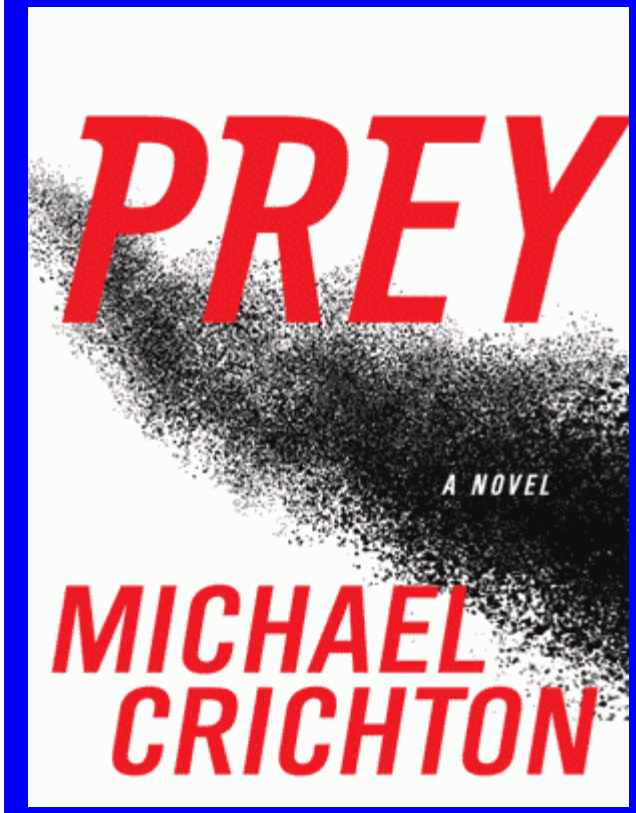
What's the buzz about nano?

Peter Grutter

Supported by
NSERC, FQRNT, CFI,
CIAR, CIHR, NanoQuebec,
IBM, GenomeQuebec,
James McGill Fellowship

Science Fiction:



Convergence:
GMO, AI & nano

7of 9 on Star Trek

Doc Ock (Spiderman)

Nano sells!

na

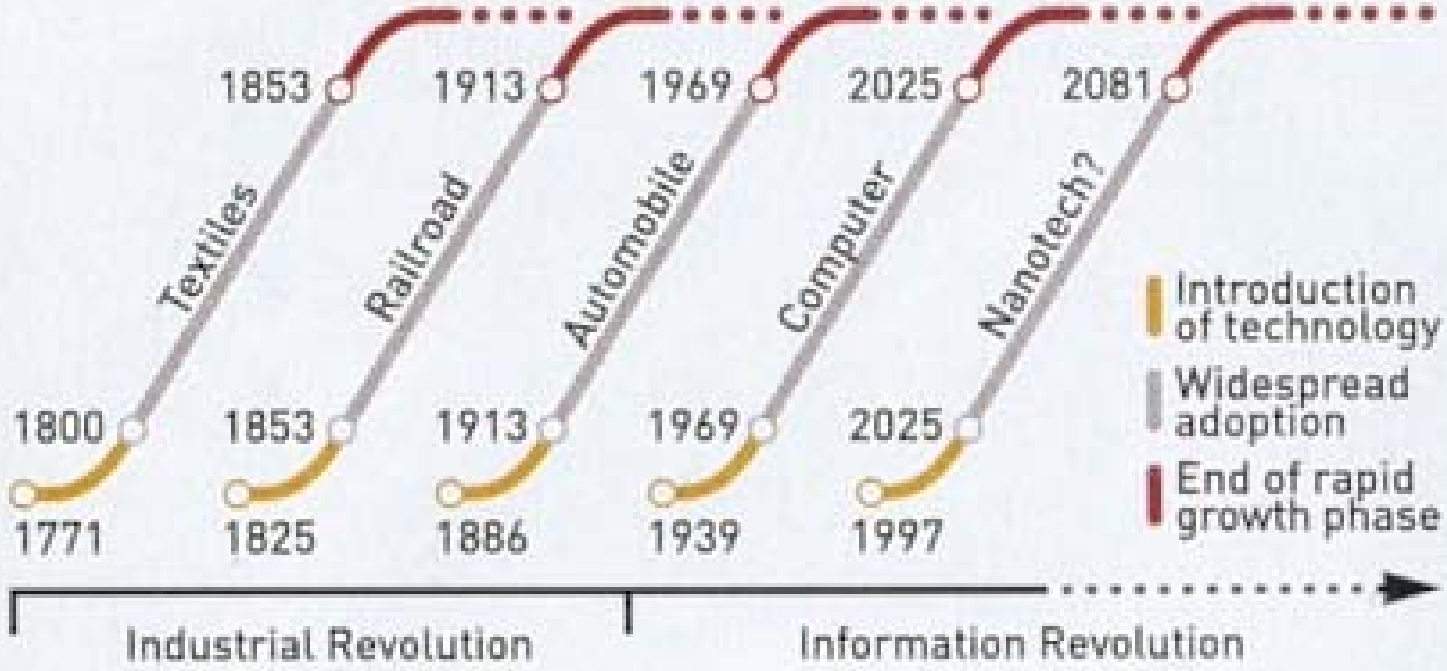
opants

k

Nanocube

REVOLUTIONARY FORCES

Basic advancements in science and technology come about twice a century and lead to massive wealth creation.



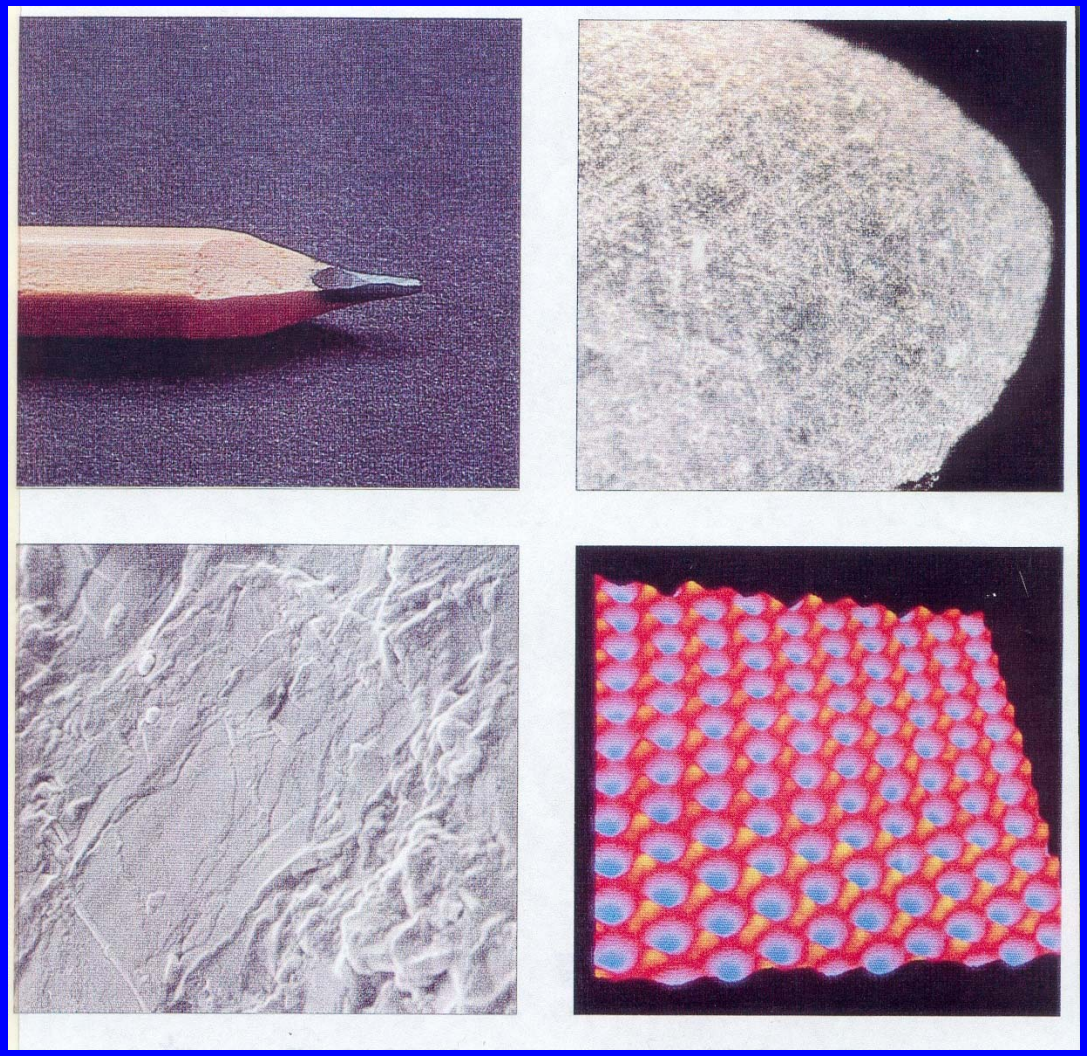
SOURCE: Norman Poire, Merrill Lynch

So – what is nano?

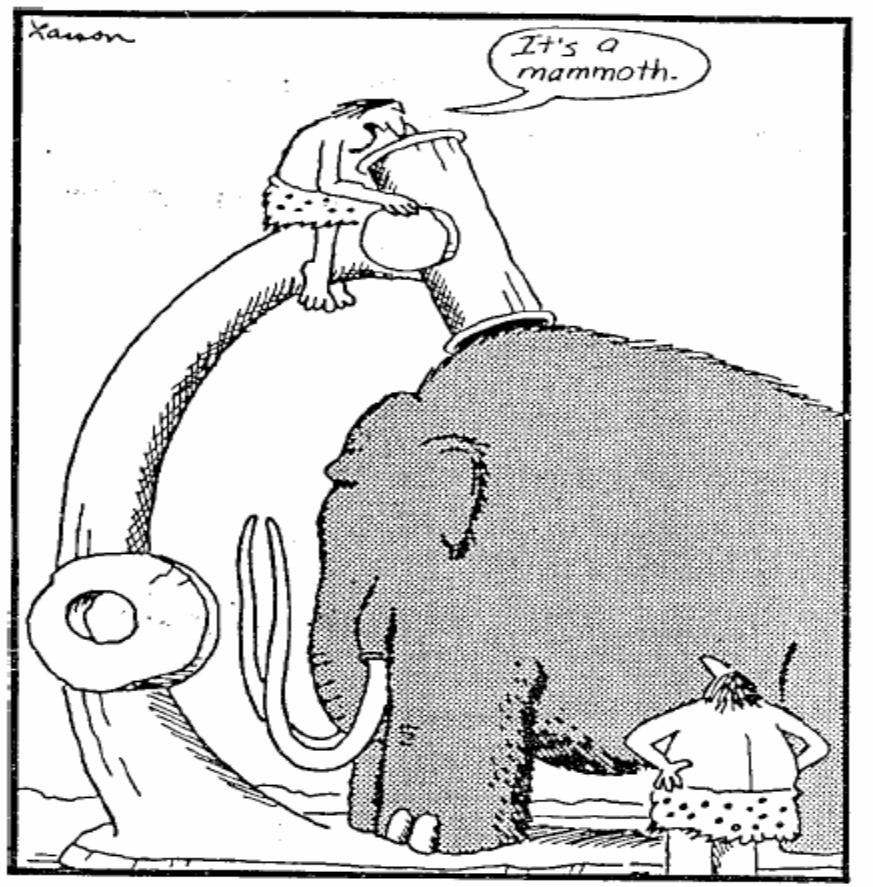
1. Making mundane, ordinary science and/or delusional scientific concepts sound like revolutionary scientific “innovations” and/or look feasible by putting the word “nano” somewhere in the text.
2. A flim-flam method of extracting grants from gullible and clueless scientific funding bodies based on minimal scientific substance and giving little in scientific return.

http://lachlan.bluehaze.com.au/nanoshite/

How big is a nanometer?



What enables Nanoscience and Nanotechnology?

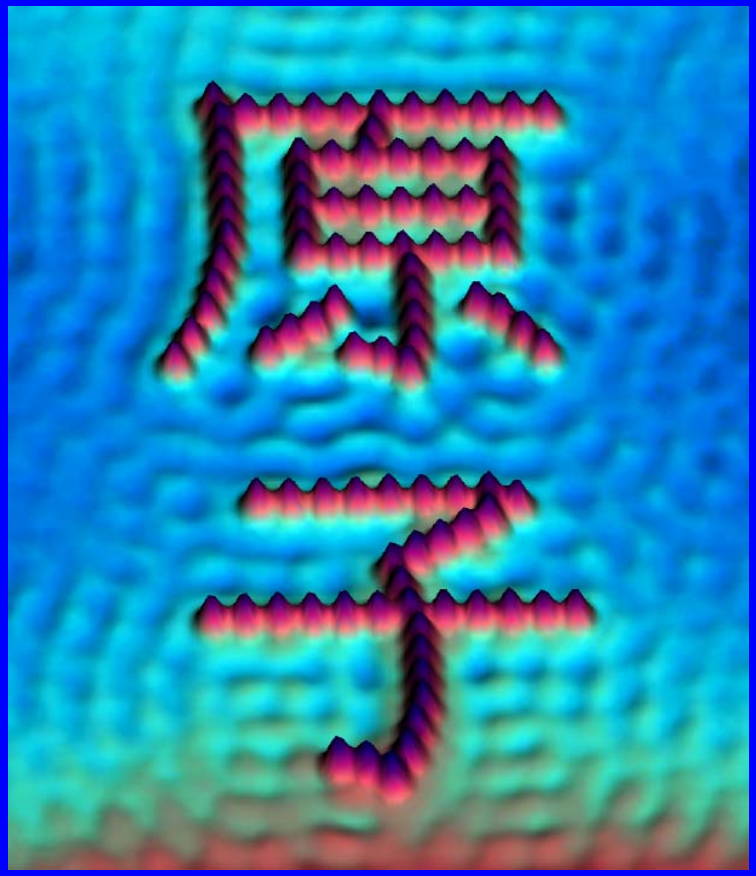


Early microscope

New tools!!!

- Drive discoveries
- Enable technology
- Are a high value added business opportunity

Storing information atom by atom



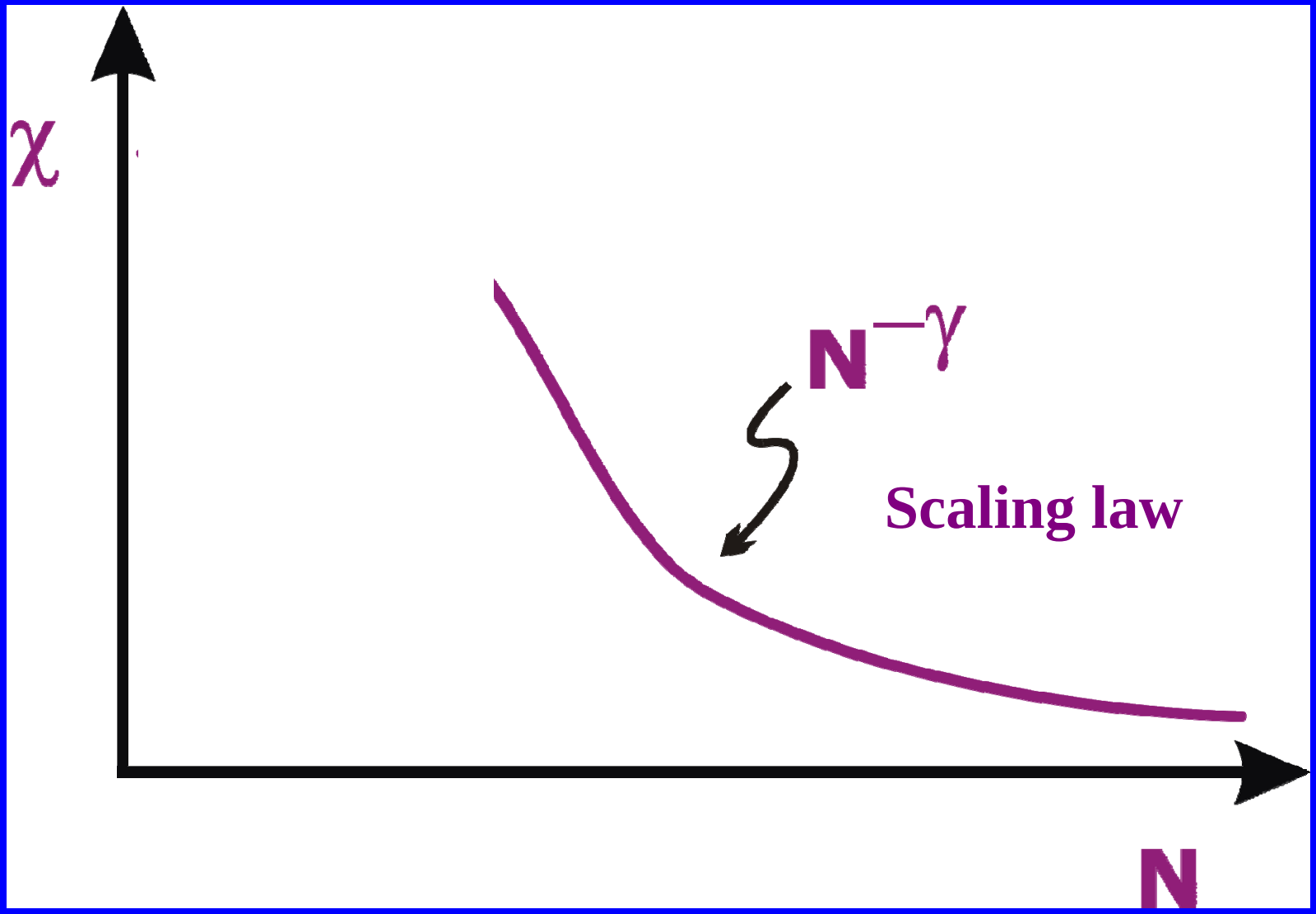
Ultra high density (Library of Congress on a pin head)

Ultra slow (needs life time of universe to write)

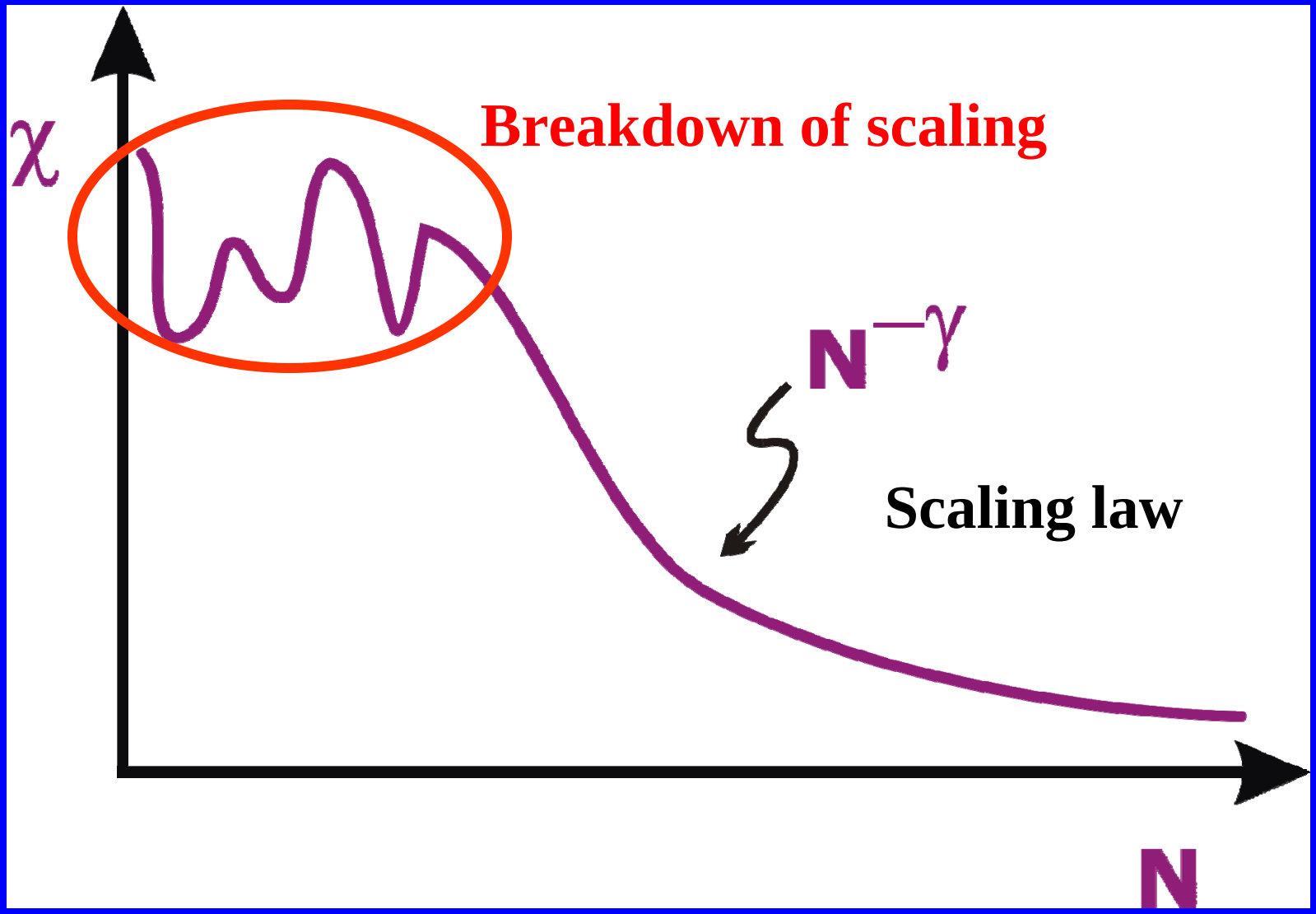
Huge footprint (UHV 4K STM)

D. Eigler, IBM Almaden

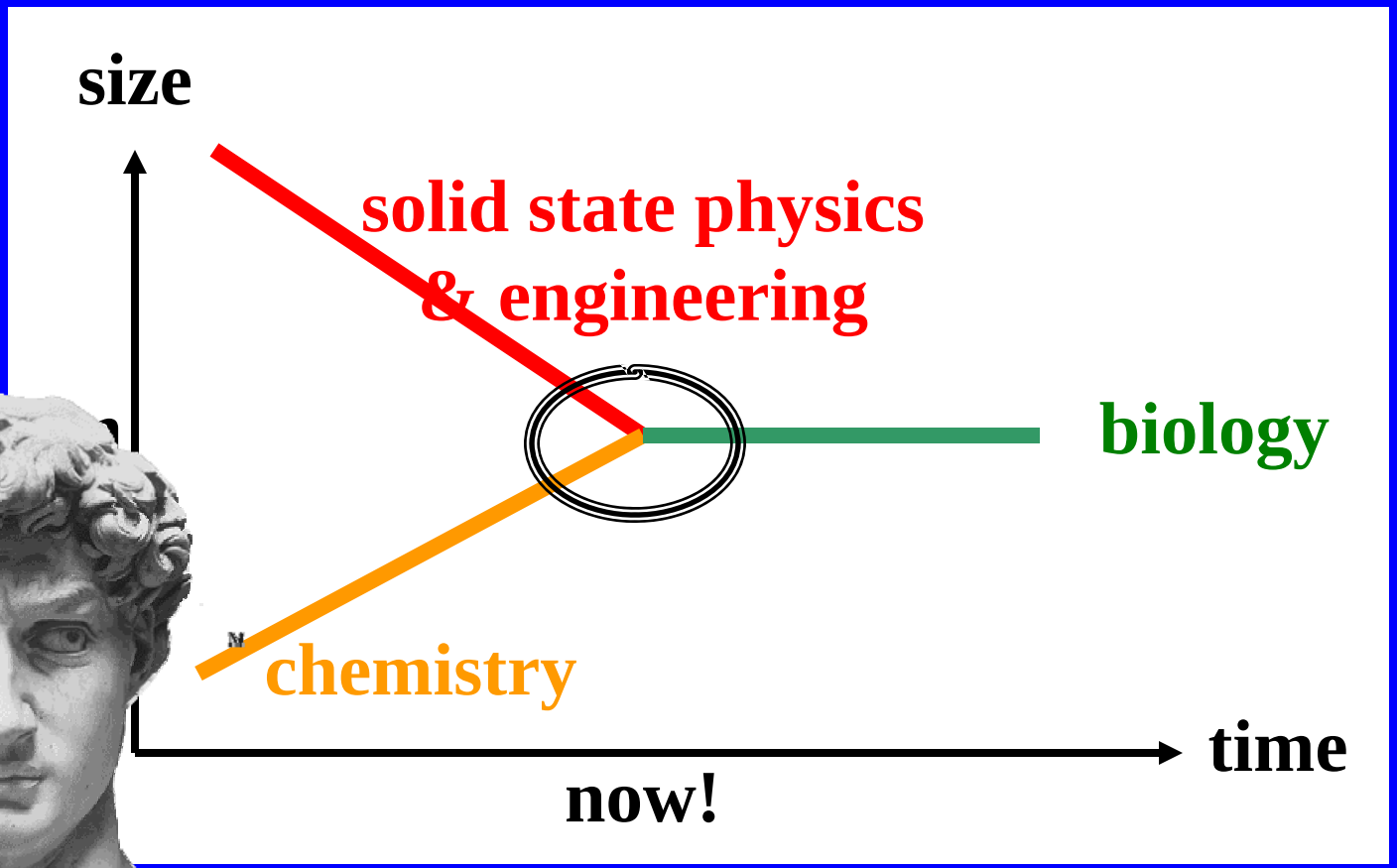
Small is different

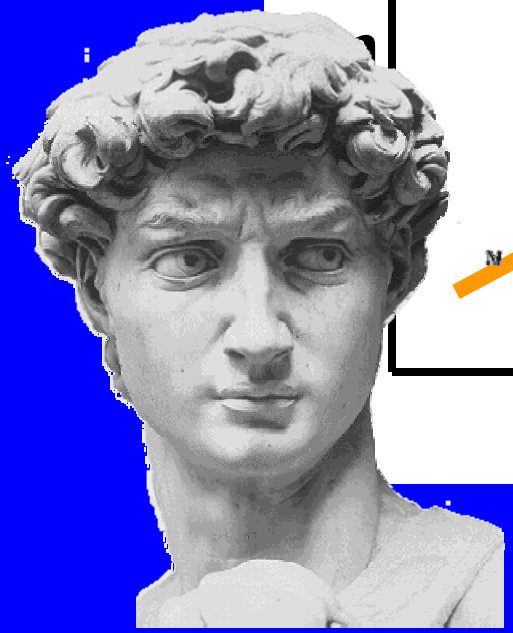


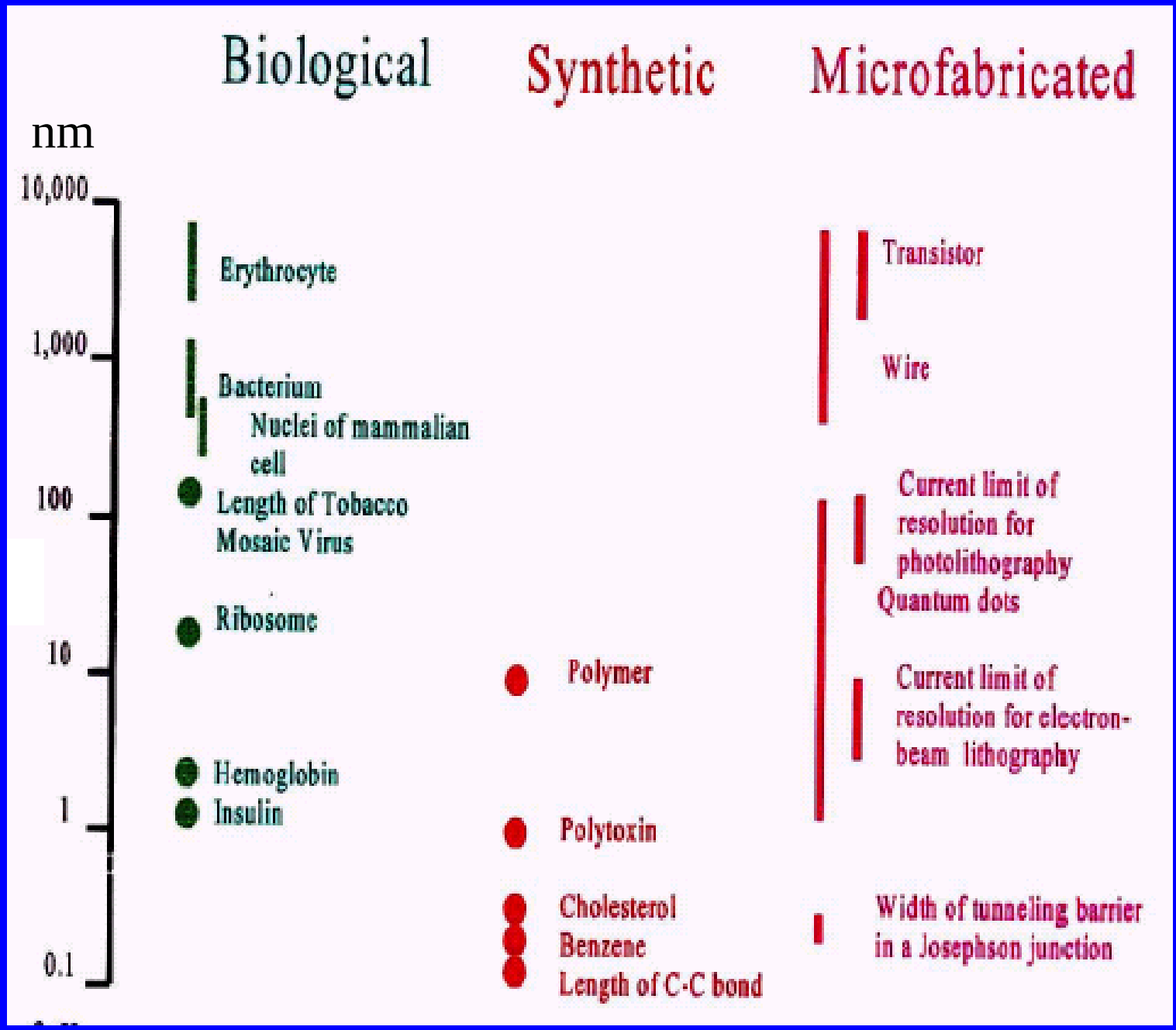
Small is different



Nano: Renaissance Science !

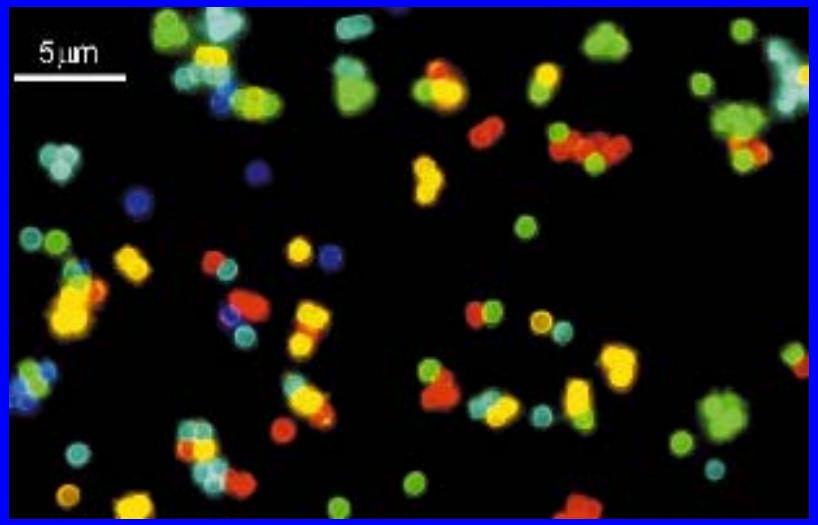





Biological
Synthetic
Microfabricated
nm
10,000
1,000
100
10
1
0.1
Erythrocyte
Bacterium
Nuclei of mammalian cell
Length of Tobacco Mosaic Virus
Ribosome
Hemoglobin
Insulin
Polymer
Polytoxin
Cholesterol
Benzene
Length of C-C bond
Transistor
Wire
Current limit of resolution for photolithography
Quantum dots
Current limit of resolution for electron-beam lithography
Width of tunneling barrier in a Josephson junction

“Labors of the Months” (Norwich, England, ca. 1480).
(The ruby color is probably due to embedded gold nanoparticles.)

Nano materials in labeling



Basis: size dependent emission color of ZnS capped CdSe nano particles

- High throughput multiplexed assays (‘nano bar code’)
- Optical tracking on a cellular level with tagged CdSe quantum dots: which gene is active?

The Benefits of Nanotech: Nanoshell Cancer Therapy

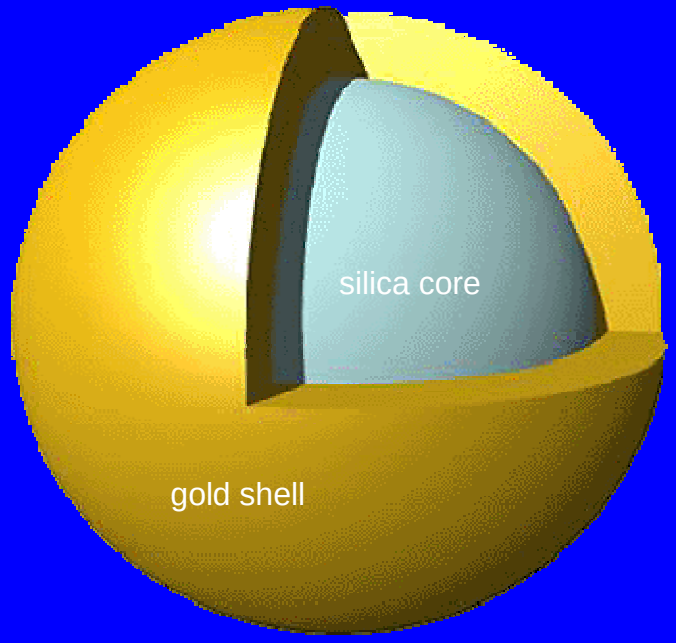
Gold Nanoshells

Are biocompatible

Small enough to pass through circulatory system

Easily attached to antibodies for specific cellular targeting

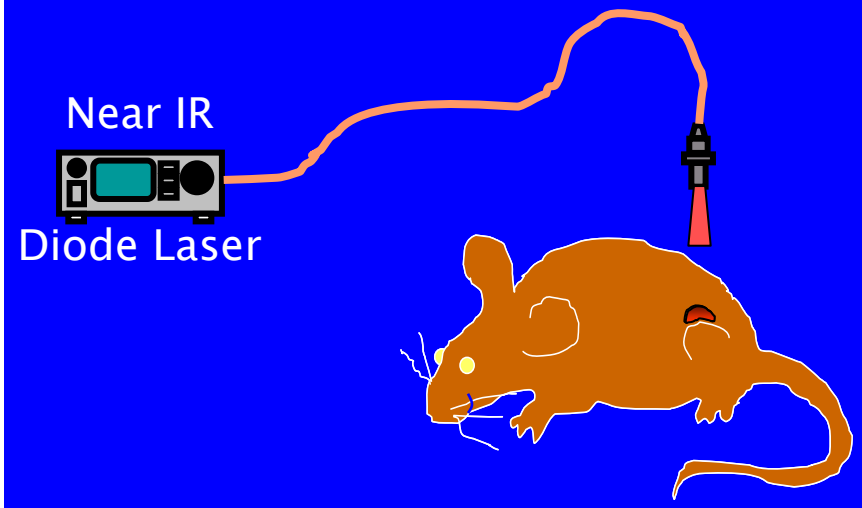
Are strong absorbers of light in the near infrared, where light penetrates up to 7 cm into the human body



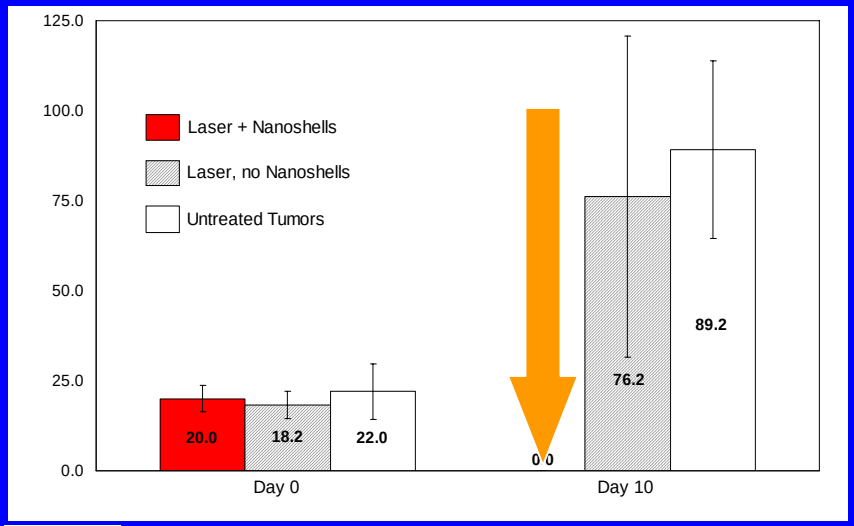
10-300 nm diameter

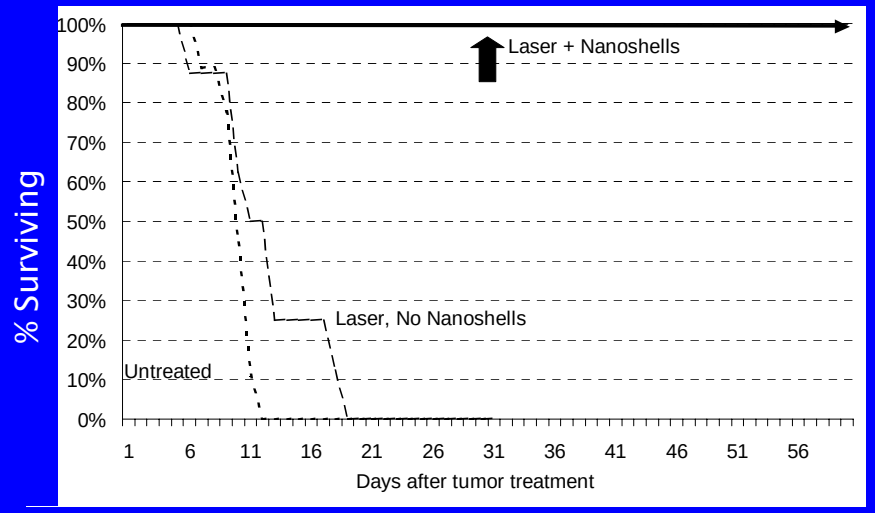
Courtesy of Prof. Naomi Halas, Rice University

The Benefits of Nanotech: Nanoshell Cancer Therapy



- BALB/c mice innoculated with CT26.wt mouse colon carcinoma cells
- Systemically delivered pegylated nanoshells via tail vein injection
- 6 hrs post injection, tumors irradiated through skin with 4 W/cm^2 810 nm diode laser for 3 min
- Tumor surface temp. monitored
- Tumor size monitored for 2 months



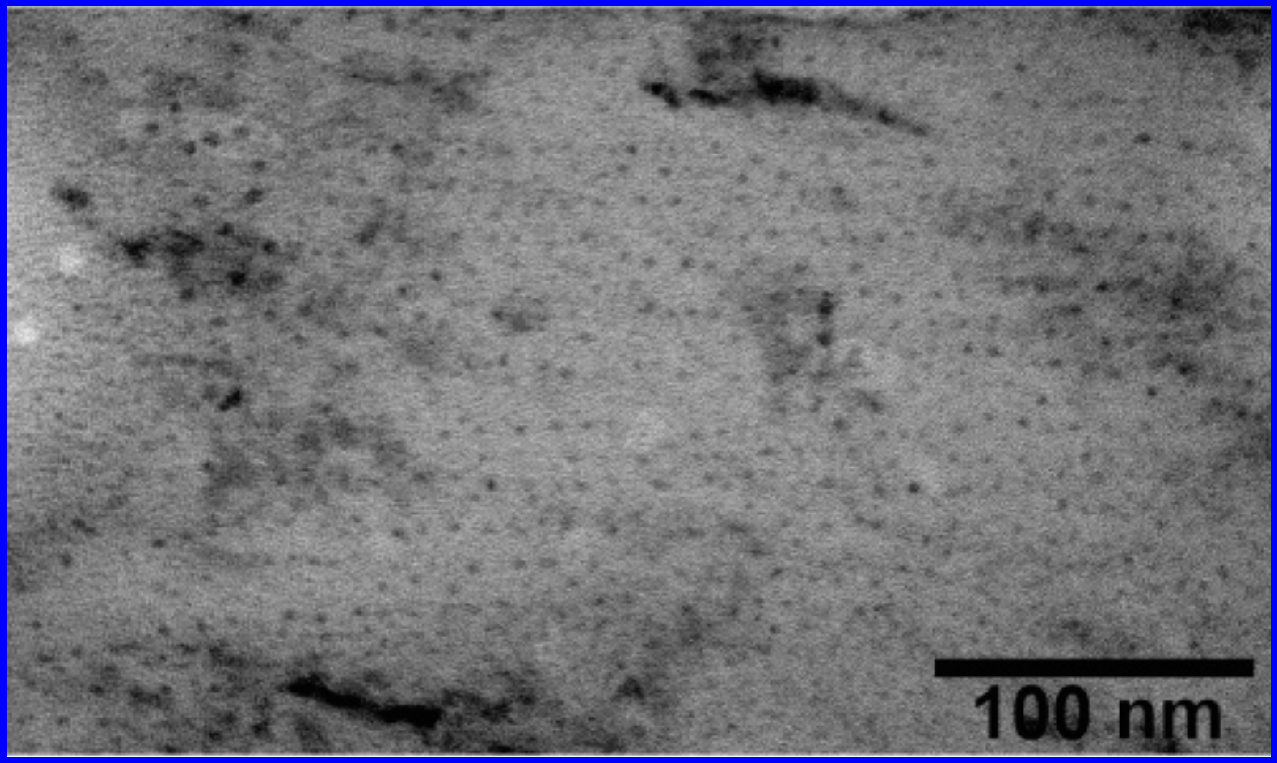


Courtesy of Prof. Naomi Halas, Rice University

The art of dying grey hair – 4000 years ago

Mixture of PbO and $Ca(OH)_2$ diluted in water to form a paste

Reaction with amino acids in hair leads to the formation of PbS crystals

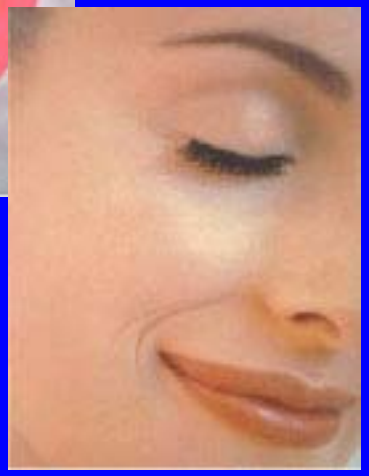


Centre de recherche et de restauration des Musées de France

(NanoLetters 6, 2215 (2006))

Nanotechnology you are using

Nanoparticulates in sunscreens and cosmetics



Nanosomes

(L'Oréal)

Cosmetics have become a Nanometer-Scale Technology

New materials: non-permeable, self-cleaning, anti-septic,...

Air-D-Fense (InMat, New Jersey):

nanoclay/butyl thin film

- 3000 fold decreased permeability

Lotus leaf (artificial):

nm sized hydrophobic wax

- size: water rolls (not slides) -> cleans
- sol-gel based technique -> on market

Self-cleaning plastic, textiles:

- TiO_2 nanoparticles in polymer matrix
- Textiles with 'Stain Defender'

Ceramic Coatings: (Inframat)

No barnacles on ship hulls: reduced drag

Nano and Water

UN (2002): 1.1 billion without access to safe water
2.6 billion without adequate sanitation
Results in death of 4500 children per day

- **Filtration (membranes): remove NH_3 , concentrate it and use as fertilizer**
- **Oxidation with nano TiO_2, Ag^+ functionalized zeolite ceramics to replace UV and heat treatment**
- **Desalination and arsenic removal (ZnO)**
- **Advanced nano sensors to detect pathogens**

See www.meridian.org for more info

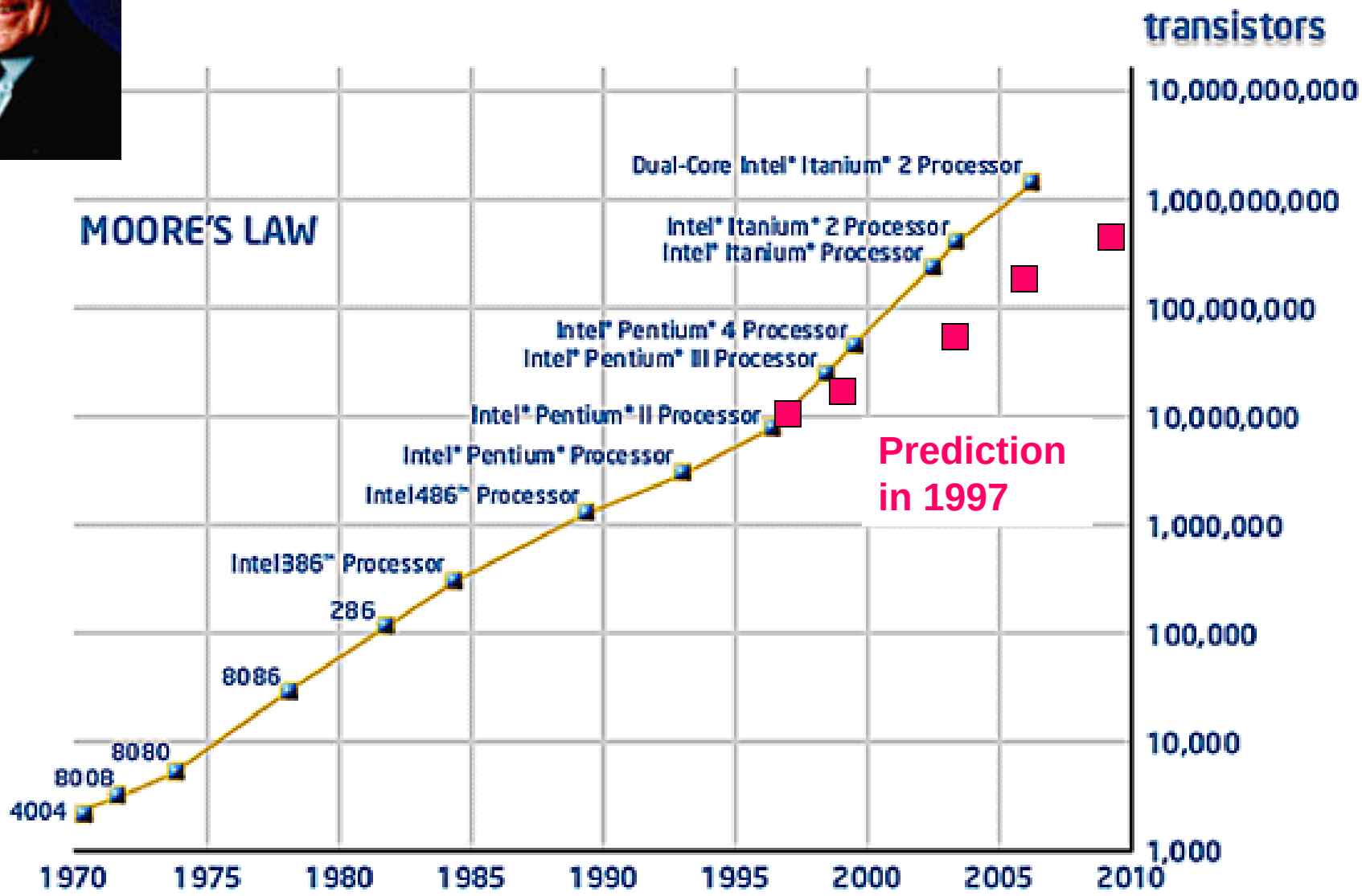
This is what do I do at conferences

SPM applied to nanoelectronics: the Grutter Research Group

• Magnetic reversal	MFM with in-situ field
• Molecular electronics	UHV AFM/STM/FIM, AFM/STM/SEM
• Quantum dots	4K, 8T and 50mK, 16T AFM
• Interfacing to living neurons	AFM + patch clamp + single photon fluorescence + TIRFM
• Biochemical sensors	Cantilevers and electrochemical cells

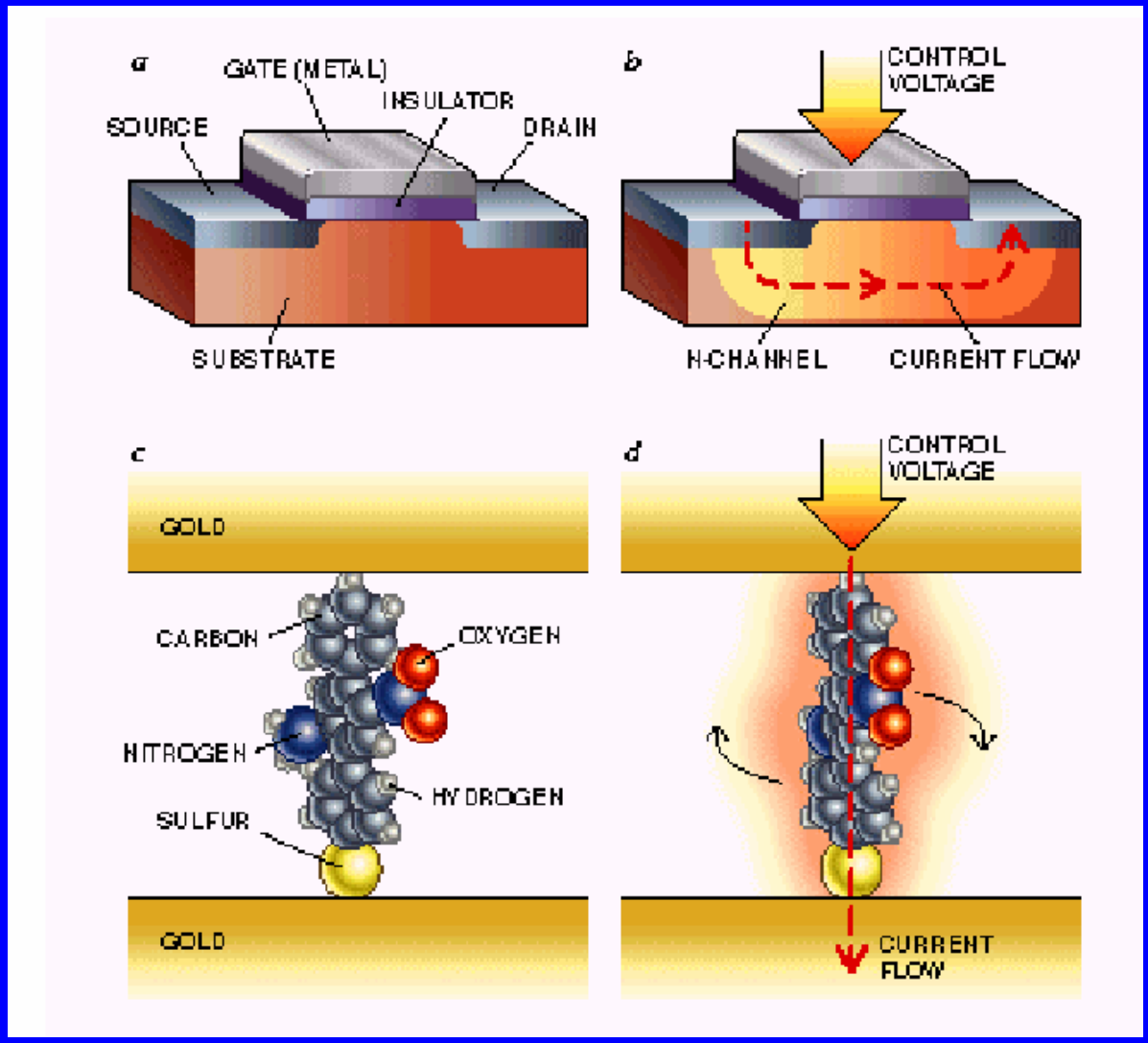
www.physics.mcgill.ca/~peter

Moore's Law

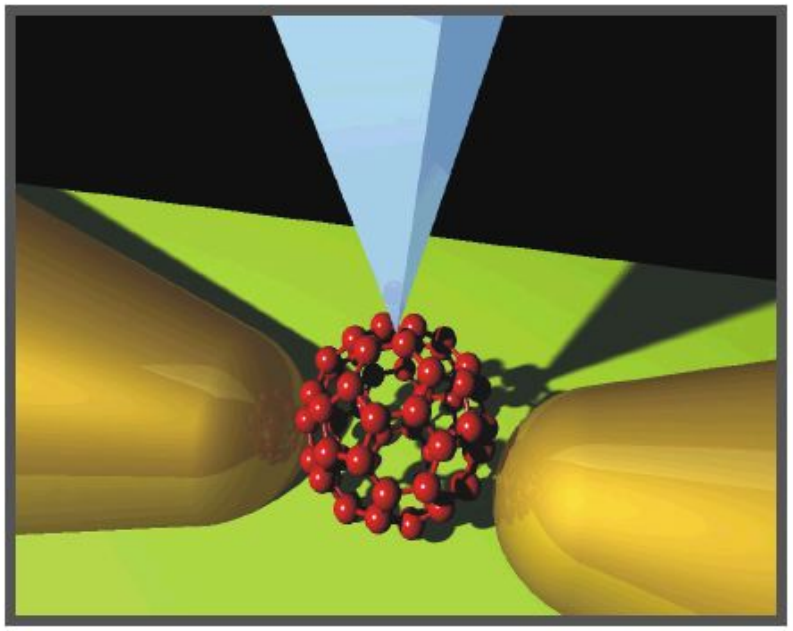


Source: Intel Corporation

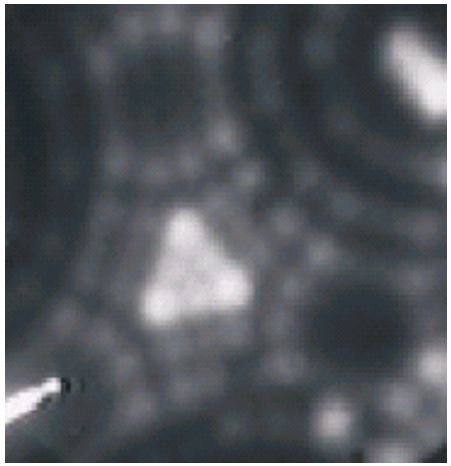
A molecular transistor



Beware of
PowerPoint Science
or
Cartoon Engineering !!!



FIM of W(111) tip



Imaging at 5.0 kV

A. Schirmeisen,

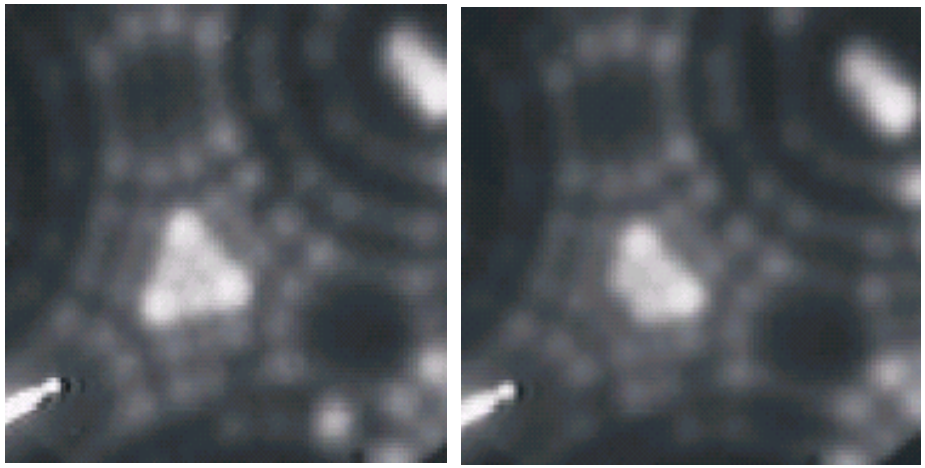
G. Cross,

A. Stalder,

U. Durig

P. Grutter

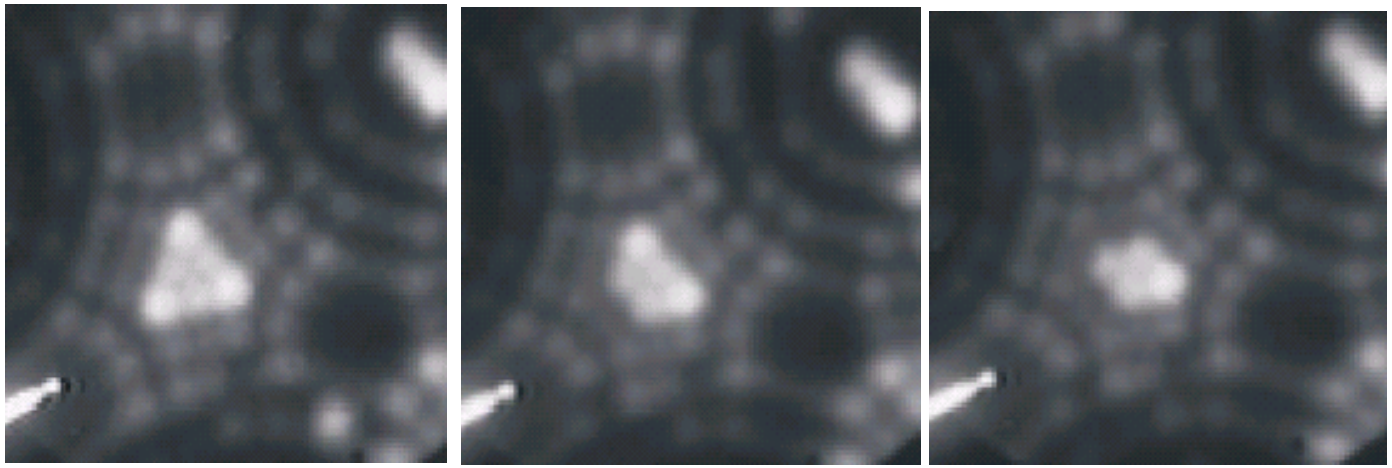
FIM of W(111) tip



Imaging at 5.0 kV

Manipulating at 6.0 kV

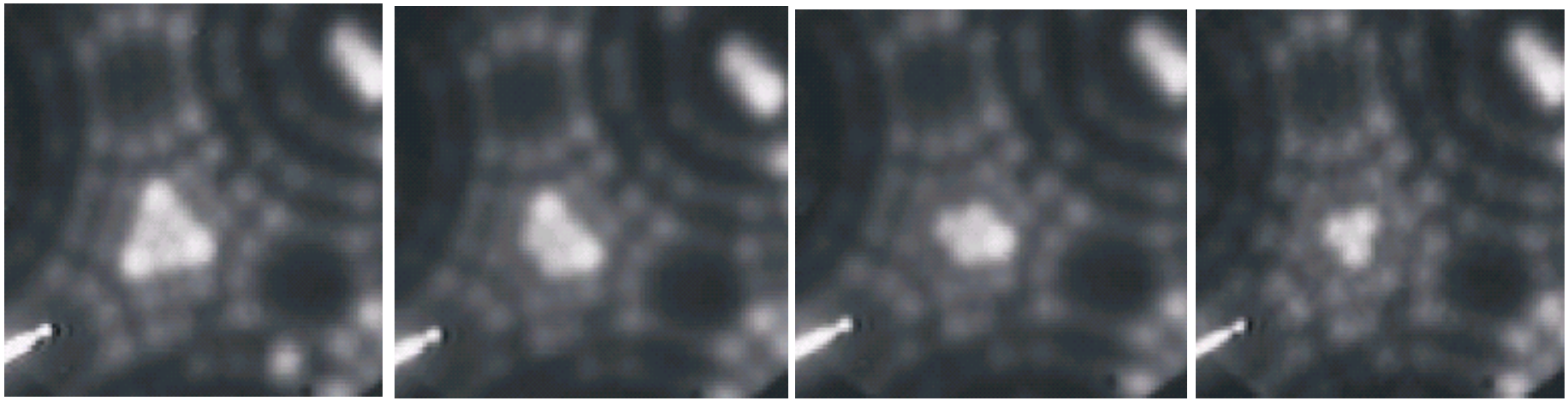
FIM of W(111) tip



Imaging at 5.0 kV

Manipulating at 6.0 kV

FIM of W(111) tip



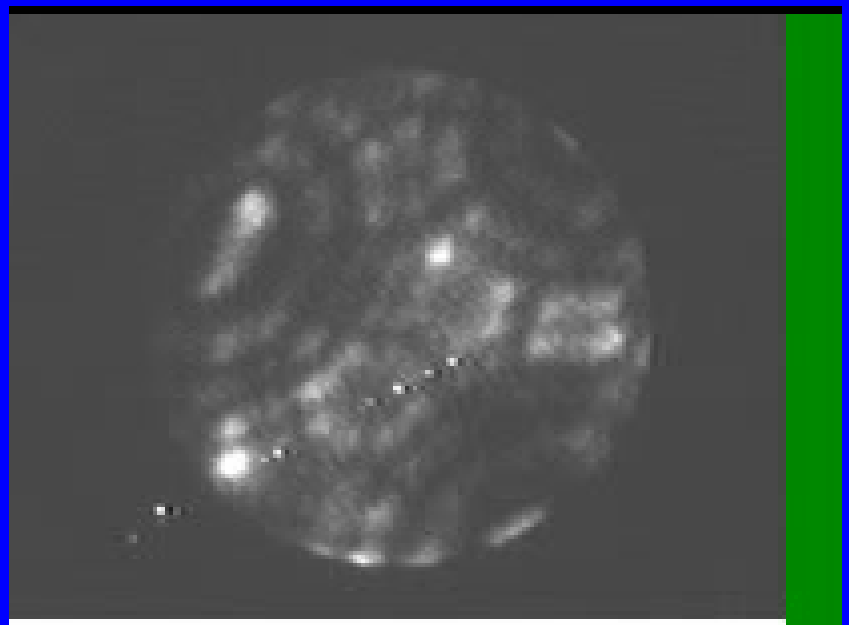
Imaging at 5.0 kV

Manipulating at 6.0 kV

Single atom on W(111) tip

Imaged at 2.1 KV

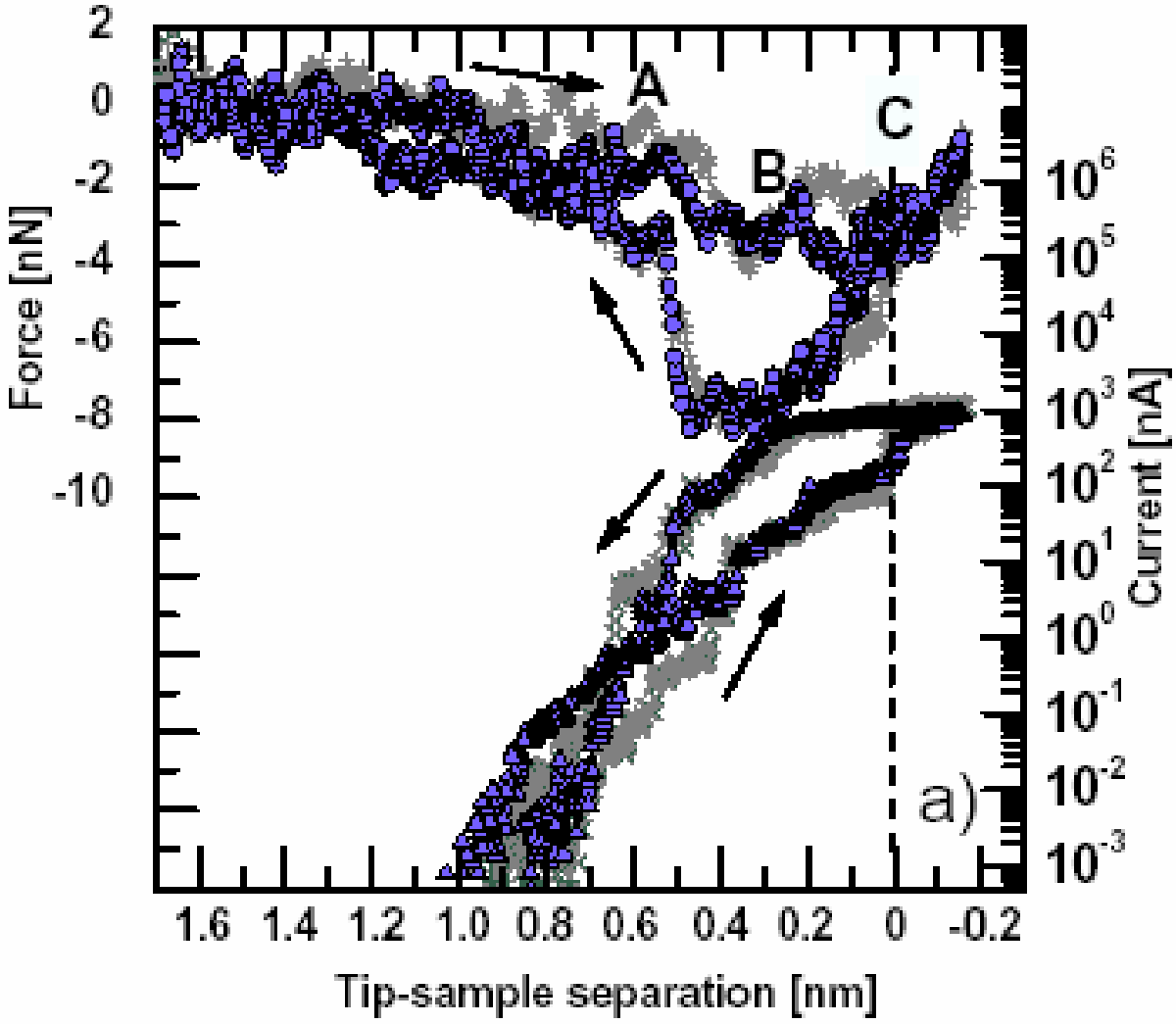
Machining a needle atom by atom



Anne-Sophie Lucier

Grutter Group,
McGill

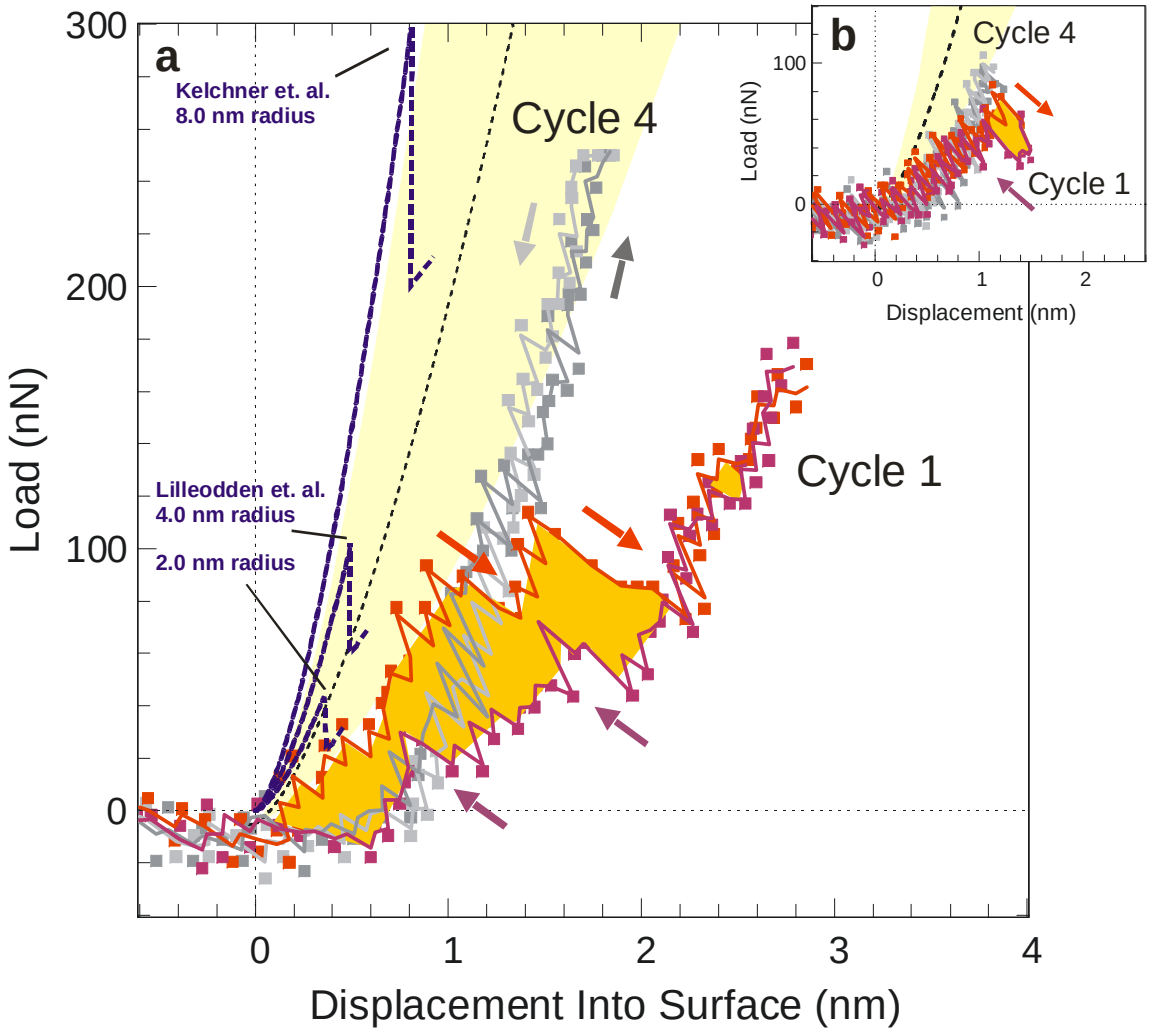
Force and Current vs. Distance



Cross et al, Phys. Rev. Lett. **80**, 4685 (1998)

Sun et al, Phys. Rev. B, **71**, 193407 (2005)

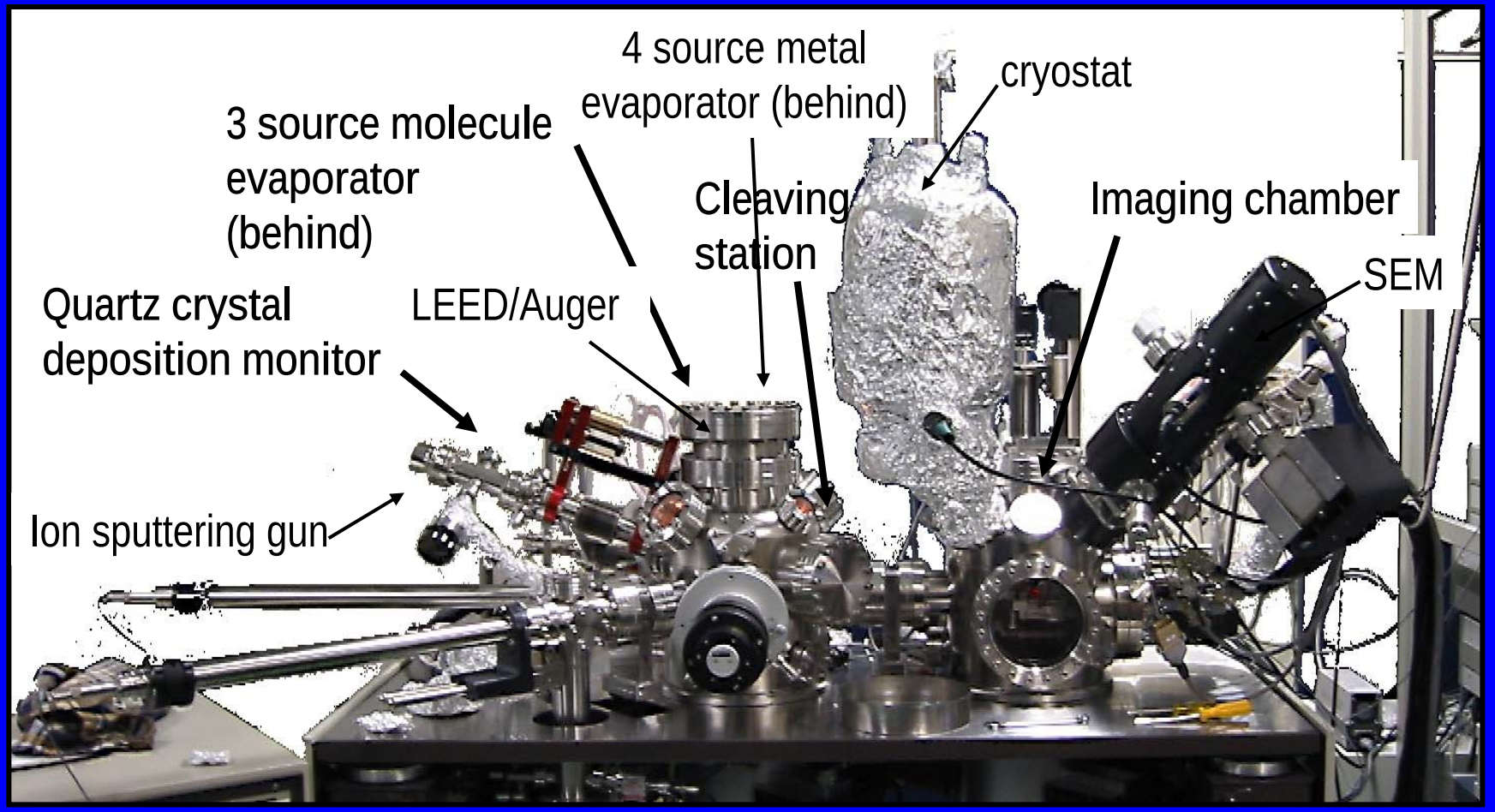
Indentation vs. load and cycle



Cross, Schirmeisen, Grutter and Durig, Nature Materials **5,** 370 (2006)

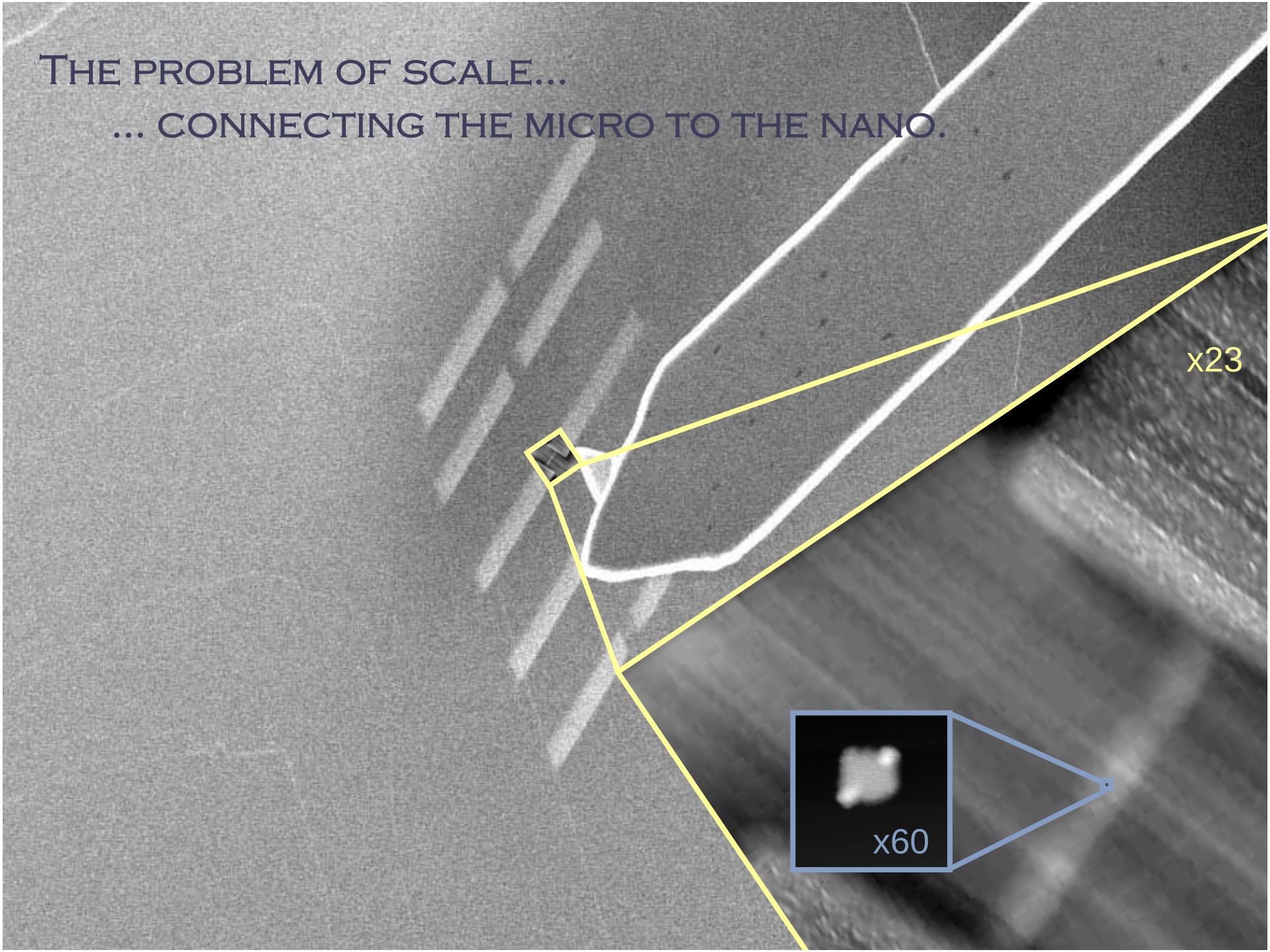
Experimental set-up

JEOL-JSPM 4500a with NanoSurf PLL
(UHV AFM/STM/SEM, 30-800K)

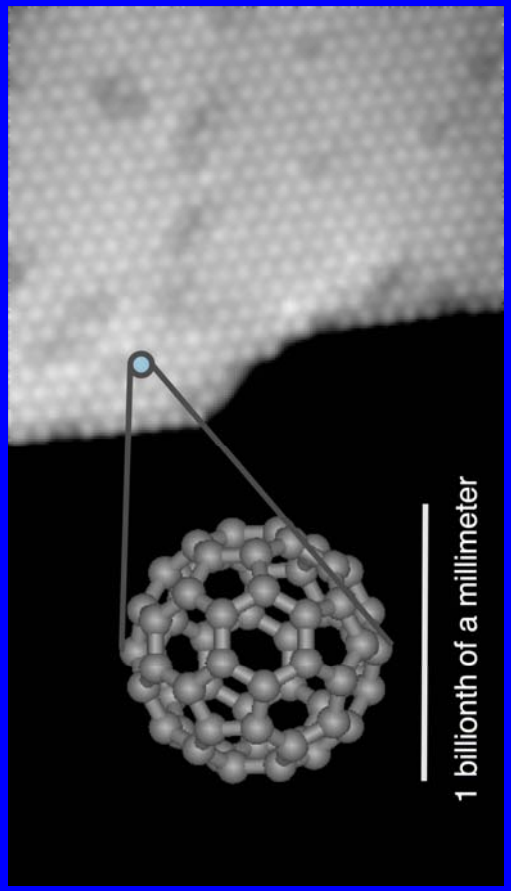


The problem of scale...

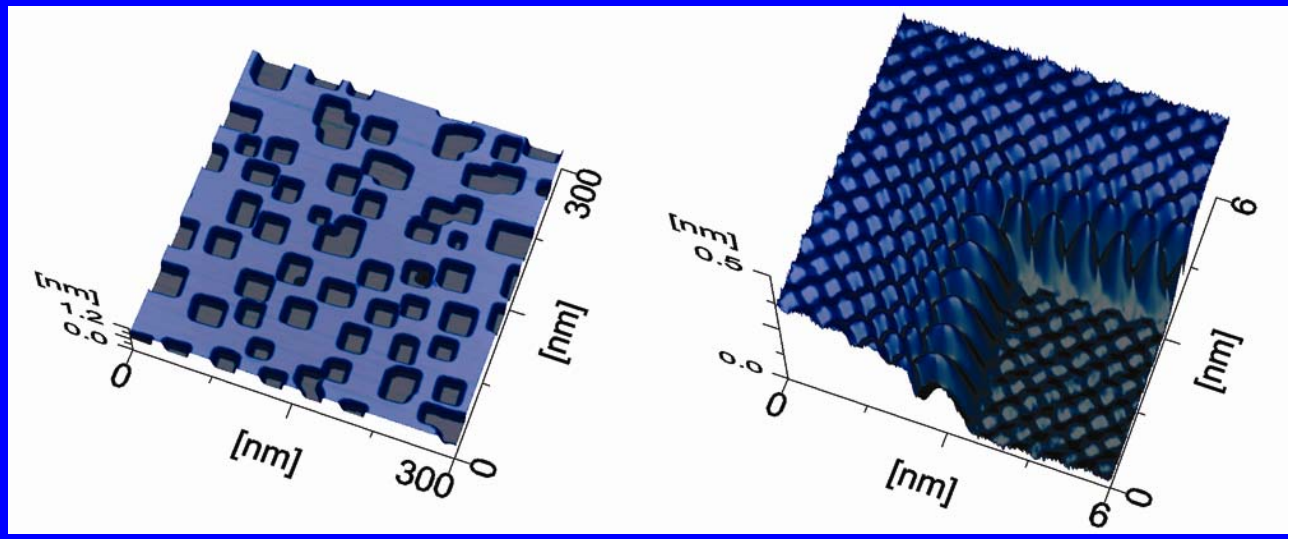
... connecting the micro to the nano.

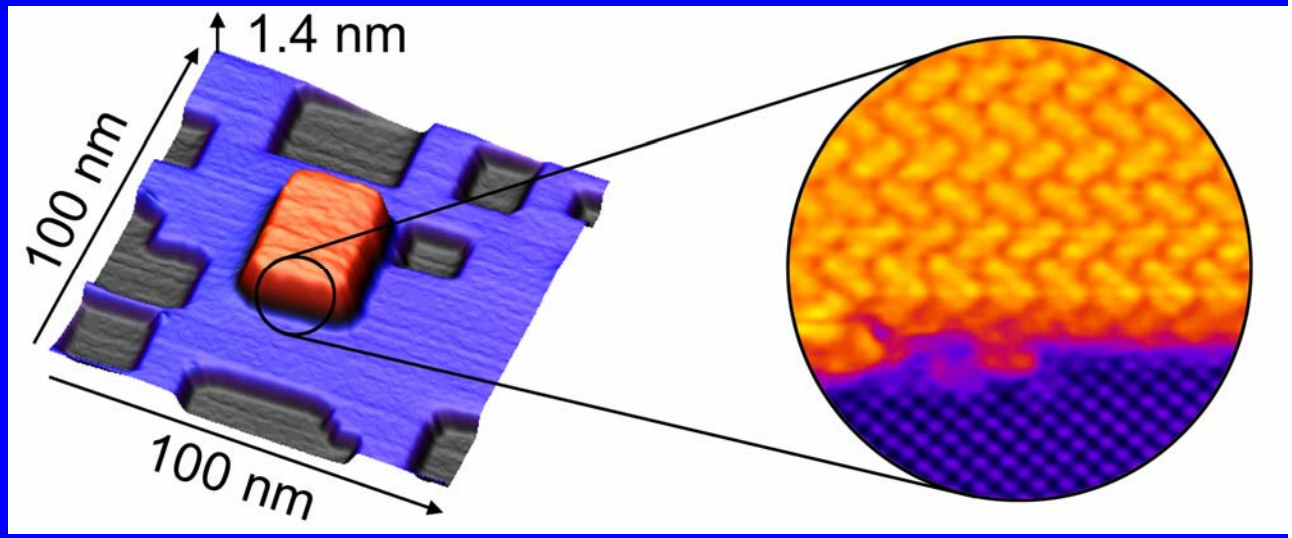


AFM - in imaging mode…



Burke et al,
PRL **94**, 096102 (2005)



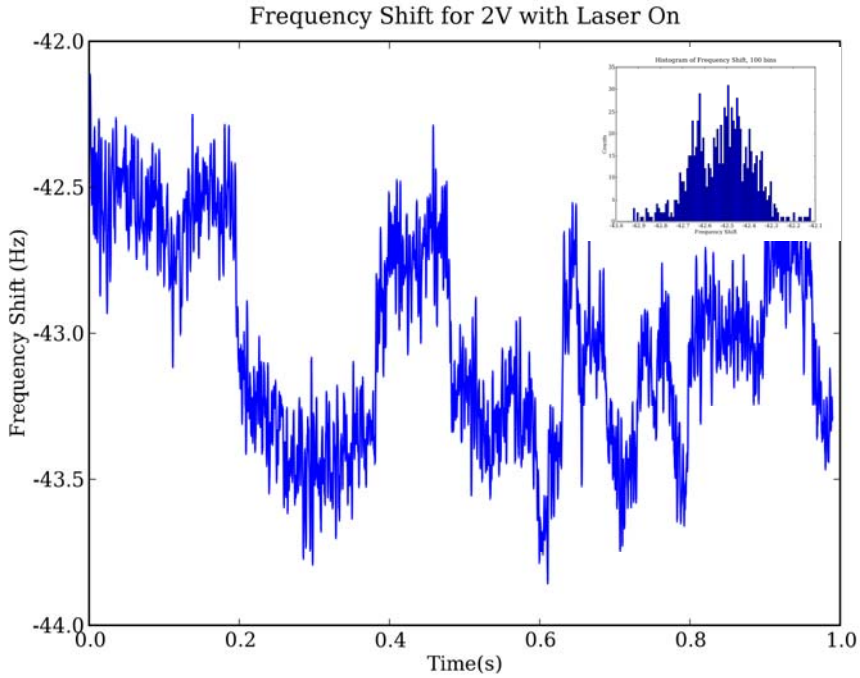


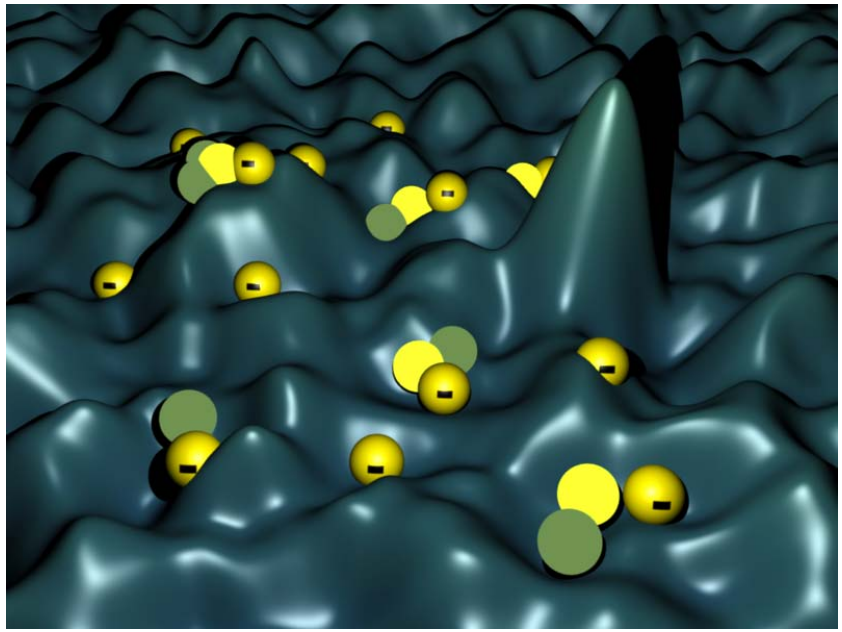
J. Mativetsky, S. Burke, S. Fostner, R. Hoffmann, P. Grutter

Origin of noise:

Optical excitation of charges screening ionized dopants in weak traps (2 or few level systems)

Sqrt T dependence of noise amplitude?

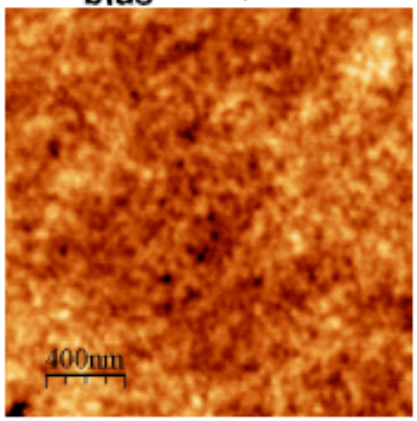




McGill

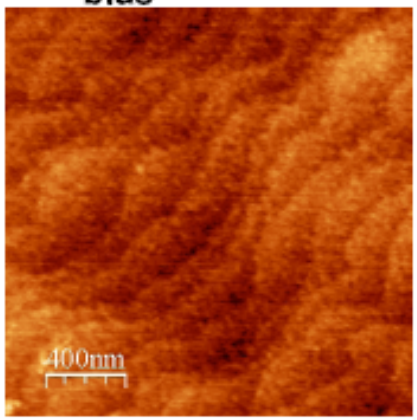
Contact Potential and Imaging as f(V)

$V_{bias} = +1.0V$

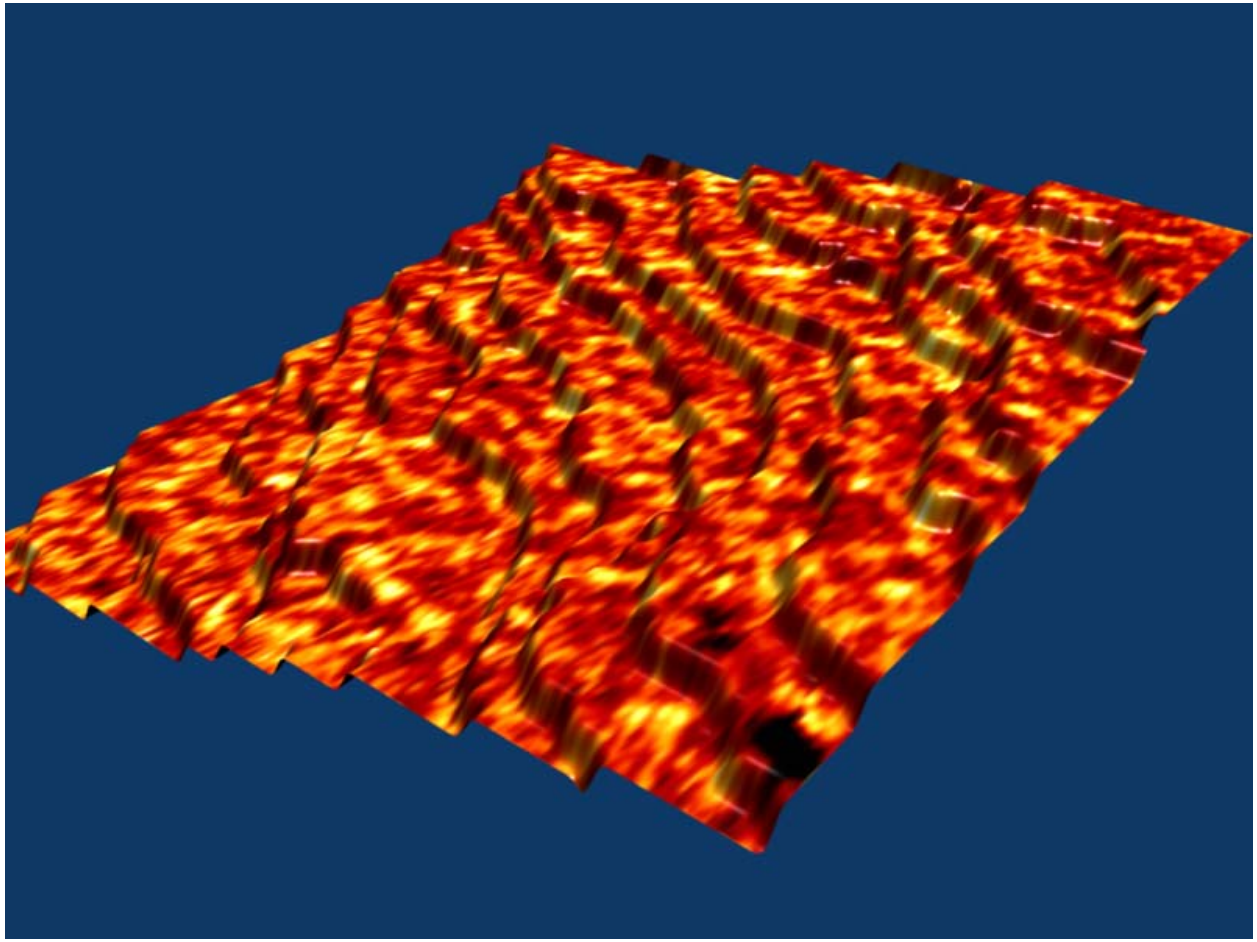


—

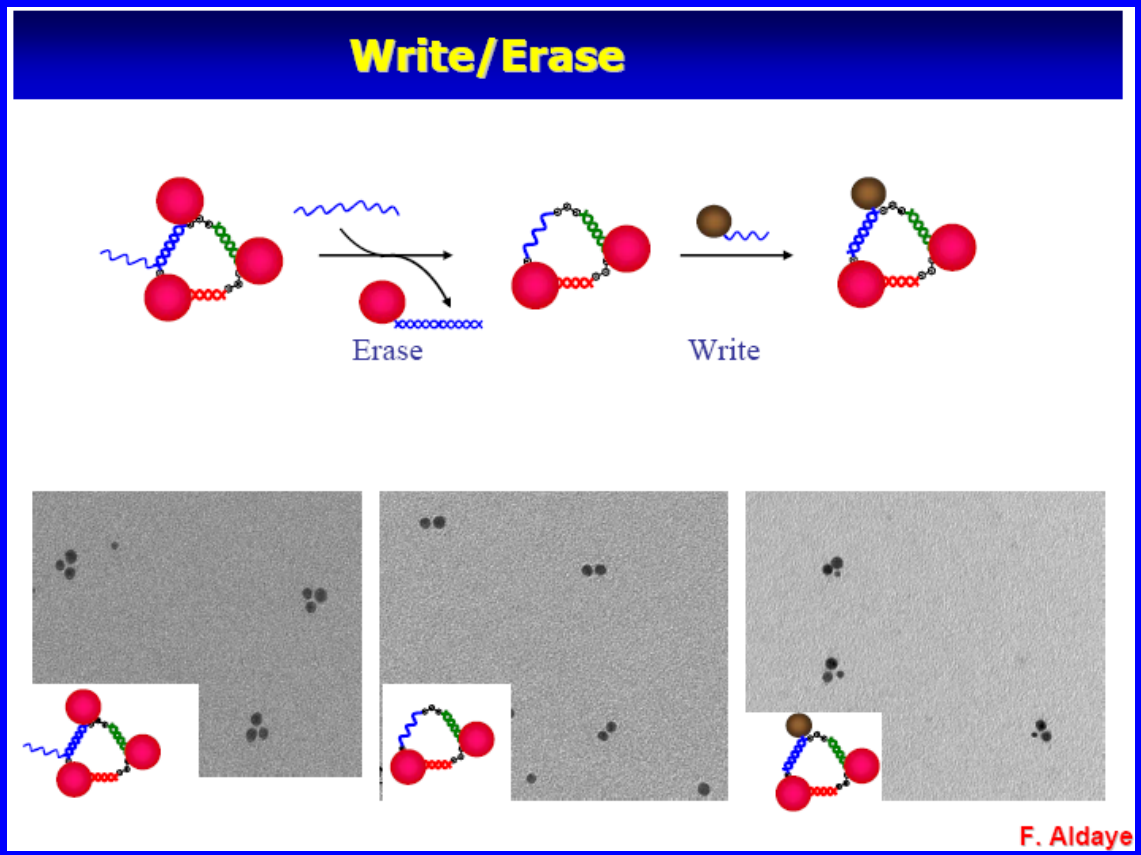
$V_{bias} = -0.6V$



InP, 77K

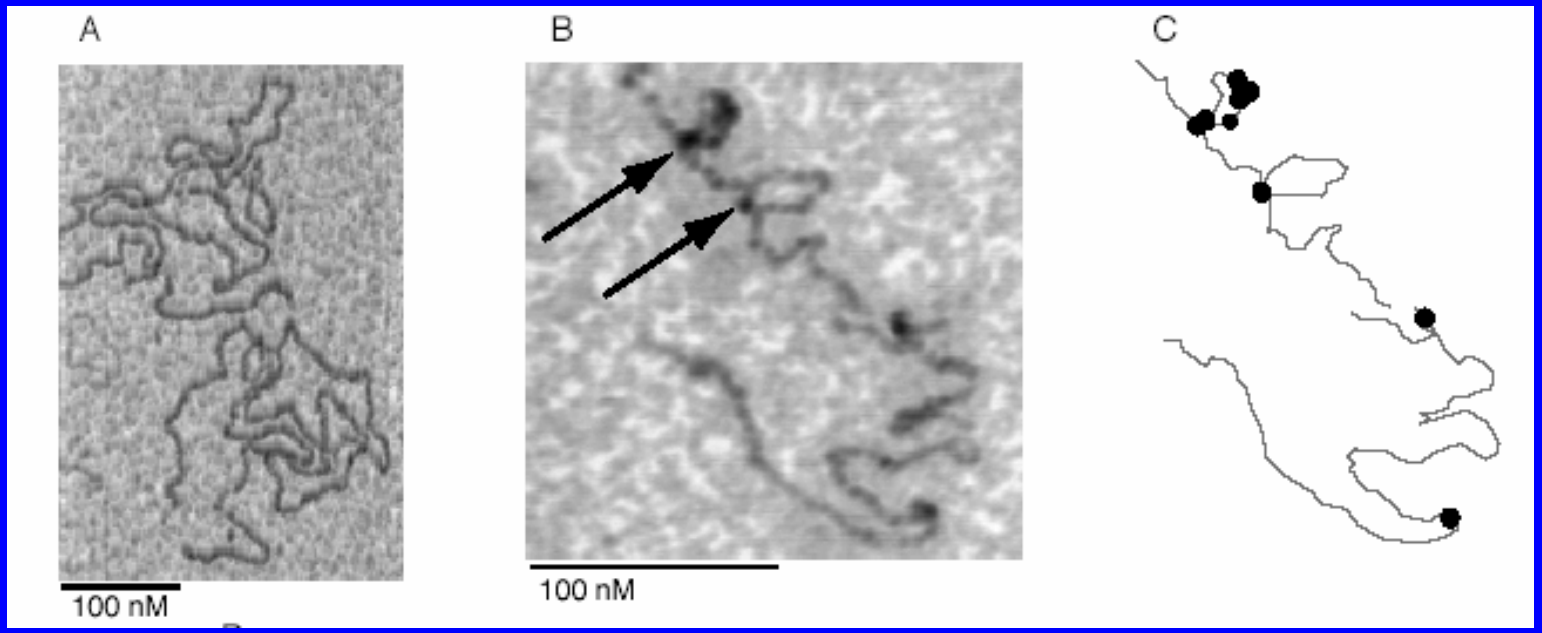


Structured assembly of 5 nm Au crystals with DNA

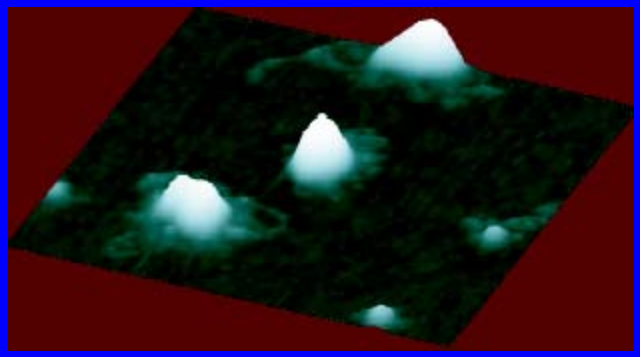


Faisal Aldaye and Hanadi Sleiman, McGill University

Understanding compactification of DNA

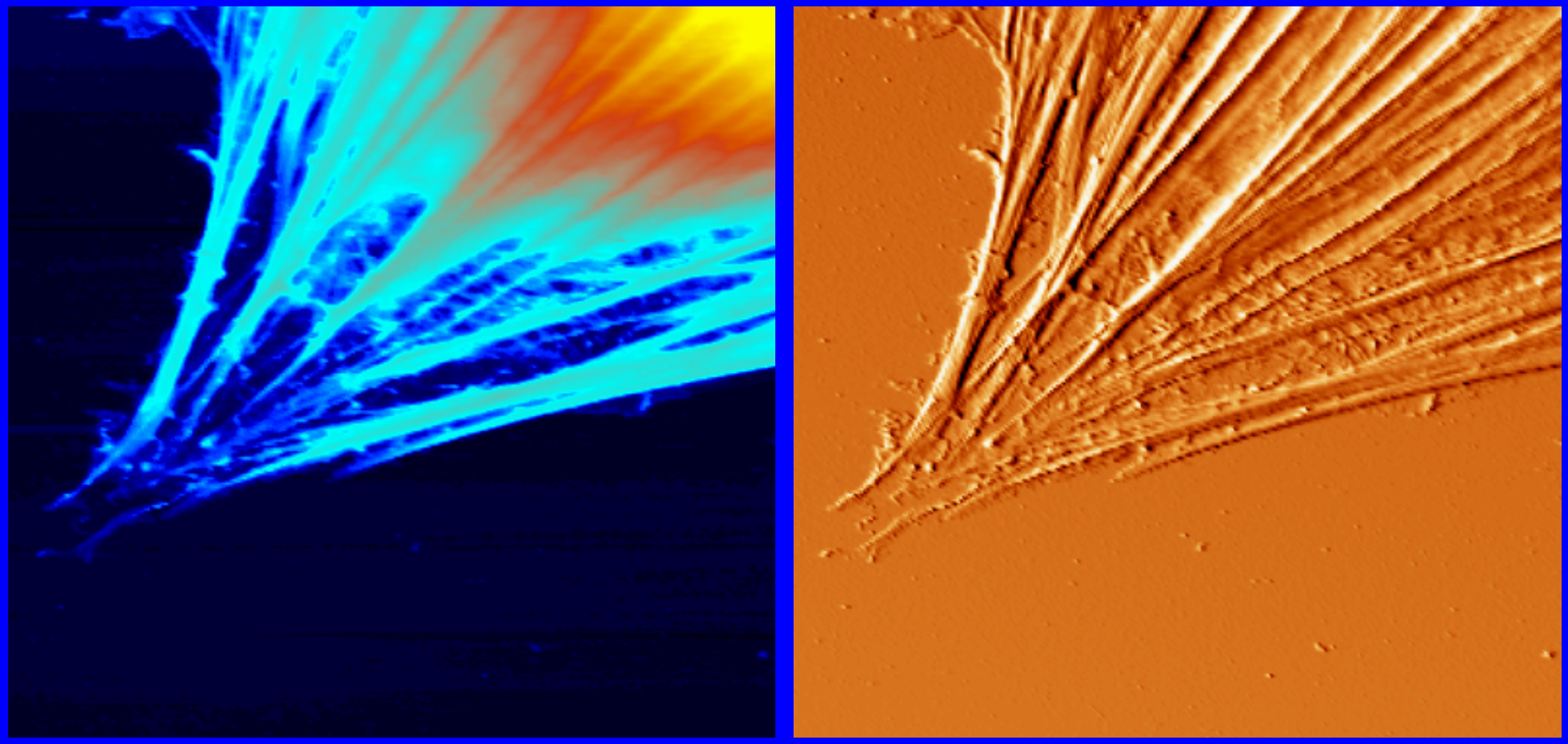


B. A. Kaufman, N. Durisic et al
(Shoubridge and Grutter groups,
MNI and Physics, McGill)



Live Cell Imaging:

- Smooth muscle cell from rat trachea.
- The contractile dynamics are relevant in the study of asthma.



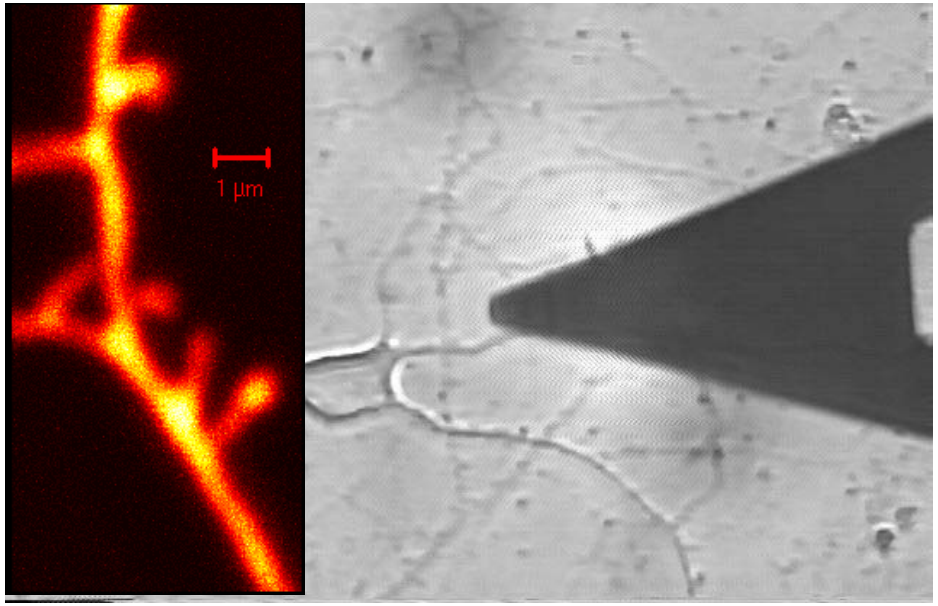
Time-lapse sequence after contraction stimulation (~20min/frame).
Images are 50x50 μm. B. Smith, B. Tolosko, J. Martin, P. Grutter

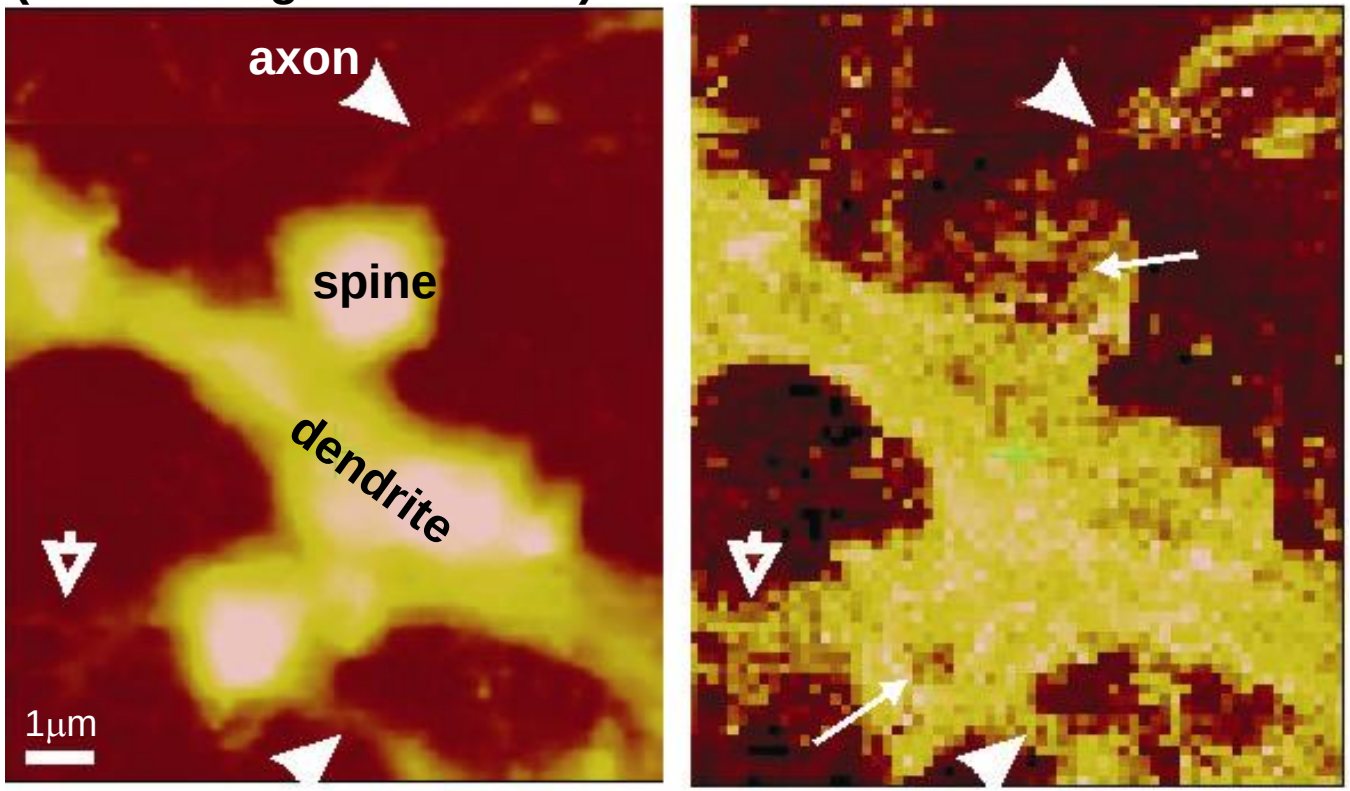
Electro-Mechanical Properties of Neuron Synapses

Determine how structure of channel protein leads to property of 'gain off-set' and 'gain adjustment':

structure-function in molecules!

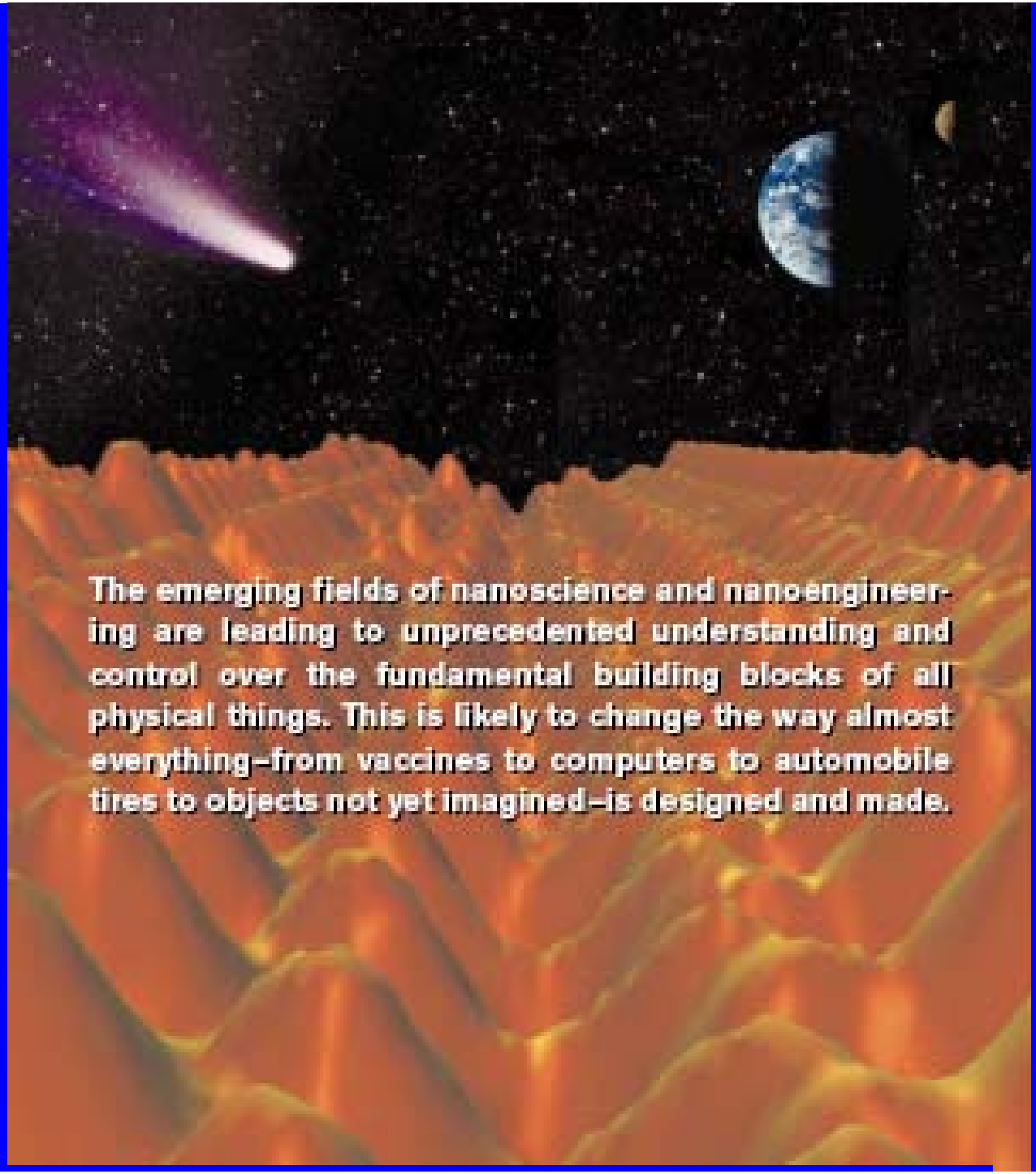
(reverse engineer Nature)





AFM images of topography and viscoelasticity of neuronal junctions (dendritic spine)

Smith, Grutter et al Biophys. J (2006)


The emerging fields of nanoscience and nanoengineering are leading to unprecedented understanding and control over the fundamental building blocks of all physical things. This is likely to change the way almost everything–from vaccines to computers to automobile tires to objects not yet imagined–is designed and made.

Canada is World Class in Nanoscience

Patents as strength indicators:

Marinova and McAleer, Nanotechnology **14**, R1-R7 (2002)

Table 3. Ranking of countries for US nanotechnology patents, 1975–2000. (Note: the data were extracted on 5 March 2002.)

Country	TS	PS	RAP	CR	Mean	Mean score rank
France	1	2	3	8	3.5	1
Japan	8	1	1	5	3.8	2
Canada	4	4	12	1	5.3	3
Germany	9	3	6	6	6.0	4
Netherlands	5	7	9	3	6.0	4
Switzerland	6	6	10	2	6.0	4
Australia	2	9	5	10	6.5	7
Great Britain	3	5	10	11	7.3	8
Italy	7	8	8	7	7.5	9
Sweden	10	11	7	4	8.0	10
Taiwan	12	10	2	9	8.3	11
Korea	10	12	4	12	9.5	12

TS…Technological Specialization Index

PS…Patent Share

RAP…Rate of Assignment (=market share)

CR…citation rate (=knowledge creation)

Nanotechnology: The Challenge Of A New Frontier

The Risk of Nanotech

The REAL Risk: Utilizing nanotechnology without evaluating the consequences

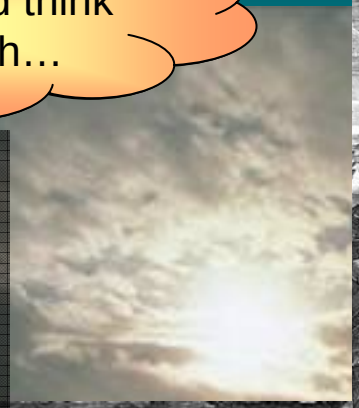
Example: The widespread introduction of nanoparticulates into the ecosphere when their toxicological impact is not known

How Shall We Make Wise Decisions About Nanotechnology ?

- Eliminate Fantasies
- Understand Motivations
- Honestly Assess Risks & Benefits

How Do We Know Something Is Safe?

I really should think this through…



The Dilemma of Columbus

It is virtually impossible to prove that something is absolutely safe

How shall we proceed in a world filled with risk?

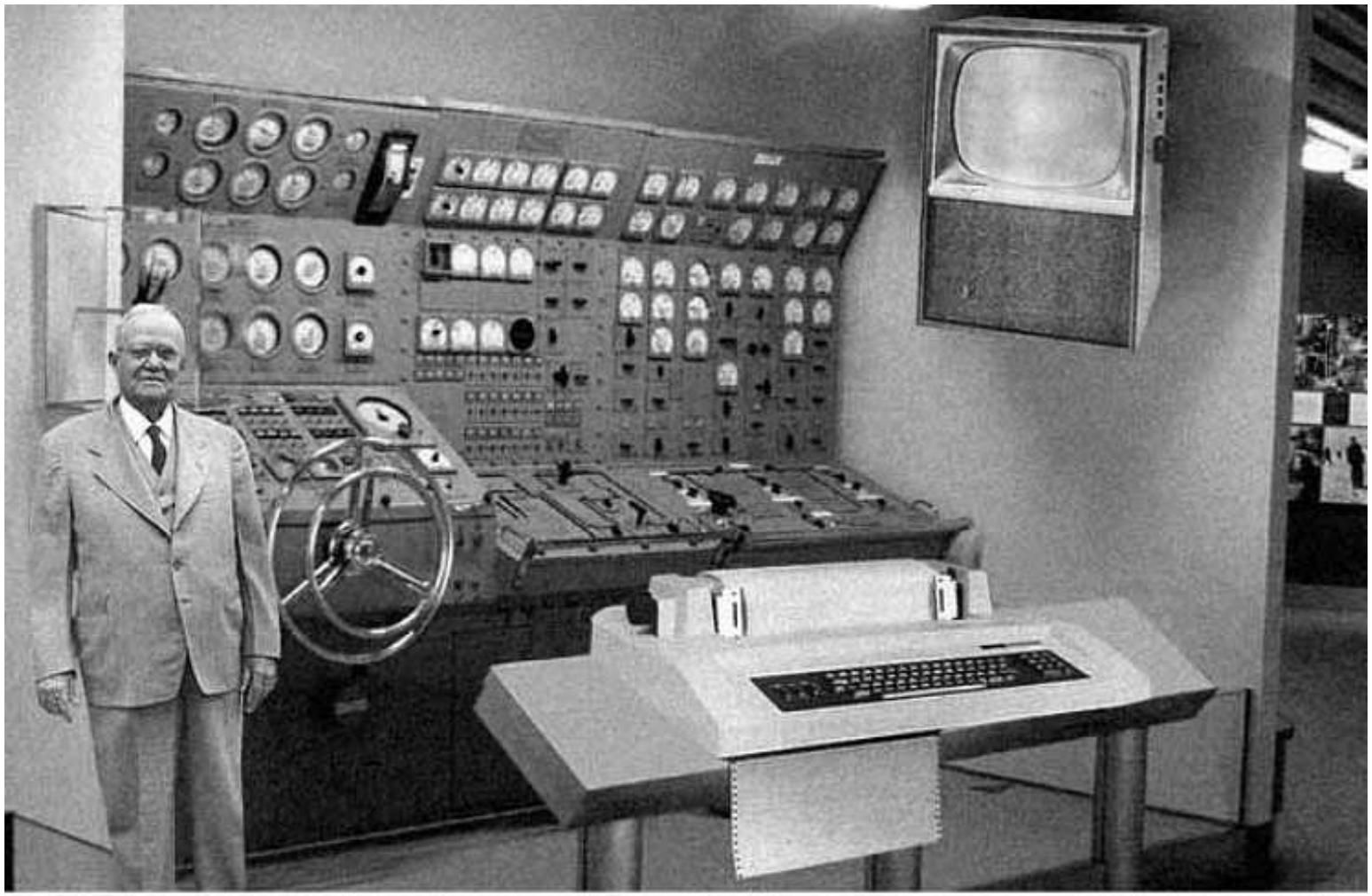
Are There Monsters ?

104. *Nauita Erythræum pauidus qui nauigat æquor,*
In proræ et puppis ſummo reſonantia pendet
Tintinnabula : eo ſonitu prægrandia Cete,
Balenas, et Monſtra marina à nauibus arcet . 5

Of Course!

And they are Hollywood Superstars

Predicting the future…



Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use.

How to succeed in nanotechnology

(a 3 step program)