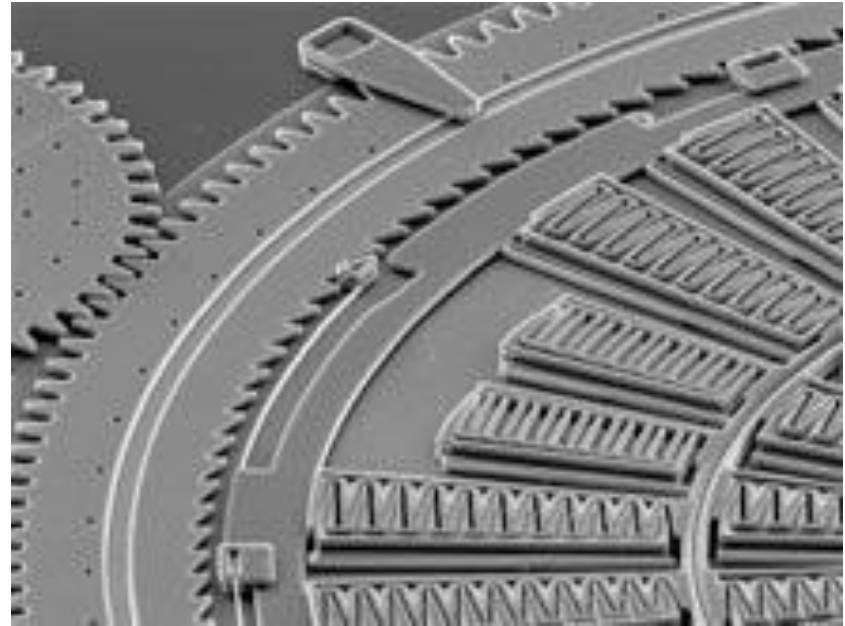
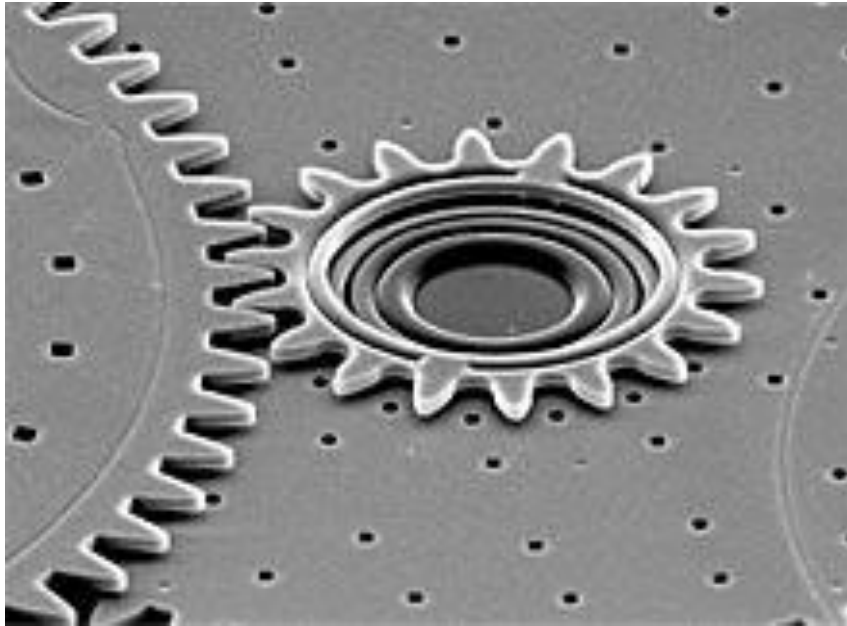
**Hoe ver kunnen we gaan ?**





# MEMS

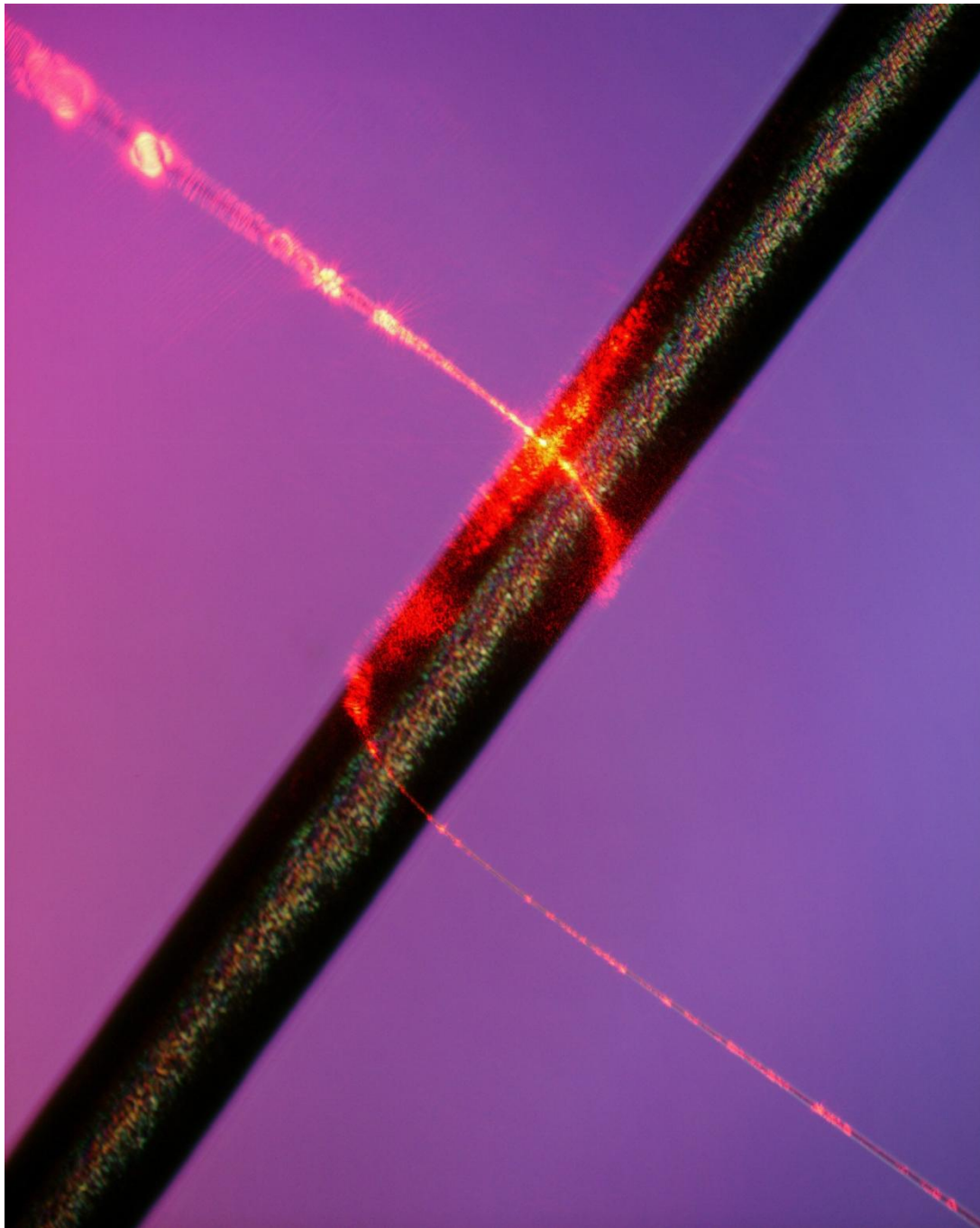
"Micro Electro Mechanical Systems"



## Application in:

- Inkjet printers
- Car airbags
- Blood pressure sensors
- Etc.





**licht-geleidende nano-  
glasfiber , gewikkeld  
om een haar !**

**Deze nanodraden zijn  
flexibel en zijn slechts  
50 nanometers in  
doorsnee , ongeveer  
een duizendste van een  
haar !**

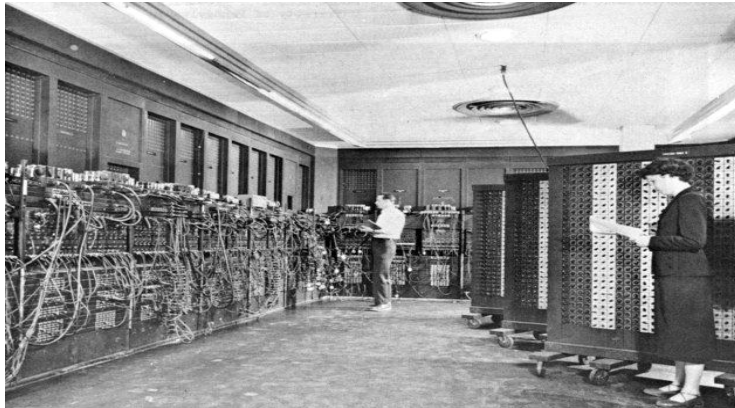
(Credit: Limin  
Tong/Harvard  
University

**Richard Feynman 1959 :**  
*"There's Plenty of Room at the Bottom"*



[www.its.caltech.edu/~feynman](http://www.its.caltech.edu/~feynman)

## Miniaturisation



**Top-down**



**1 - 100 nm**

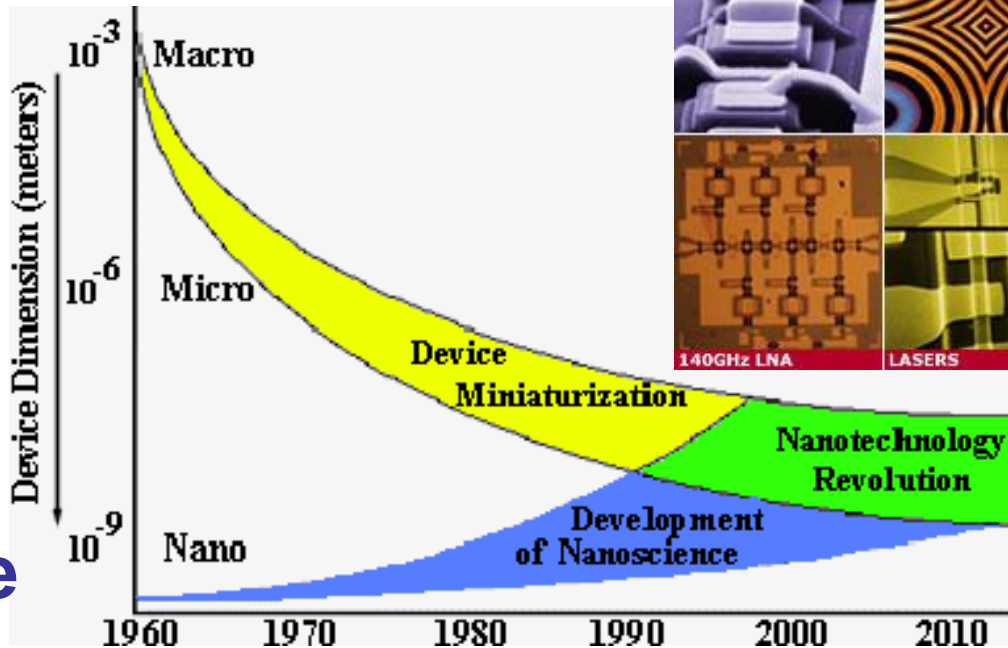


**Bottom-up**



# Top-down vs Bottom-up

## Natuurkunde

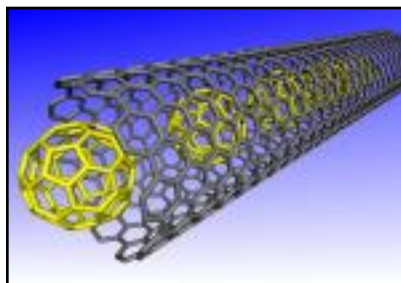


## Biologie

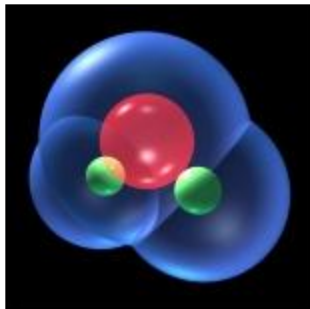


DNA ( 1 nm)

Carbon Nanotube  
( 1 nm)



Water Molecule  
( 0.3 nm)



## Scheikunde

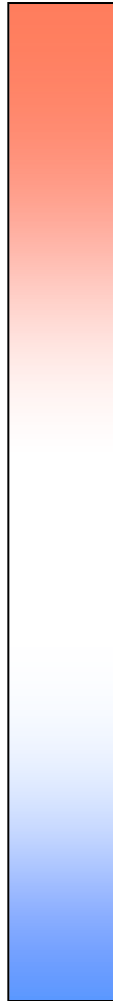


1000 nm

100 nm

10 nm

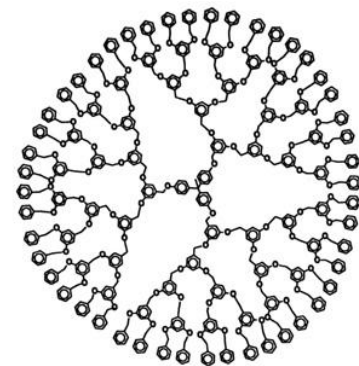
1 nm



**Litografie  
Techniken**



**Laboratorium  
Synthese**

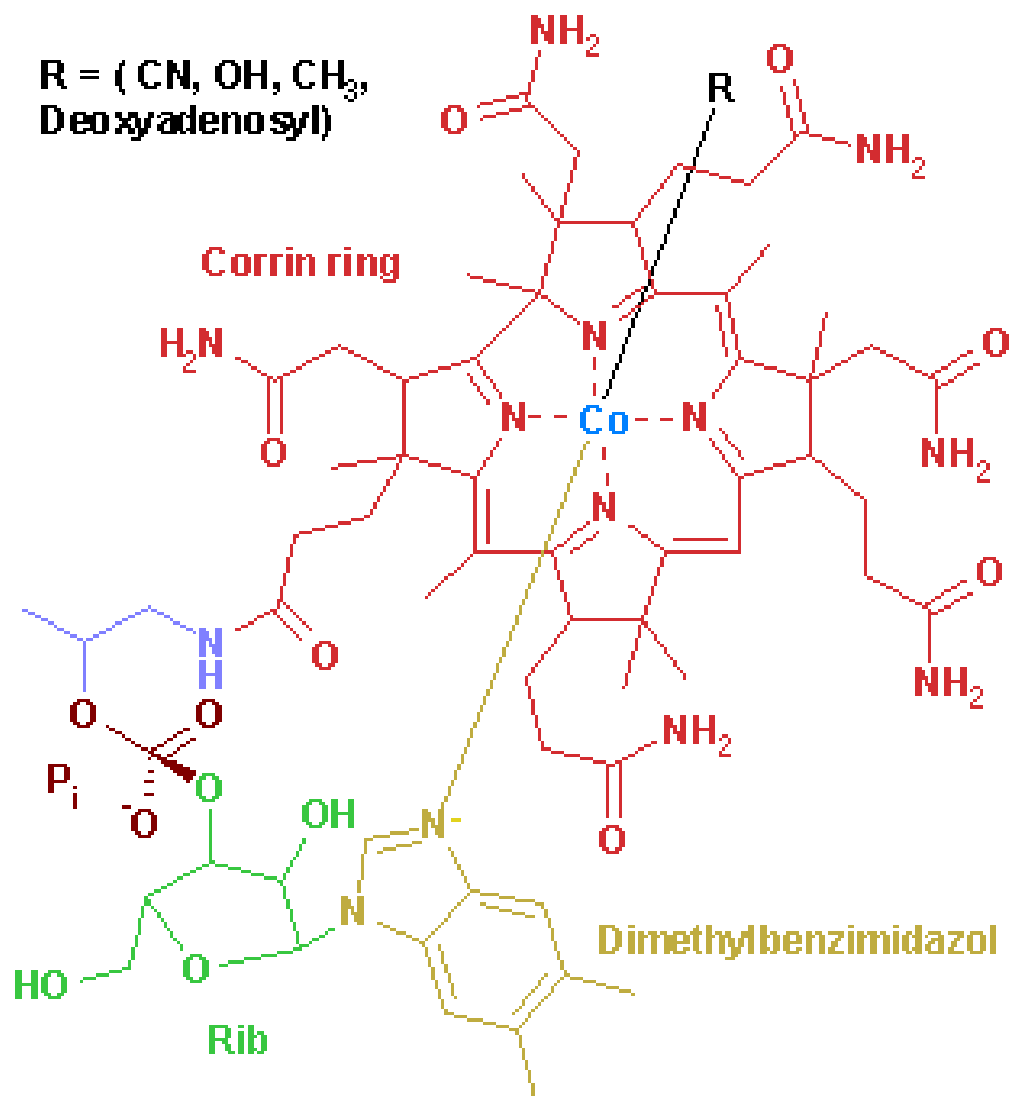


# Covalente Synthese: State of the Art



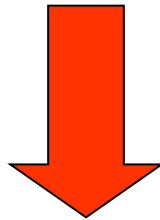
Robert Woodward  
Nobel Prize 1965

## Vitamine B<sub>12</sub>



100 reactiestappen, 100 chemici, 10 jaar

**Bouwen van “Grote” Systemen  
door Supramoleculaire Chemie**



**Zelforganisatie**



# Wat is “zelf-organisatie” ?

[www.nl.wikipedia.org](http://www.nl.wikipedia.org):

**Zelf-organisatie** is het proces waarbij in een chaotisch systeem schijnbaar spontaan structuren ontstaan.

**Je vindt het overal in de natuur !**

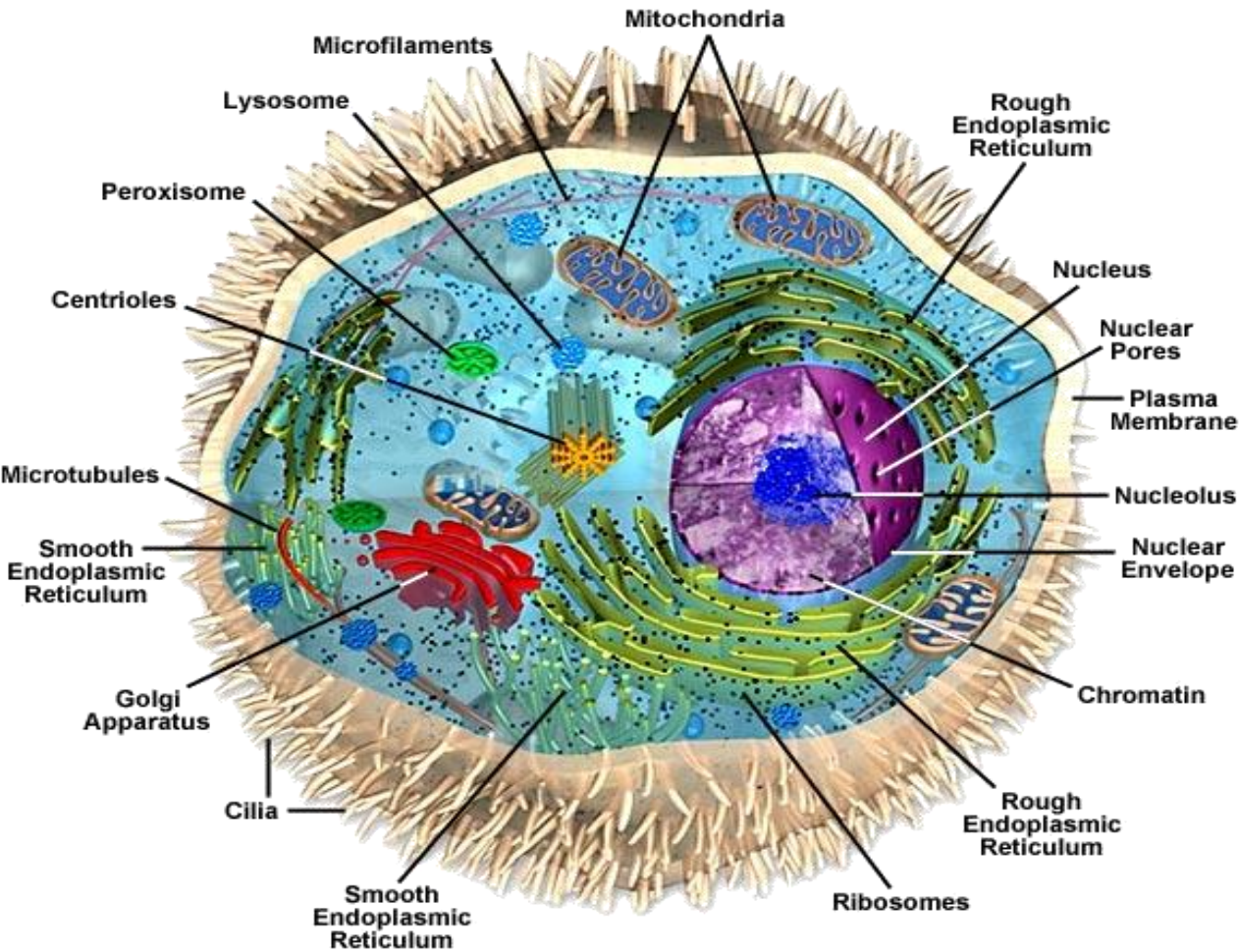
# Zelforganisatie??



(je kunt wachten tot je 'n ons weegt...)

# Maar de Natuur doet het wél !

(al heeft dat miljarden jaren evolutie gekost...)

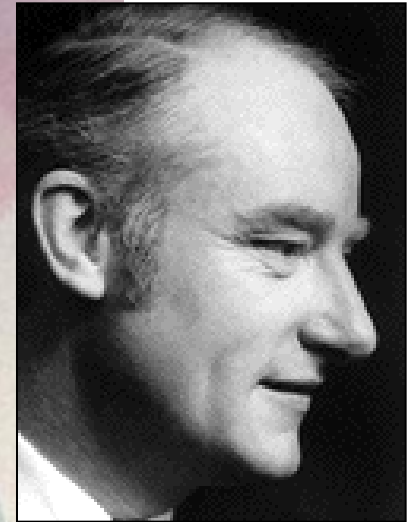
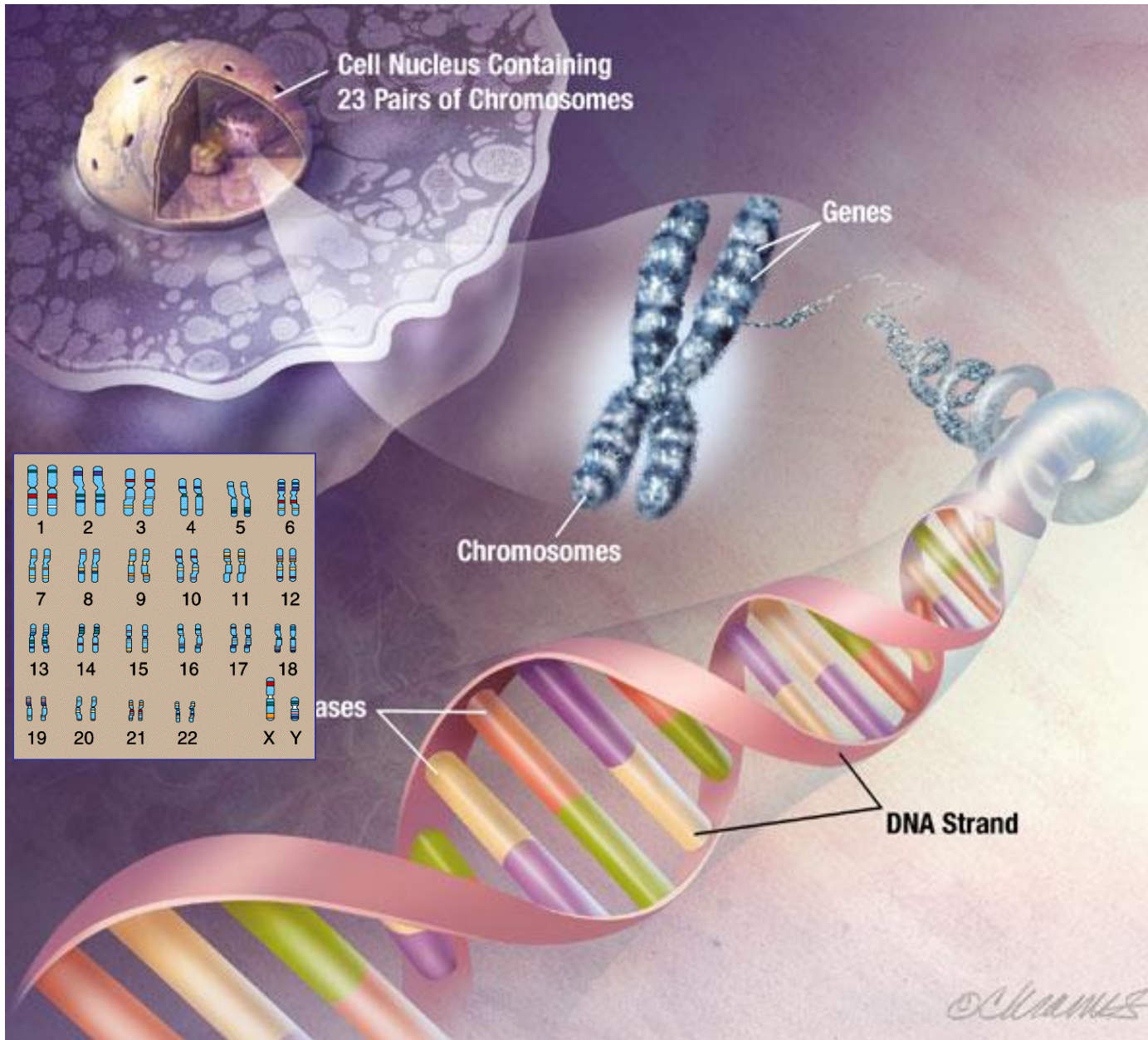


## Basiscomponenten van Leven

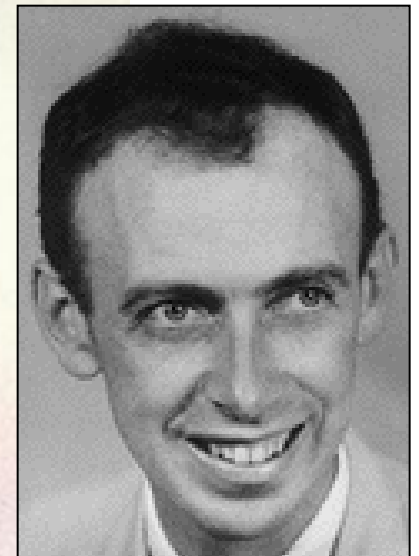
- 20 aminozuren
- 5 nucleobasen
- 2 suikers
- 3 vetzuren

en heel veel  
**water**





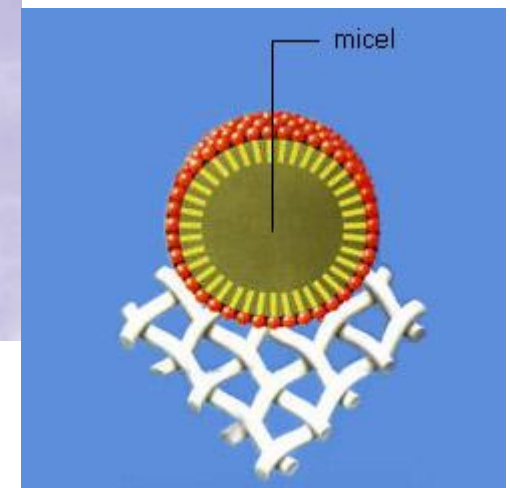
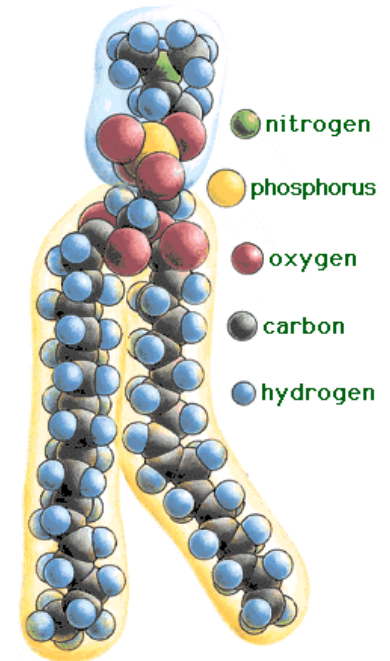
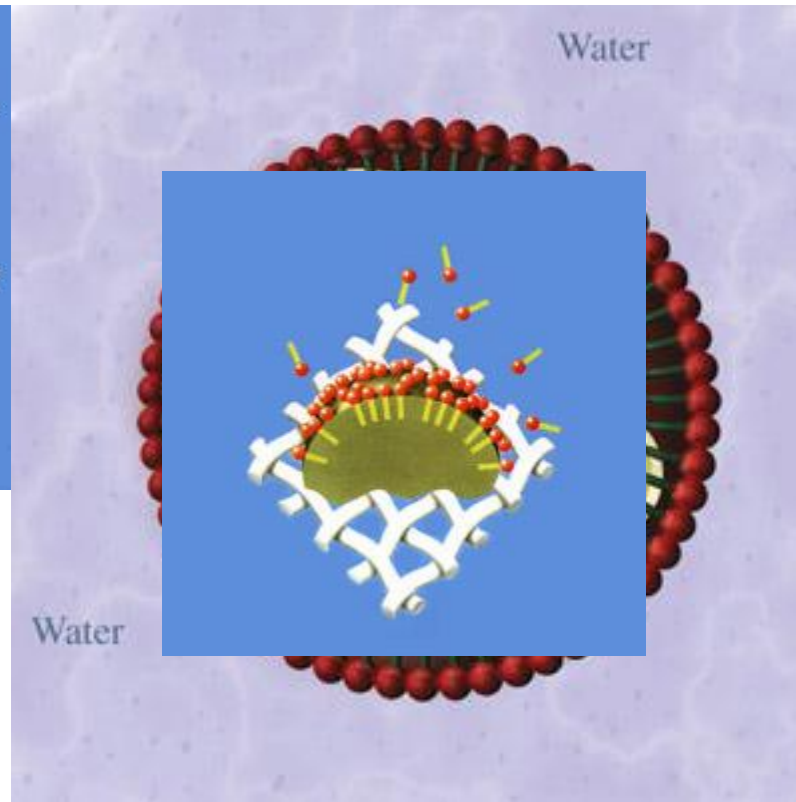
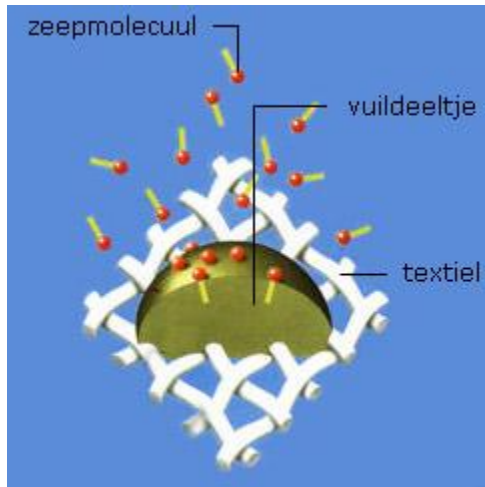
**Watson**



**Crick**

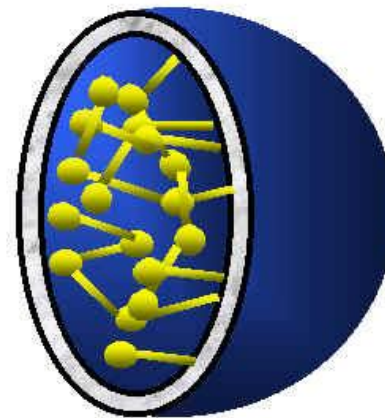
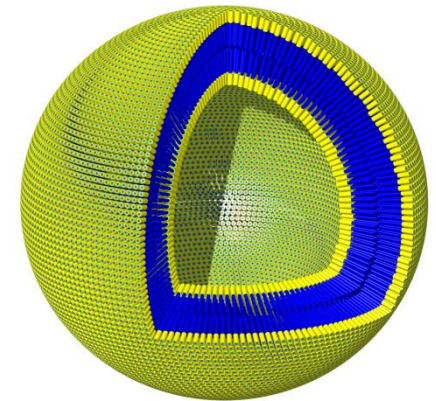
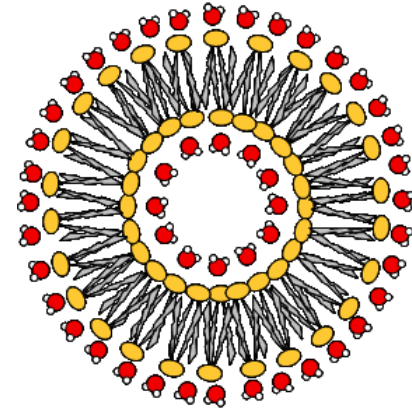
In elke cel zit 3 meter DNA, in elk persoon 20 miljard kilometer!

# Functionele materialen van *zelfgeorganiseerde* chemische verbindingen



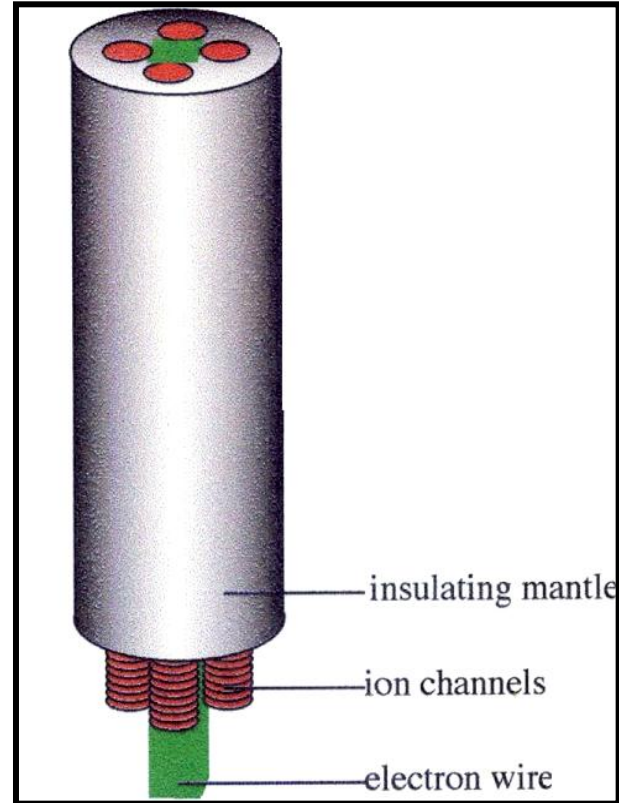
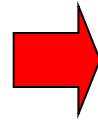
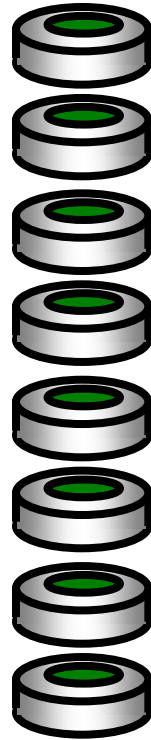
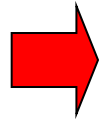
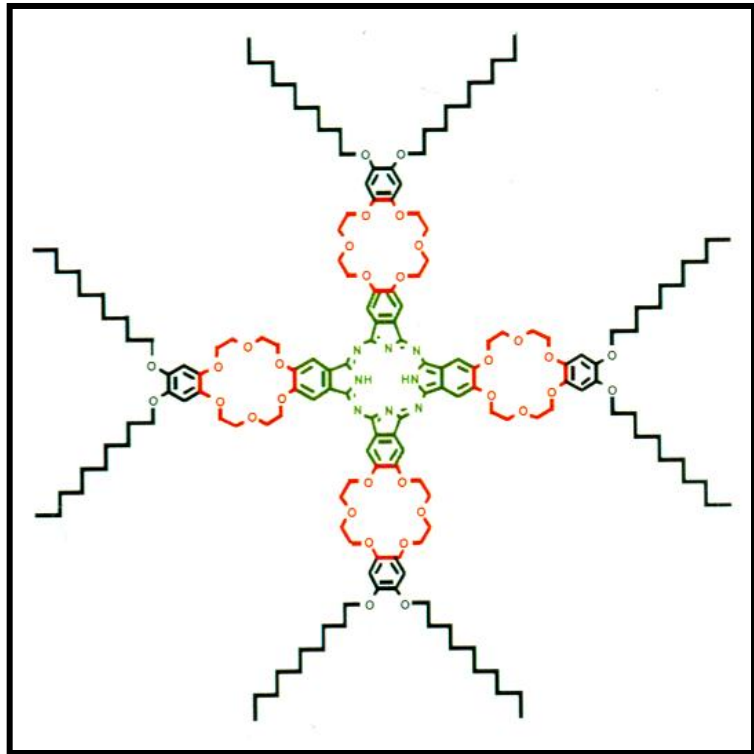
# Toepassing: capsules voor medicijnen

- Voor **gerichte** afgave
- Grootte < 25  $\mu\text{m}$
- Stabiel voor mondelinge inname
- Herkenning
- Afgave



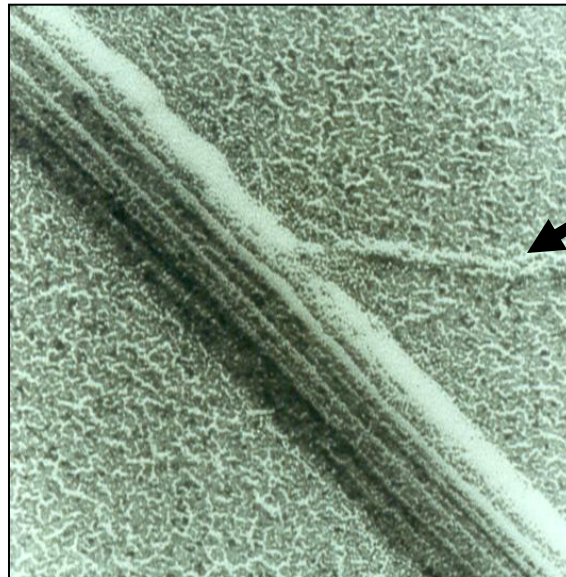
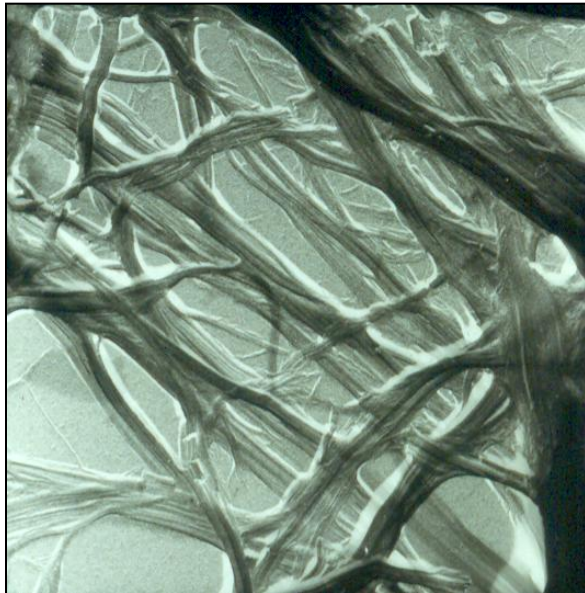
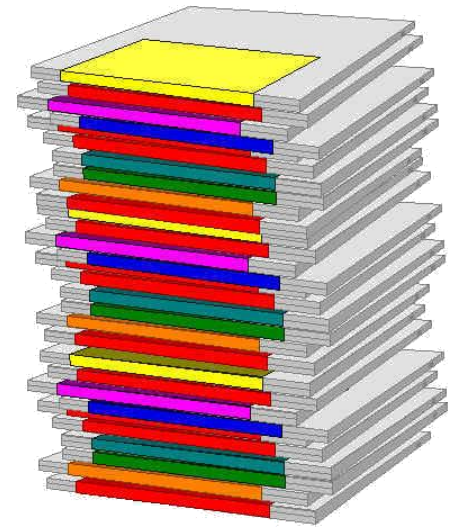
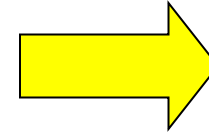
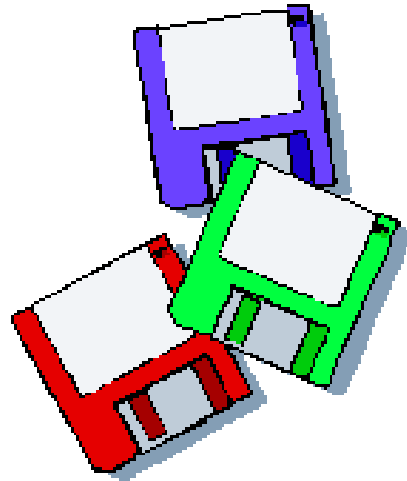
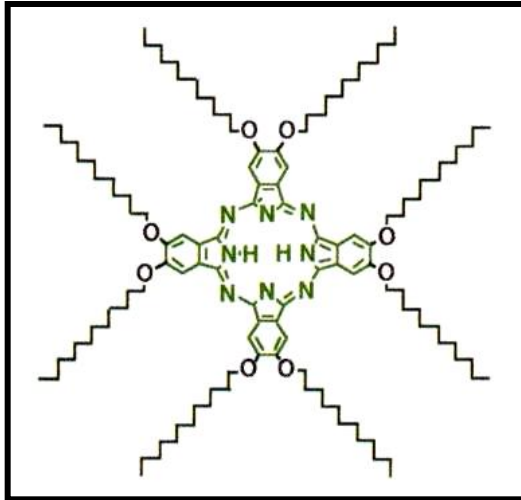


# Spontaan stroomdraadjes



**De moleculen organiseren zichzelf tot een draadje  
De binnenkant kan stroom geleiden**

# Stapelende Platte Moleculen



10.000 x  
dunner dan  
een haar



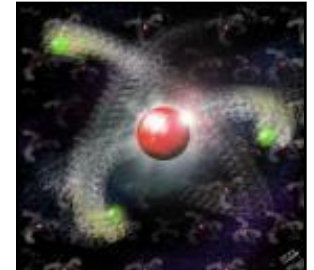
ant (2mm)

Pollen (40  $\mu\text{m}$ )



Virus (100 nm)

DNA (1 nm)



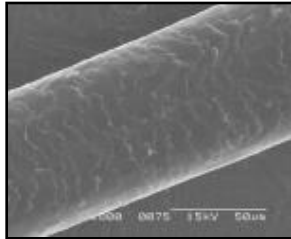
Atom (0.1 nm)



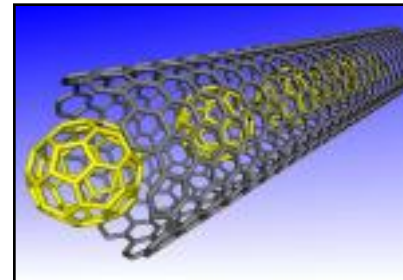
Bacteria (1-2  $\mu\text{m}$ )



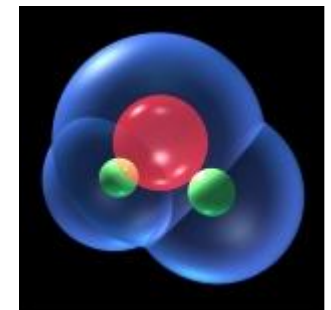
Humans (1 m)



a hair (70  $\mu\text{m}$ )



Carbon Nanotube (1 nm)



Water Molecule (0.3 nm)

