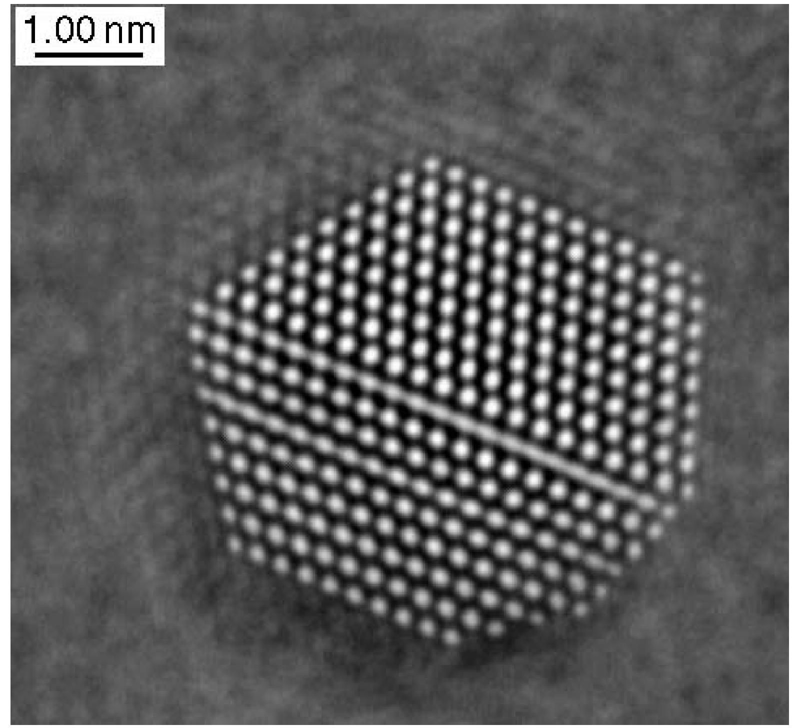
The Truth about Nanotech-nology

Niels Boeing,
29/12/2005



Source: INM, Saarbrücken

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„The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom“

Richard Feynman, 1959

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1 What is nanotechnology?

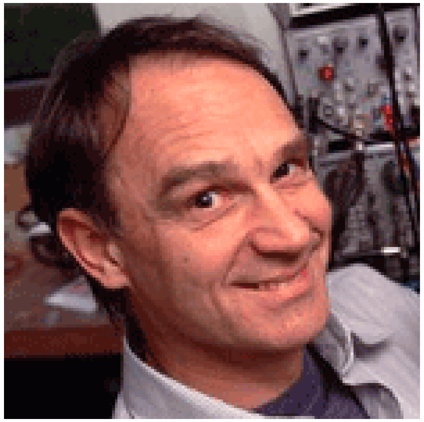
It is **not a singular technology** dealing with a special object.

It is a new phase in technology by itself:

All technical processes that deliberately create or

use **structures smaller than 100 nanometers** where quantum effects support a new handling of matter.

Different technologies in physics, engineering, computing, biotechnology and chemistry have been **merging at the nanoscale** for the past decades.



„At this moment Man is witnessing and shaping a second genesis, a fundamentally new evolution of material structures“

Gerd Binnig, 2004

From macro down to nano

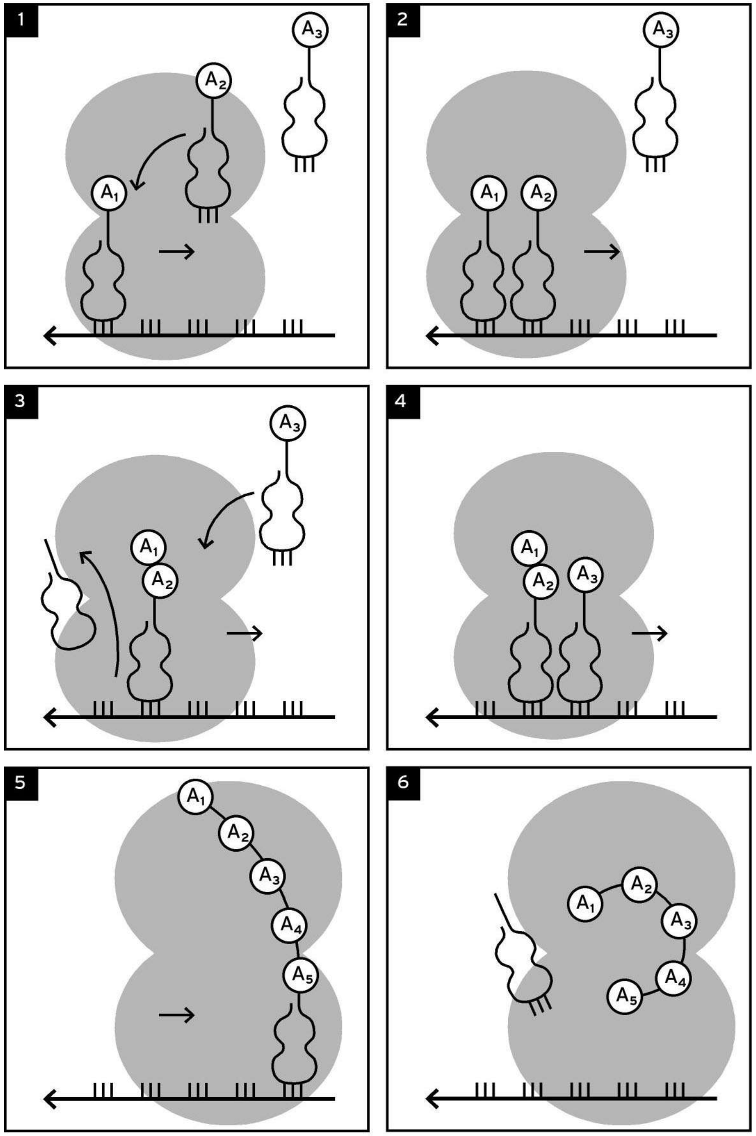
Diameter/ width in nanometers	Object	Normal Units
3.476.000.000.000.000,0	Moon	3.476 km
33.000.000.000,0	Sphere of the Berlin TV tower	33 m
23.000.000,0	1-Euro-coin	2,3 cm
50.000,0	Hair	50 µm
130,0	PC processor circuits	130 nm
50,0	**Hepatitis-C-Virus**	**50 nm**
20,0	**Ribosome**	**20 nm**
10,0	**Quantum dot**	**10 nm**
2,0	**DNA-Molecule**	**2 nm**
1,0	**Nanotube (single-walled)**	**1 nm**
0,1	**Hydrogen atom**	**1 Å**

Nanotechnology in nature

One example:

the ribosome,
a „natural nanofactory“
For protein synthesis

Diameter: 20 nm →



Grafik: Phoebe Arns/Die Zeit, Daniel Sauthoff

Nanotools

For sensing - grasping - moving

- Scanning tunneling microscopy (1981)
- Force microscopy (1986)

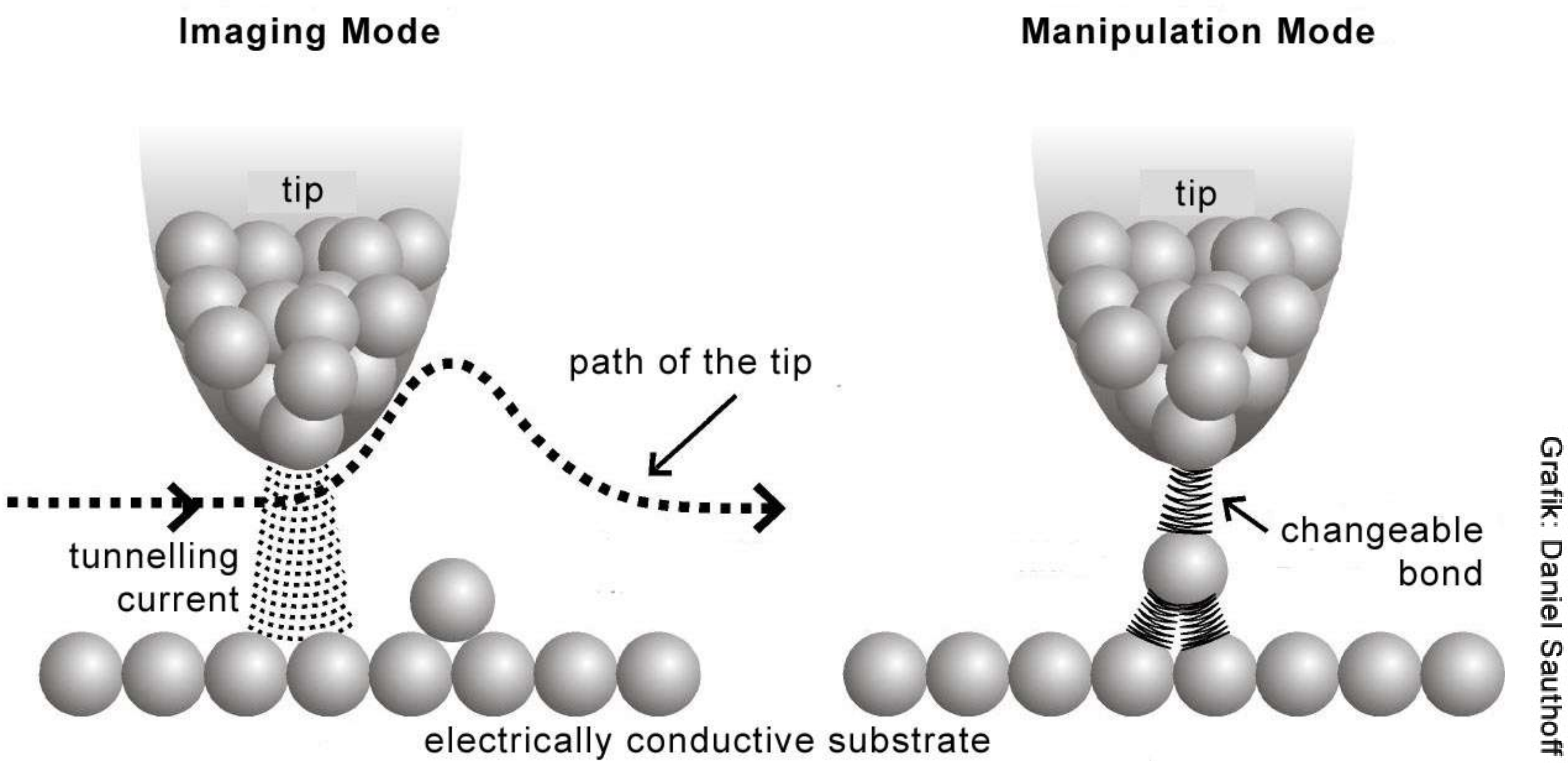
For joining

- Self-organization (sol-gel process, 1930s;
  DNA self-assembly,1990s)

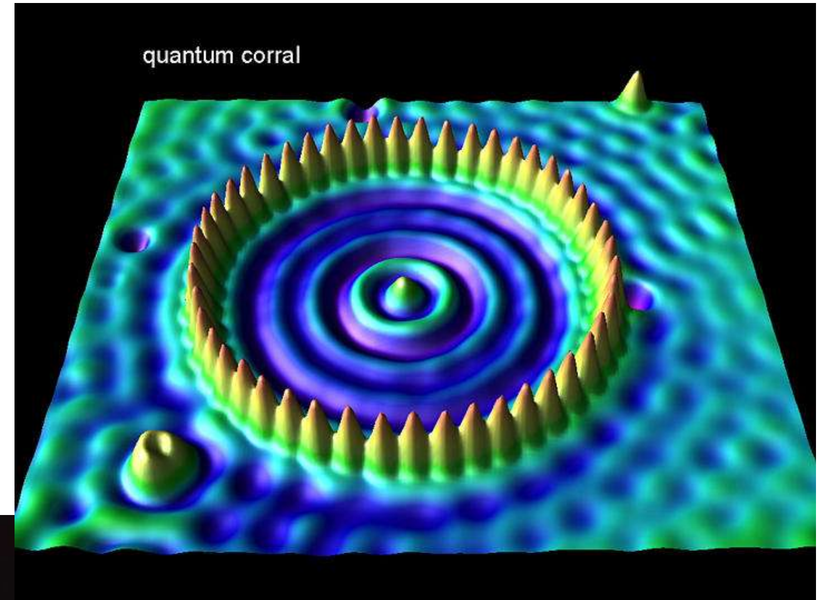
For cutting

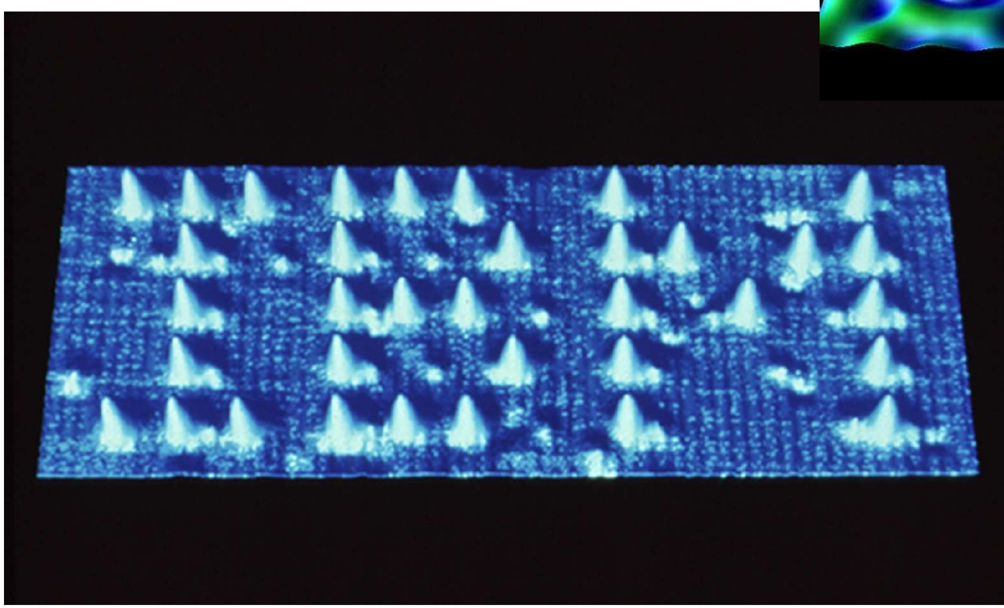
- EUV-Lithography (1990s)

The scanning tunneling microscope
(1981)



Another random discovery 1989: **atoms can be moved** by the scanning tunneling microscope...



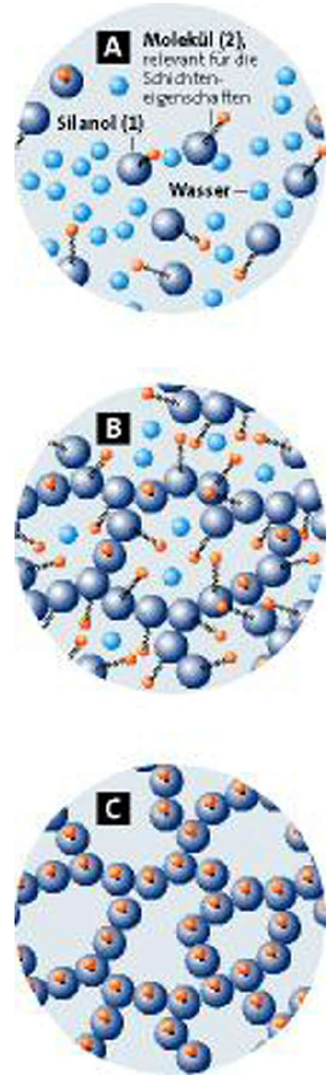


Source: IBM

The sol- gel process

Discovered in the late 30s by glass manufacturer **Schott** in Jena; in the 80s developped into the **most important method** of chemical nanotechnologie

A Sol
B Gel
C Network with structure



Grafik: Phoebe Arns, Die Zeit

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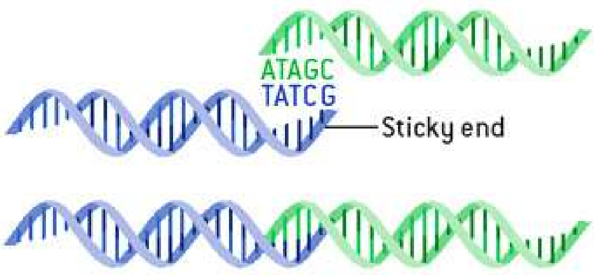
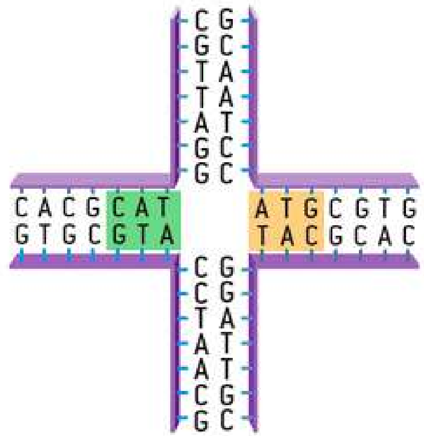
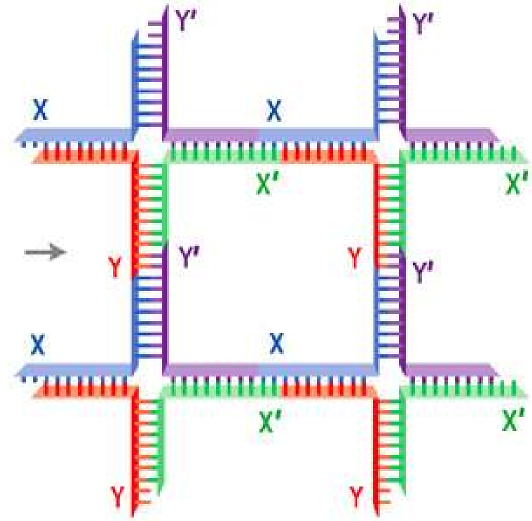
Self- assembly with DNA



Source: Scientific American





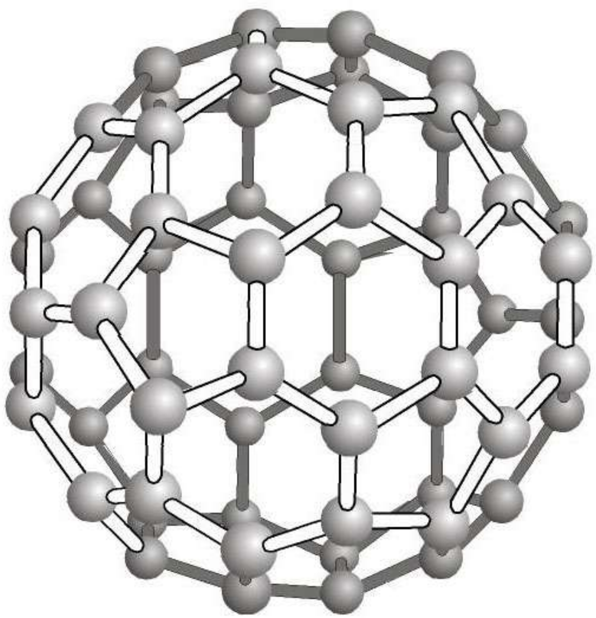
Short DNA- strands are linked into crosses („Halliday- Junctions“) that could be use as extended DNA- scaffolds.

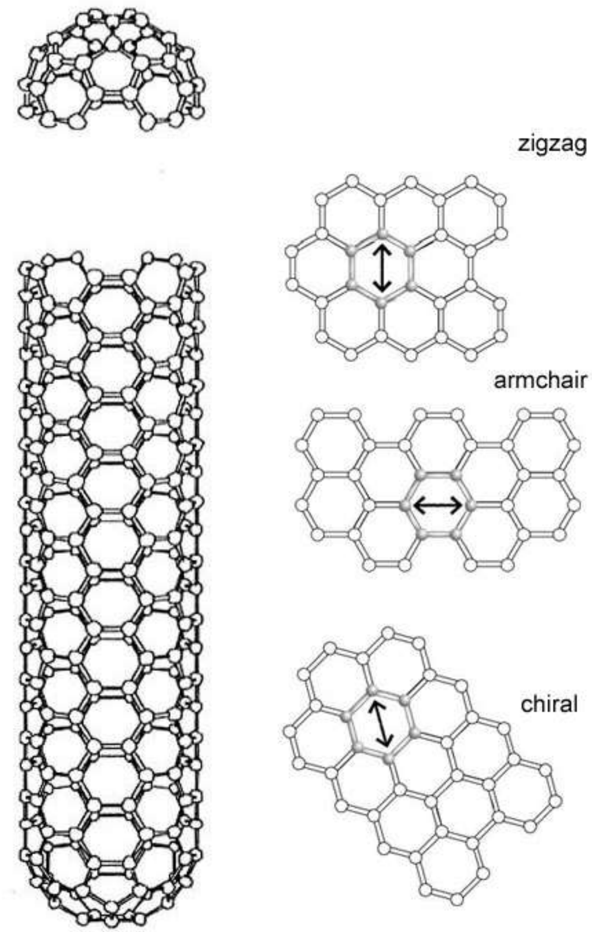
Research for instance at Columbia University New York or University of Munich.

New molecules

For example carbon:

Buckyball (C_{60}) & **Nanotube** →





Grafik: Daniel Sauthoff

2 What can nanotechnology already achieve?

1 OLEDs for Displays

2 Nano-solar-cell film

3 Scratch-proof, self-cleaning windows

4, **5** Stain-repellent fabrics

6 light-weight bucky-tube reinforced frame

7 Hip-joint made from biocompatible materialien

8 Anti-corrosive nanoparticle paint

9 Thermo-chromic glass to regulate light

10 Magnetic layers for compact data memory

11 Carbon nanotube fuel cells

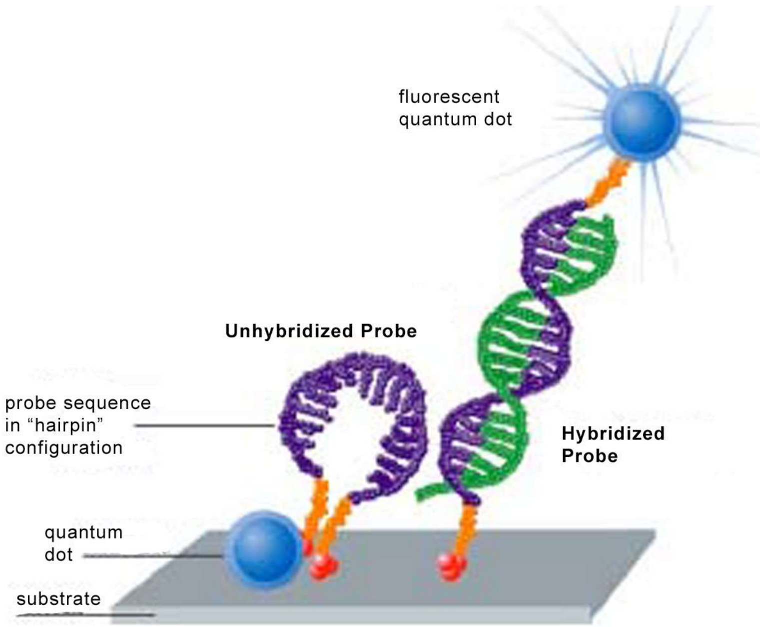
12 Nano-engineered cochlear implant

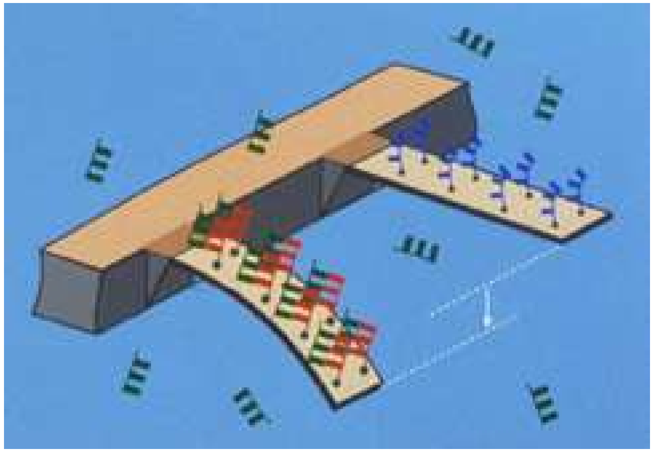
Source: New Scientist

Nanosensors

Tiny structures react on single molecules:

1 Cantilevers for cola- Tests as well as medical tests (right)





2 „Quantum dots“ as biomarkers in biotech or as bioweapons detector

Sources: IBM, Evident Technologies

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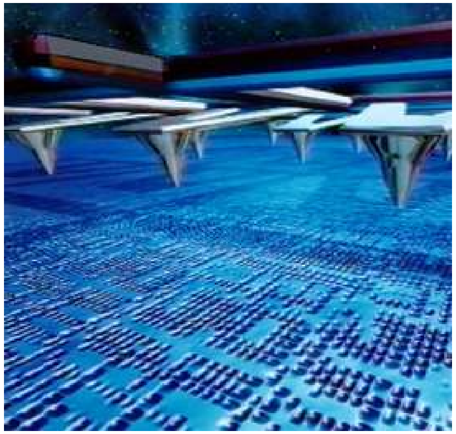
Nanoelectronics

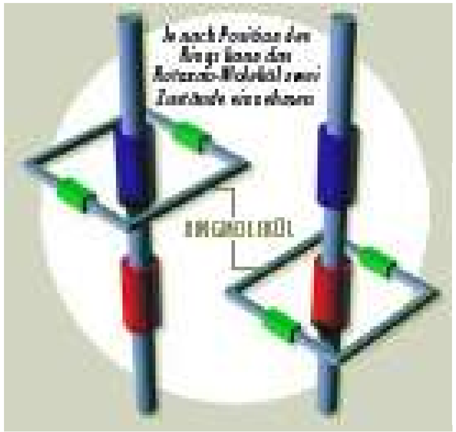
Transistor features in current state-of-the-art chips have a size of 90 nm. Features smaller than about 40 nm are not feasible with today‘s technologies. Possible solutions:

1 „Millipede“ (IBM), 1 hole for 1 Bit: ∅15 nm

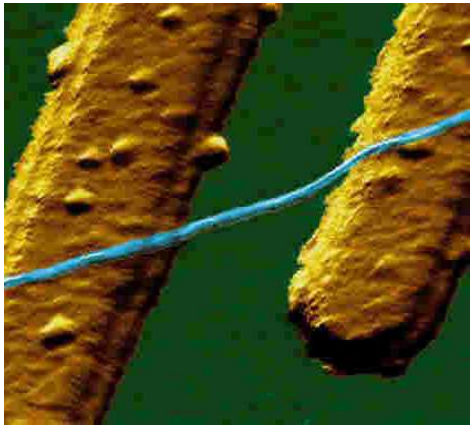
2 „Crossbar Latch“, (Hewlett-Packard)

3 Nanotube-Transistors





Grafik: Nicole Krohn



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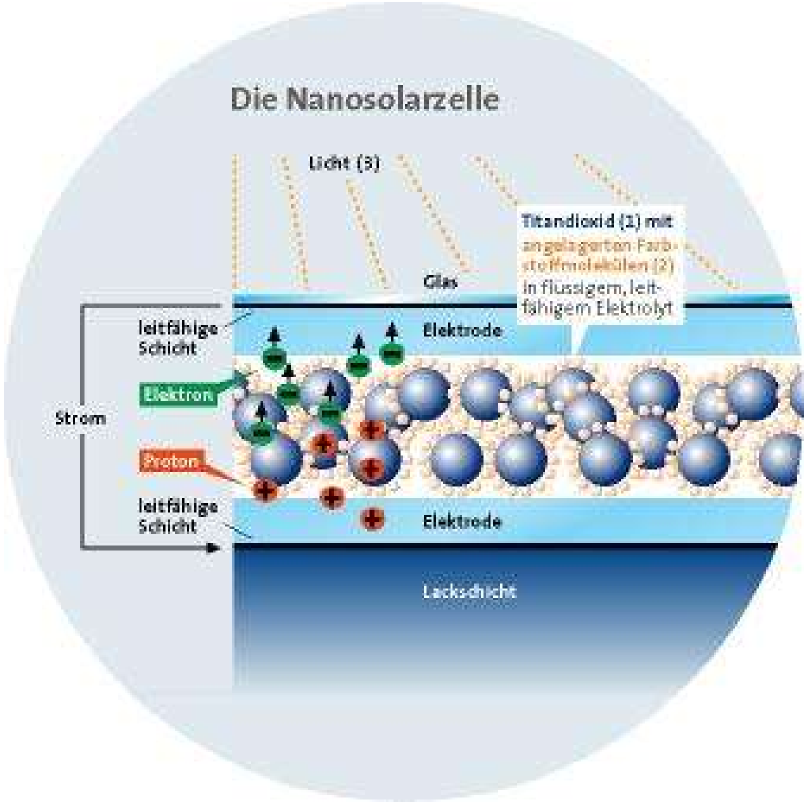
Nano solar cells

In the 80s chemist **Michael Grätzel** discove-

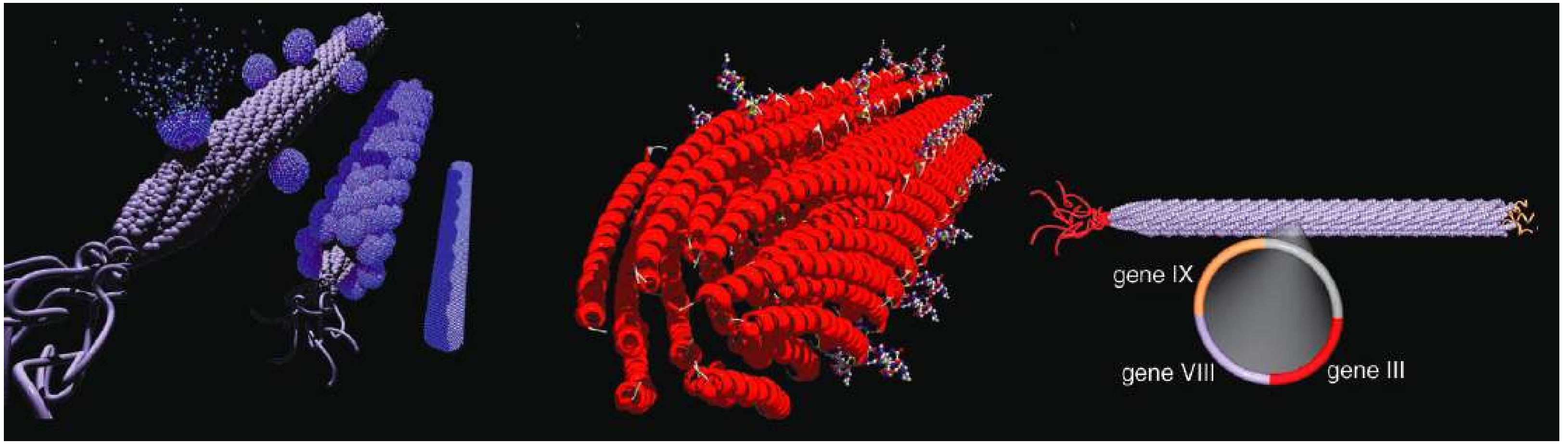
red that a mixture from titaniumdioxide nano-crystals and dye-molecules generate a current under light exposure (right).

Maximum efficiency: 10 %, half of silicon solar cells - but even under average daylight conditions



Grafik: Phoebe Arns, Die Zeit

Nanobiotechnology



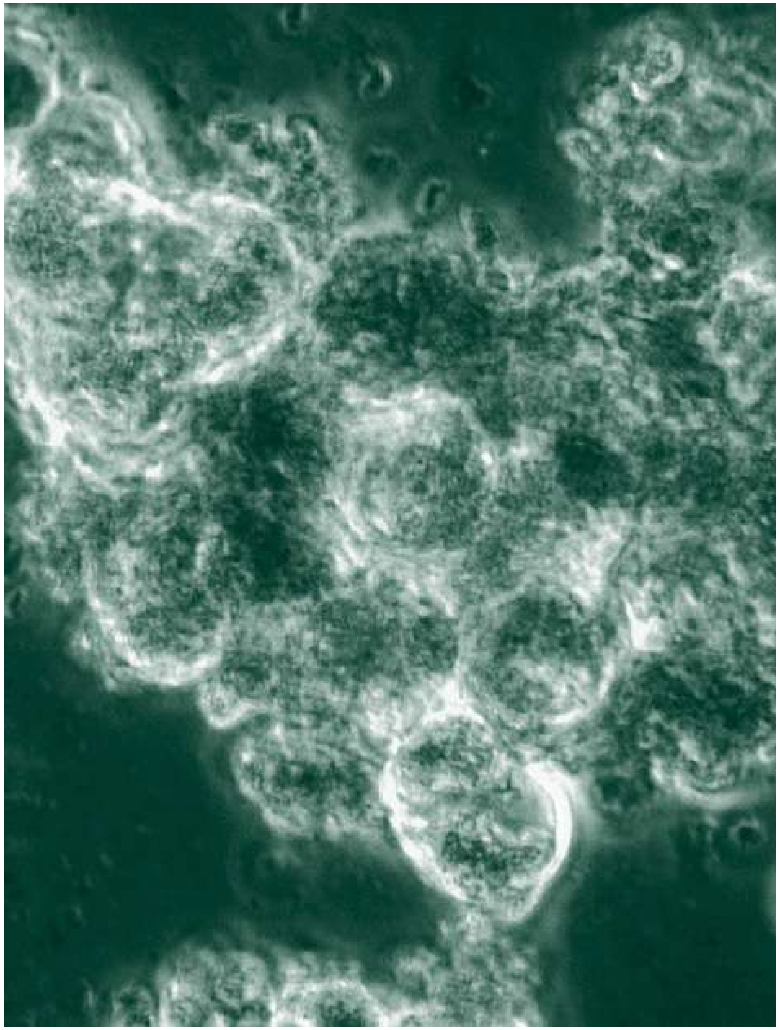
Source: Science

Example: Viruses for wires
In a process developped by **Angela Belcher** of MIT genetically engineered viruses (bacteriophages) express a protein coat that attracts semiconductor particles.

Nanomedicine

Superparamagnetic nano-particles coated with biomolecules are injected into a tumor and move into the cells. Applying an alternating magnetic field they start vibrating. The resulting heat kills the tumor cells.

Developped by **Andreas Jordan**, Charité Berlin, this therapy is already in clinical trials and will be available by 2007.



Source: Andreas Jordan, Charité

3 What does not work (yet)?

Bottom- up- technologies:

deliberate, automizable and fast integration of many nanosystems into a macroscopic objekt,

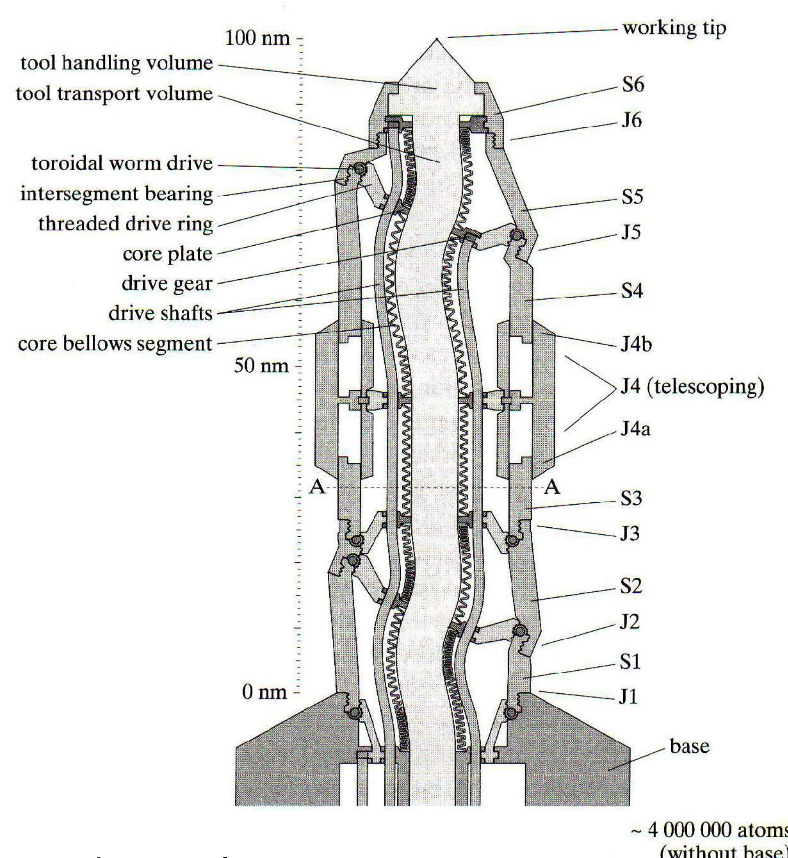
e.g. 1 Mio. nanotube- transistors on one chip in one step

Moleculare nanotechnology: Assembly of any object atom by atom with an „assembler technology“, as proposed by **Eric Drexler** in 1986.

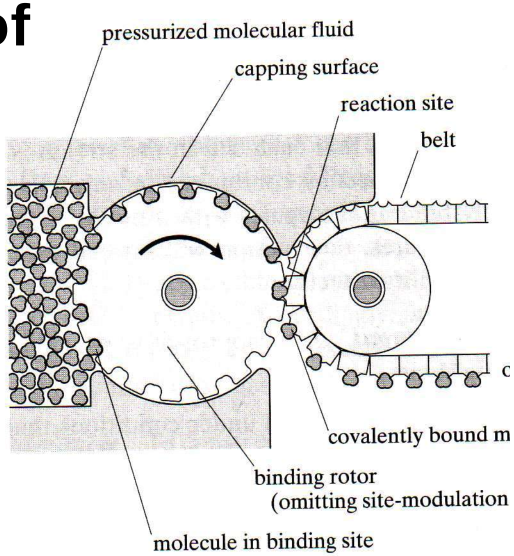
The vision of the nano-assembler

To date the parts of an assembler only exist as computer models – most scientists reject the concept as not feasible

Robotic arm:



Transport of molecules:



Source: Eric Drexler, „Nanosystems“, 1992

Alternative: the molecular fabricator

A molecular fabrication without autonomous nano-assemblers is Drexler‘s new concept of the **„Molecular Fabricator“**, a kind of desktop-factory.

The consequences of such a fabrication technology has been described in Neal Stephenson‘s SF-novel **„Diamond Age“**.

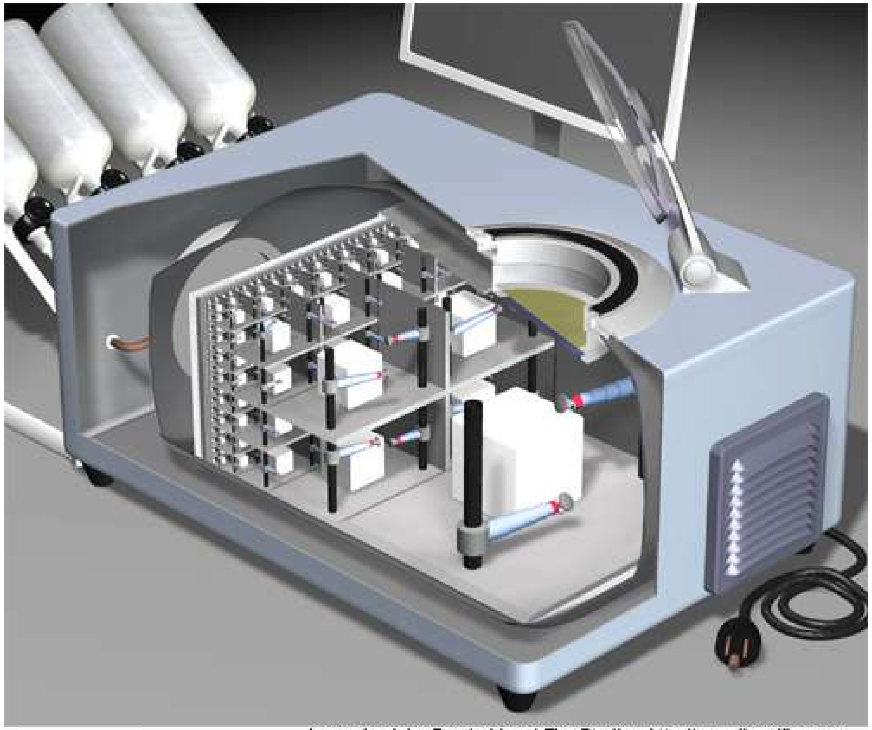


Image by John Burch, Lizard Fire Studios, http://www.lizardfire.com

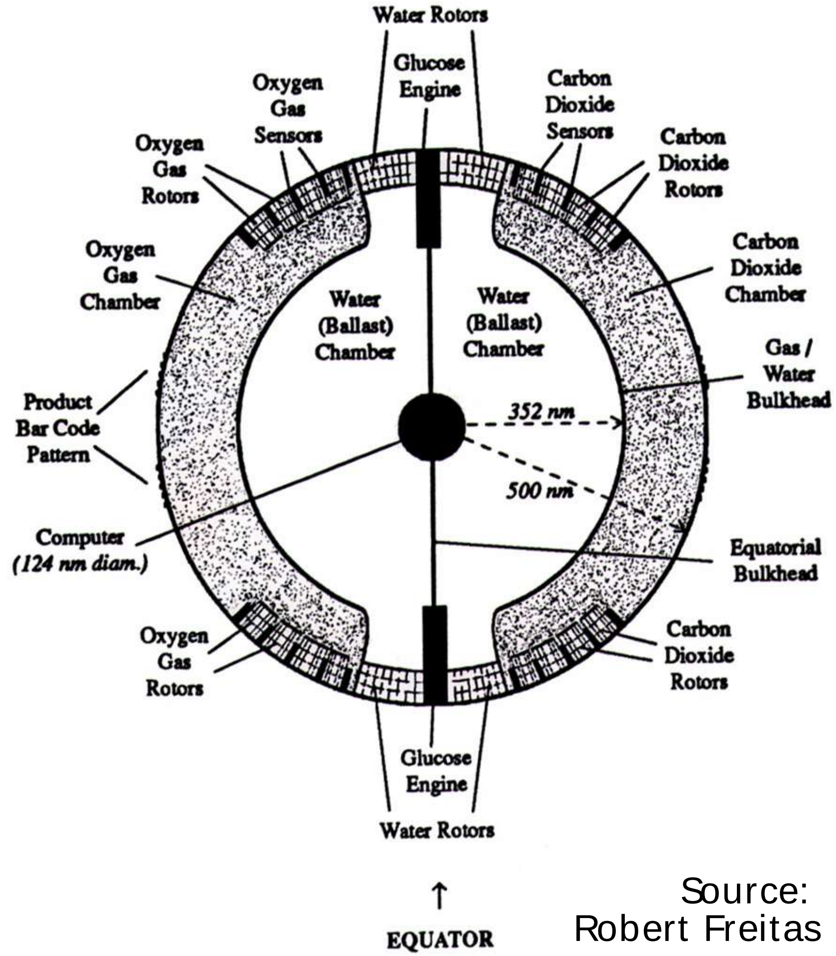
Proposed desktop-scale molecular manufacturing appliance. Tiny machines join molecules, then larger and larger parts, in a convergent assembly process that makes products such as computers with a billion processors. (Parts shown as white cubes.)

Nanomedical utopias

Artificial red blood cell, called „**respirocyte**“

Diameter: 1 µm

Theoretical concept by **Robert Freitas** (1999)



Source: Robert Freitas

4 How hazardous is NT?

Proposal for a classification of nanotechnology with regard to potential ecological hazards

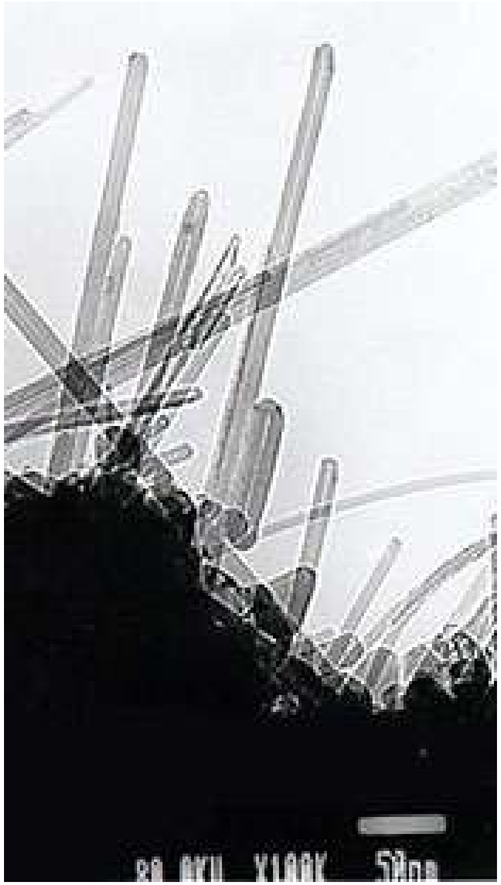
1. **„contained“ NT**
   Embedded non-biological nanocomponents, e.g. in new materials, nanoelectronics or analytical devices
2. **„bioactive“ NT**
   A) Free non-biological nanoparticles; B) methods to manipulate biological systems
3. **„disruptive“ NT**
   Autonomous nanosystems, artificial viruses

Class 2A: bioactive nanotechnology

Free non-biological nanoparticles (NPs) can be **toxic.**

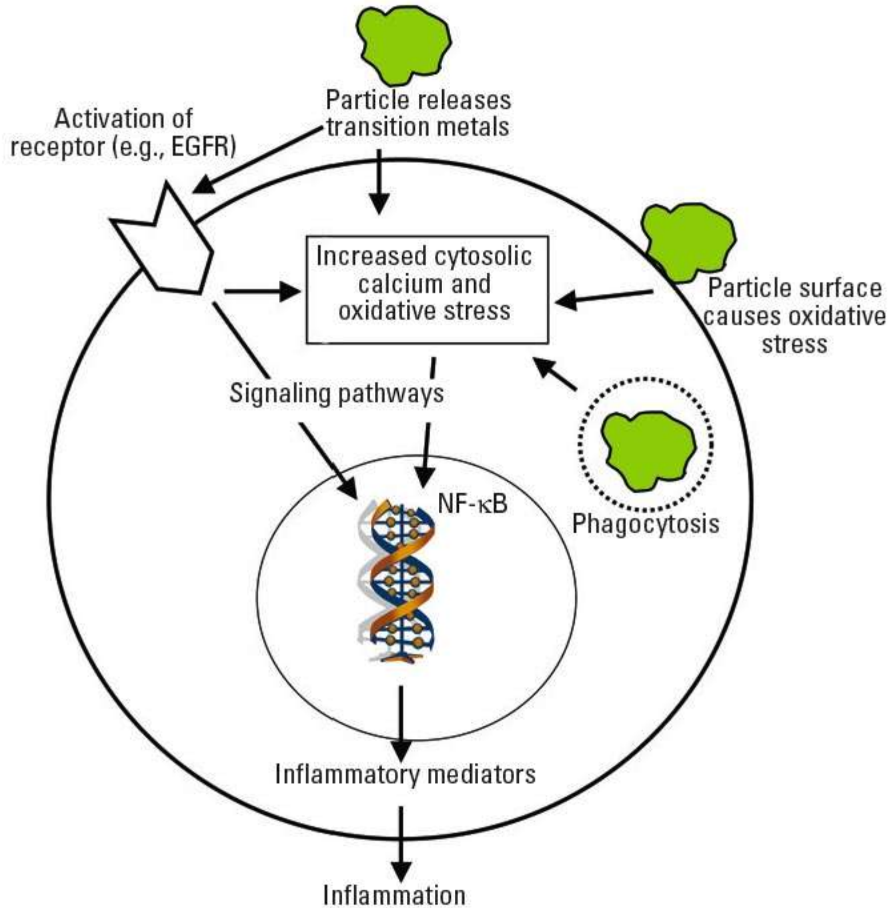
Toxicological studies have shown:

- NPs move along the olfactory nerves into the **brain**
- NPs move from the lung alveoli into the blood circulation and further into **liver**, **spleen** and **bone marrow**
- NPs pass the **blood-brain-barrier**
- NPs enter **cells**



Source: CMU

Effect of NPs on cells



Example

In- vitro studies:
Nanotubes in bacteria
Nanotubes in liver cells
C_{60}- Cluster in bacteria

In- vivo studies:
Nanotubes in the lung
Nanotubes in the brain
C_{60} in the brain (fish)
TiO_2 in the lung

Source: G. Oberdörster et al., EHP Juli 2005

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The R- word: to regulate or not?

„We recommend, that…
…factories and research laboratories treat manufactured nanoparticles as if they were hazardous…
…chemicals in the form of nanoparticles be treated as new substances…“

Royal Society and Royal Academy of Engineering, UK, 2004

„There‘s limited toxicity information. It‘s not sufficient for corporate risk assessment.“

Rob Aitken, Institute of Occupational Medicine, UK, 2005

Class 2B: bioactive nanotechnology

Biological molecules or NPs in nanomedicine could be used in a different context for military purposes, e.g. as „**ethnic weapons**“

Proposal:

- Deliberately damaging agents that are smaller than cells should be subject to the C-weapons convention
- Partially or entirey artificial microsystems that enter the body should be subject to the BT-weapons convention

(J. Altmann/M. Gubrud, Bochum Verification Project)

Class 3: disruptive nanotechnology

Artificial viruses (synthetic biology, z.B. Codon, C. Venter)

Autonomous nanosystems („Nanobots“ or „Nanoassembler“, not yet feasible

Worst-case-scenario „**Grey Goo**“: At a speed of 10 meters per second self-replicating nanoassemblers out of control would need **23 days** to spread from one point around the entire globe.
(Calculation by R. Freitas)

5 How could nanotechnology contribute to a sustainable development?

- **Energy**
  Nano solar cells, hydrogen storage for fuel cells
- **Better materials**
  light-weight, stronger, more durable
- **Drinking water**
  Filters with nanopores

For an „Open nanotechnology“

A. Open = transparent

Comprehensive datebases on nanotoxicology;
new Material Safety Data Sheets for nanomaterials;
Public discourse (e.g. like the „Nanojury UK“)

E. Open = Open Source

Limited patentability of new nanomaterials;

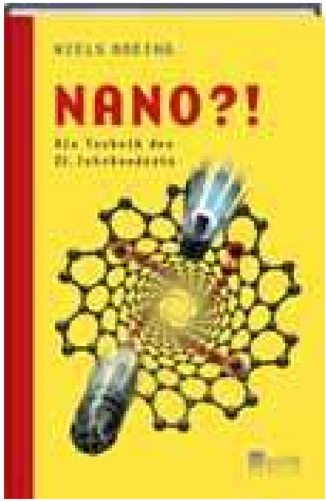
Initiating an Open Material Design Domain (to prevent a nano-divide analogous to the digital divide)

Links and texts on NT…

…on the web:

http://nano.bitfaction.com,

the site accompanying the book „Nano?! Die Technik des 21. Jahrhunderts“ (Rowohlt Berlin) - sorry, only in German.



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