Nanoscience and Water – Challenges and Future Prospects

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WATER RESEARCH COMMISSION

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40 year old nanotech

5 year old nanotech

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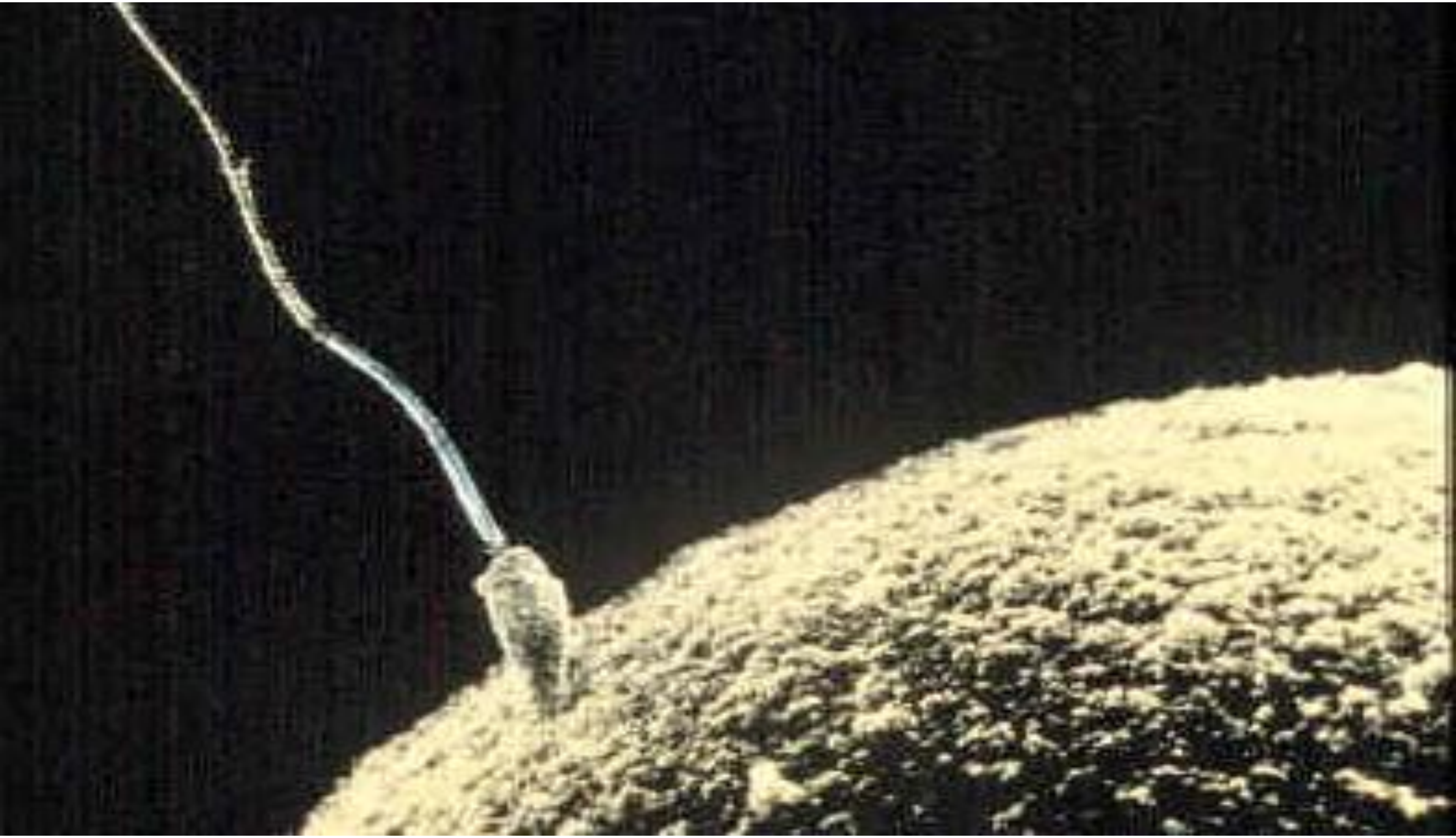
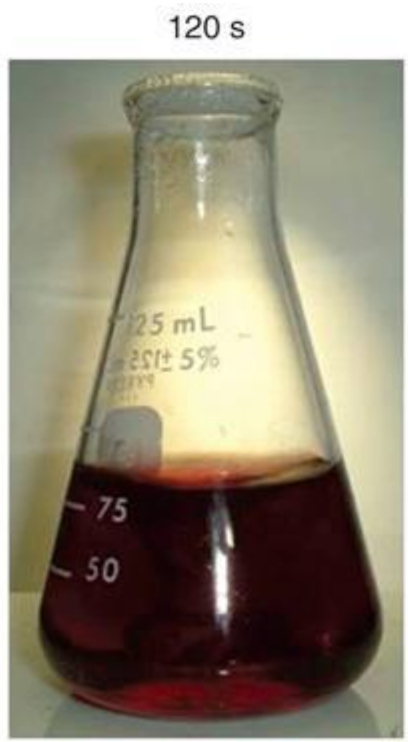
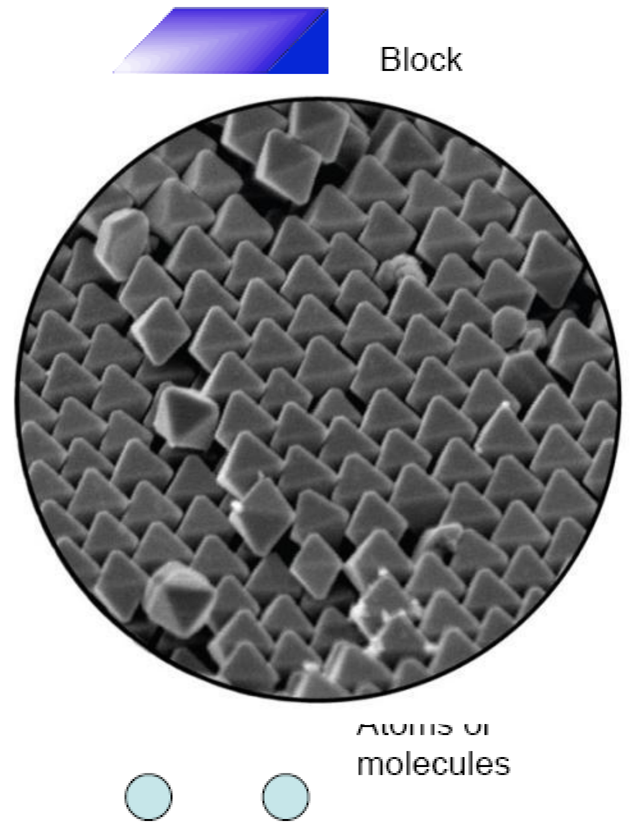
UNIVERSITY OF JOHANNESBU

How Old is NANOTECHNOLOGY?



How do we MAKE something this small?





Top-down or Bottom-up

- SCIENCE has many ways to define “A nanomaterial”

- Nano = Dwarf (or 10^{-9})

(A billionth of a meter)

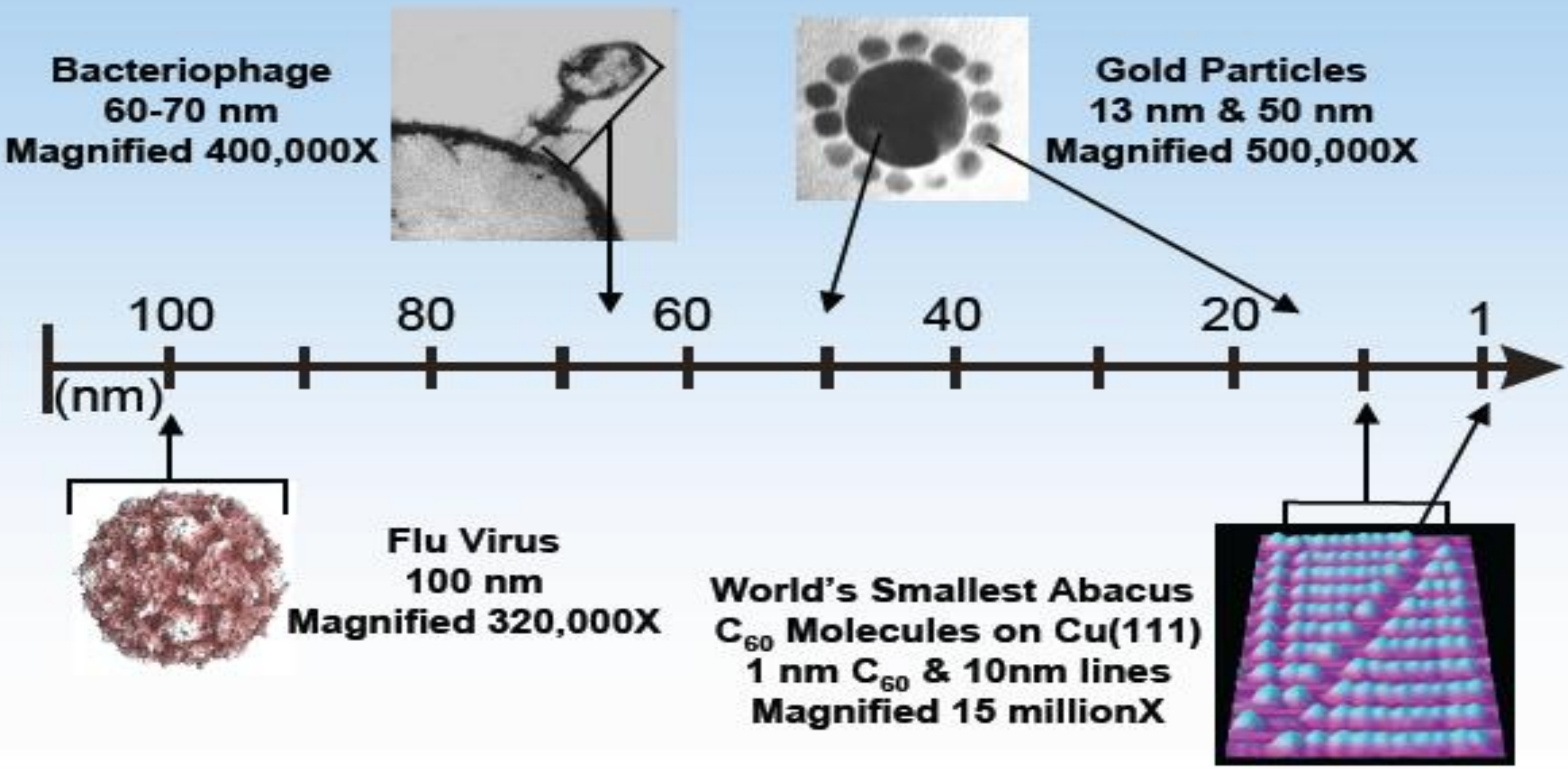
- has one or more dimension of 1 to 100 nm

Scales of 10: How Small is a Nanometre!!?

Arm	~ 1.000000000 m	1 m		
Hand	~ 0.100000000 m			
Finger Nail	~0.010000000 m	1 cm		
Thickness of a Finger Nail	~ 0.001000000 m	1 mm	10^{-3} m	Thousandth of a metre
Diameter of a Hair on a Hand	~0.000100000 m			

Limit of our Unaided Vision

The Interesting Length Scale



See NanoHub presentation on the uses of nanomaterials

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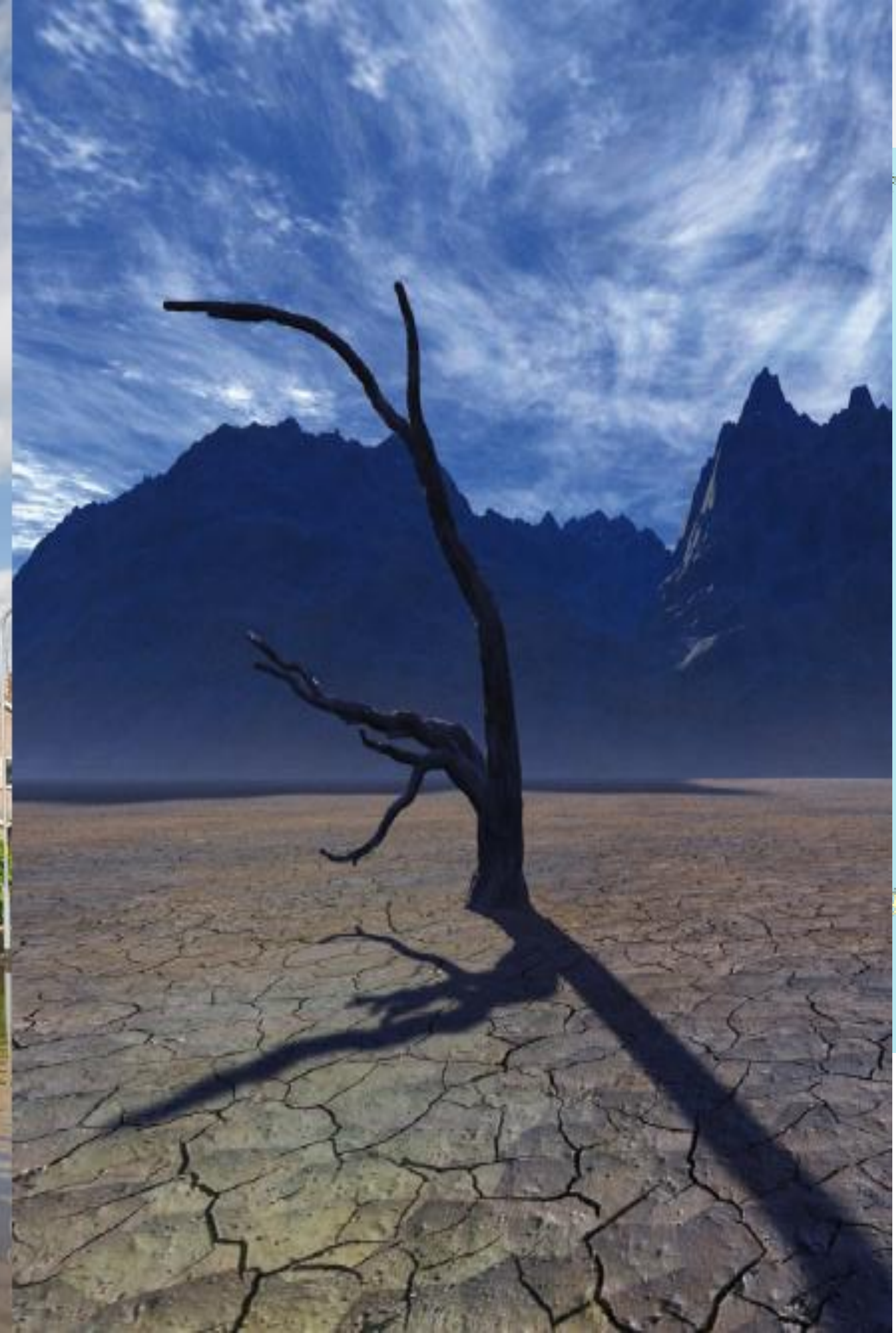

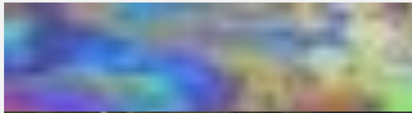

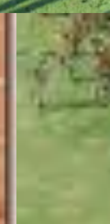

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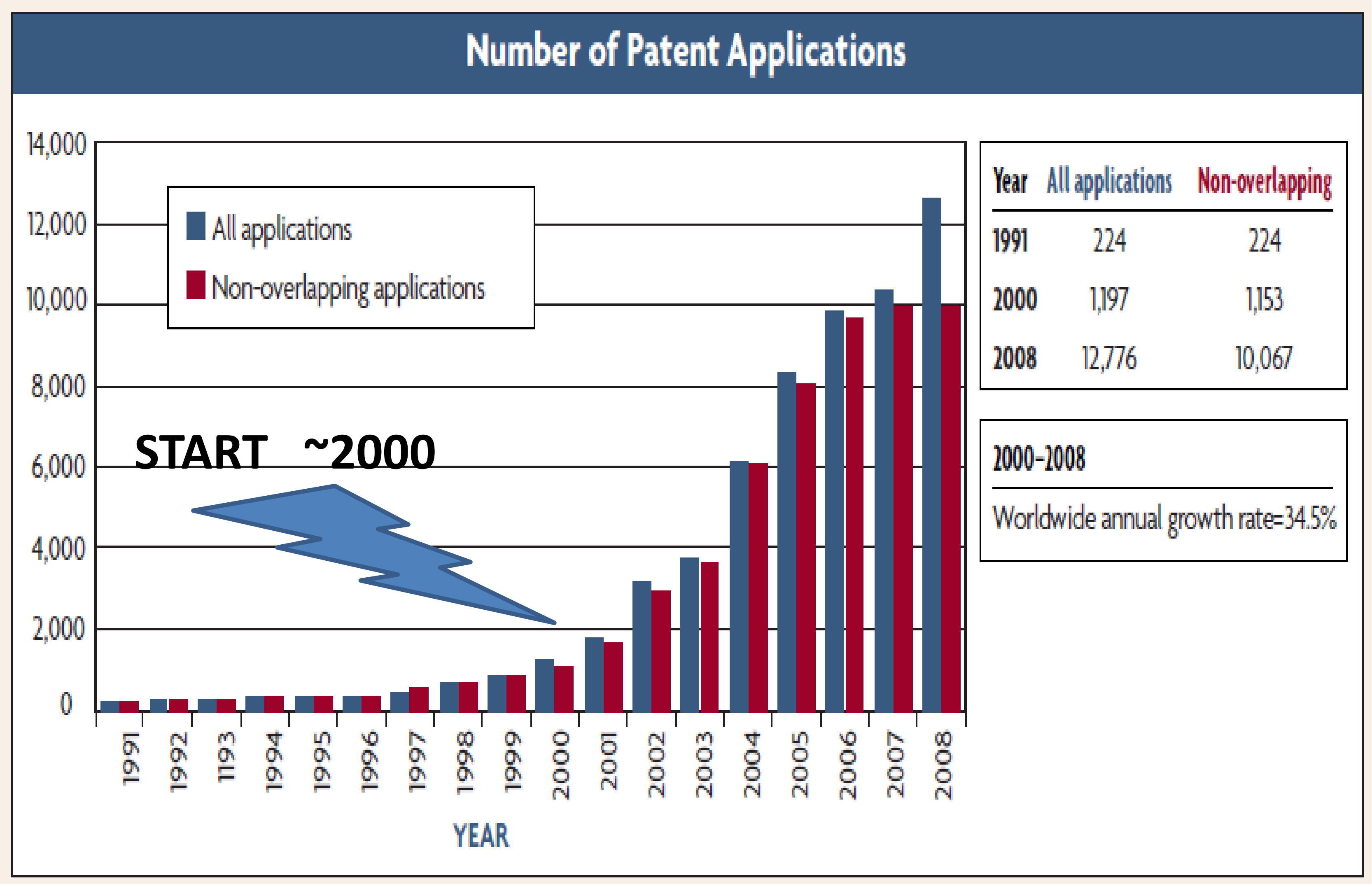
Where are we in nanotech development?



What are these patents for?

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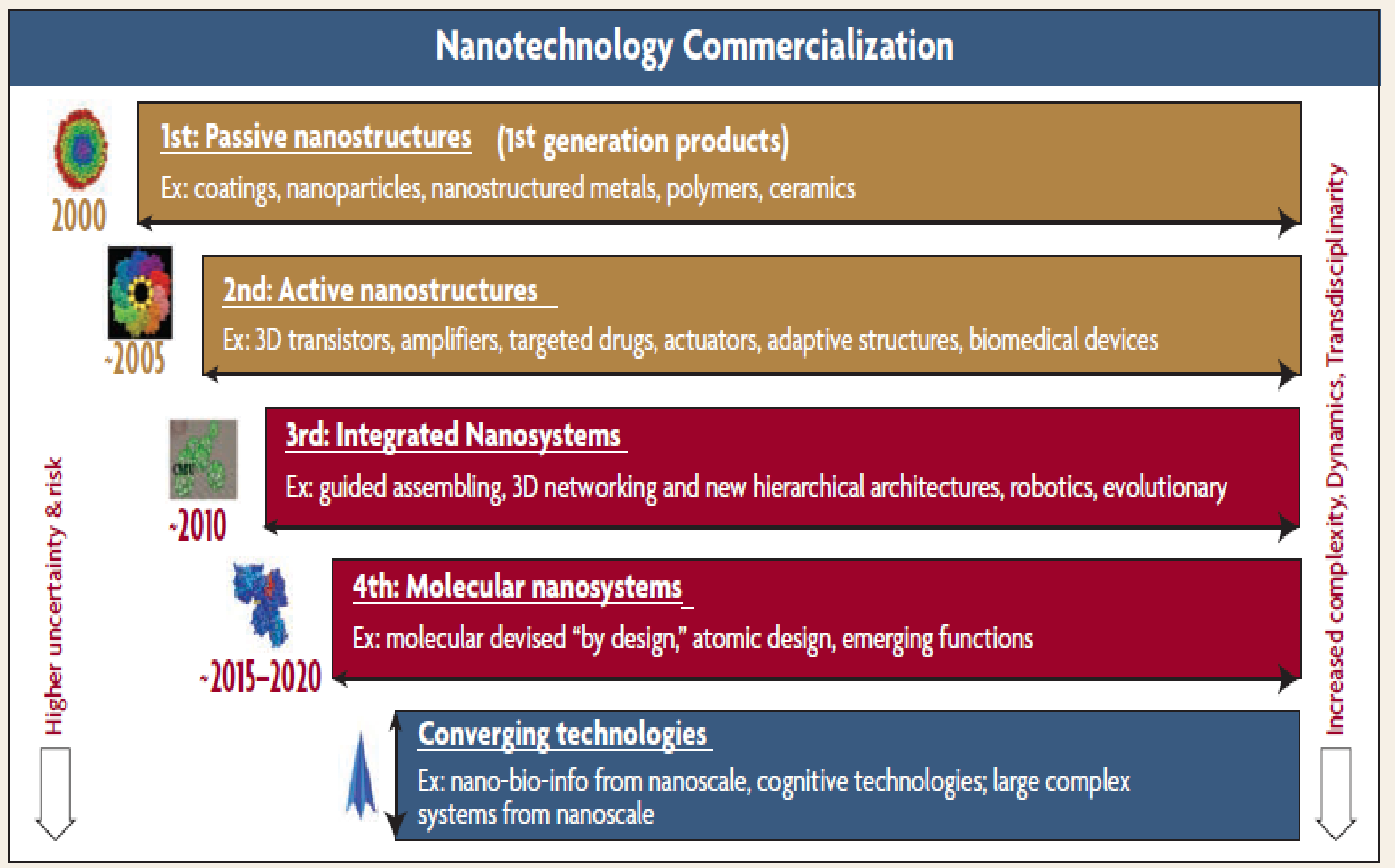


Is that the case?

Thin-film DSS solar cells

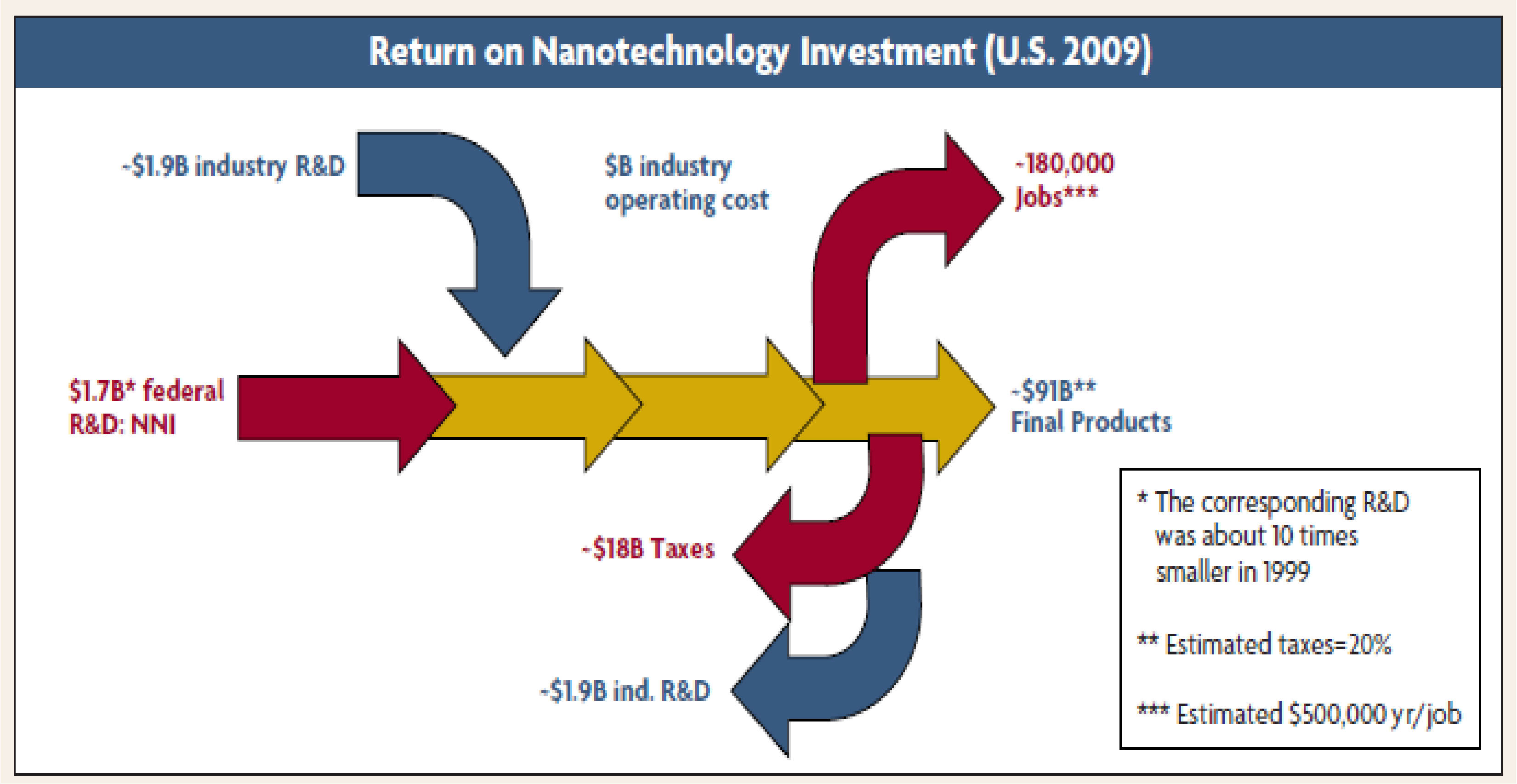
New analytical tools

22 nm transistors

Several nano-enabled medical devices

Is there generally a future in nano?

What is the return on investment?



2000-2008
Estimates show an average growth rate of key nanotechnology indicators of ~ 25%

World US	People (primary workforce)	SCI papers	Patents applications	Final Products Market	R&D Funding
2000	~ 60,000 25,000	18,085 5,342	1,197 405	~ $30 B $13 B	~ $1.2 B $0.37 B
2008	~ 400,000 150,000	65,000 15,000	12,776 3,729	~ $200 B $80 B	~ $14 B $3.7 B
2000 - 2008 average growth	~ 25%	~ 20-25%	~ 35%	~ 25%	~ 25%
2015	~ 2,000,000 800,000			~ $1,000B $400B	~ $70 B $18 B
Topics	*Research changing its frontiers from passive nanostructures in 2000-2005, to active nanostructures beginning with 2006, and to nanosystems in 2010*				

(*) Title-abstract keyword searching of papers (SCI) and patent publications

MC Roco, May 27 2010

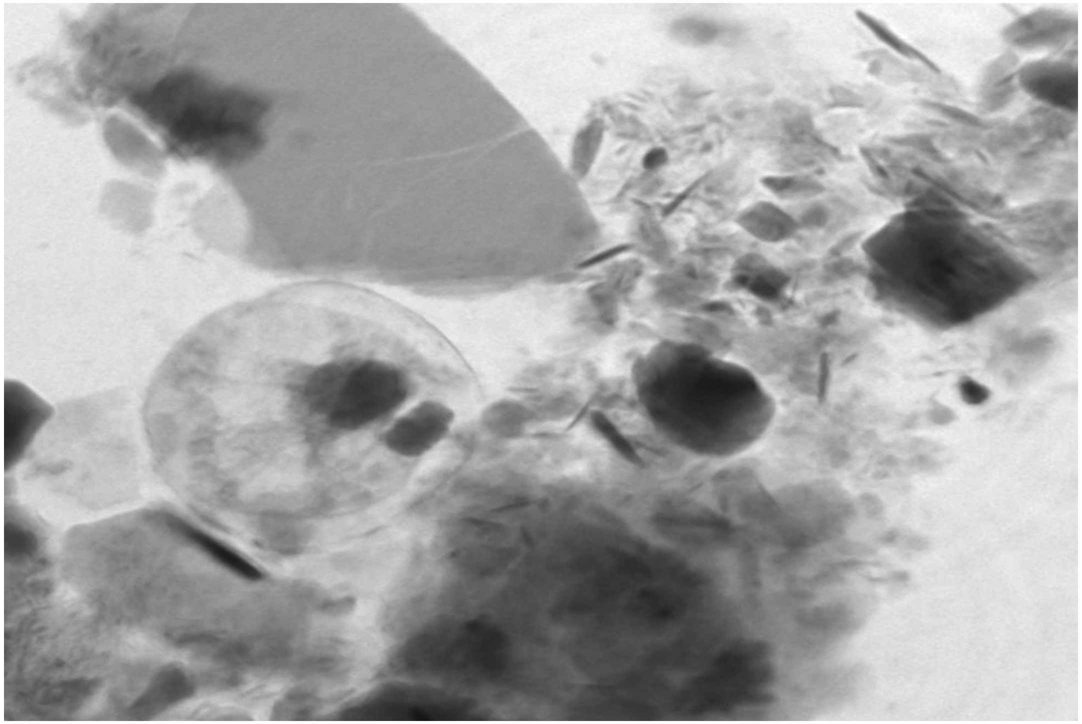
GENNESYS CONFERENCE MAY 27 2010

OK, what does this have to do with H_2O?

- Currently we're making nano-things
- These can get into the environment
- Can we use them to clean-up water?
- Nature also makes nano-things
- What are the consequences?

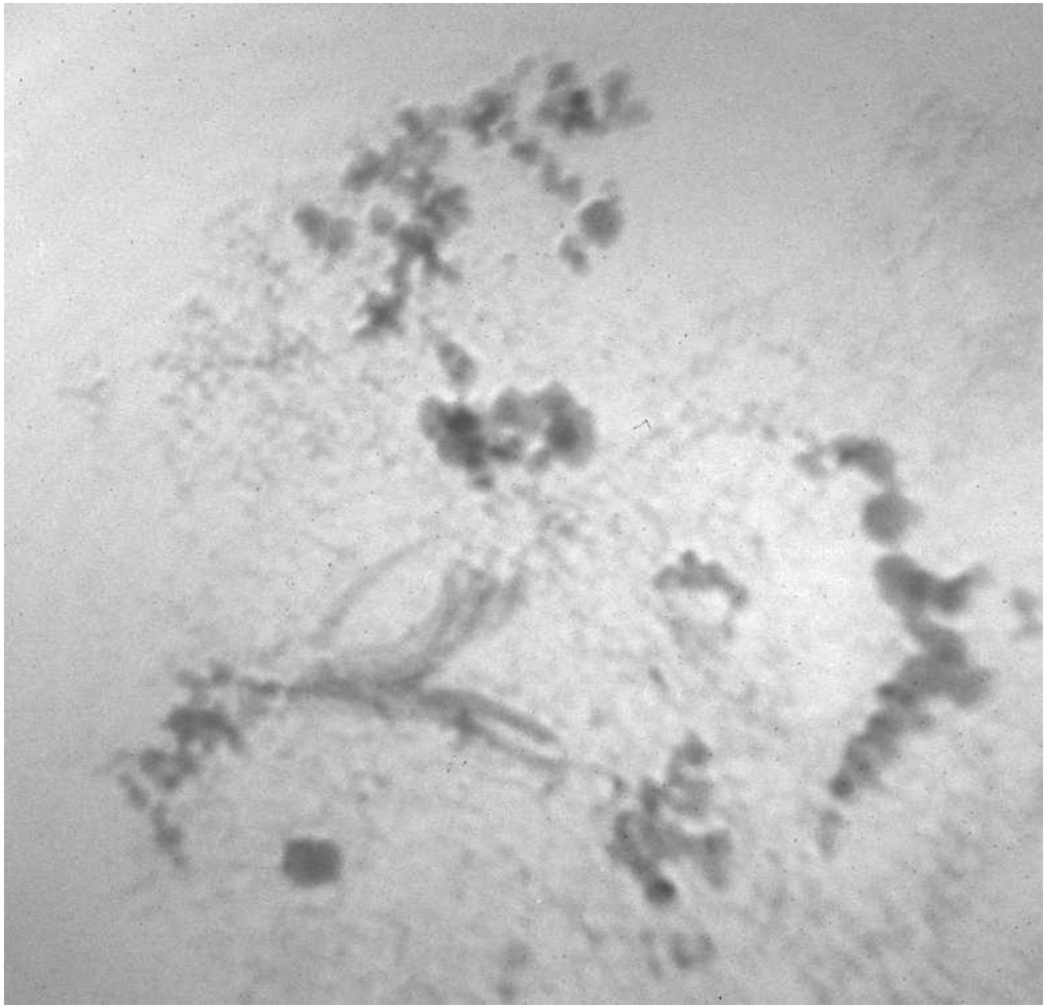
Natural Nanoparticles

The more we started to look the more we realised that Nature is a genius at making nanomaterials!

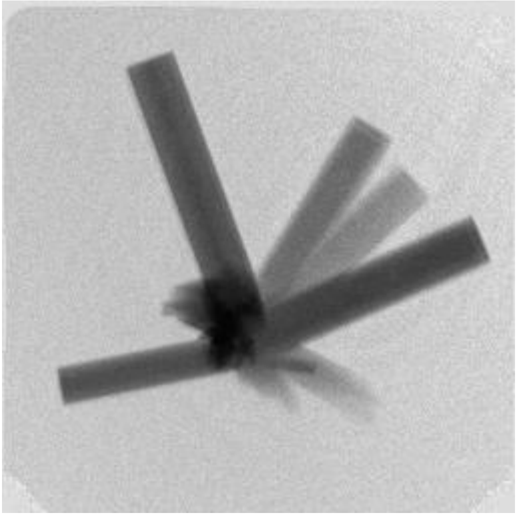


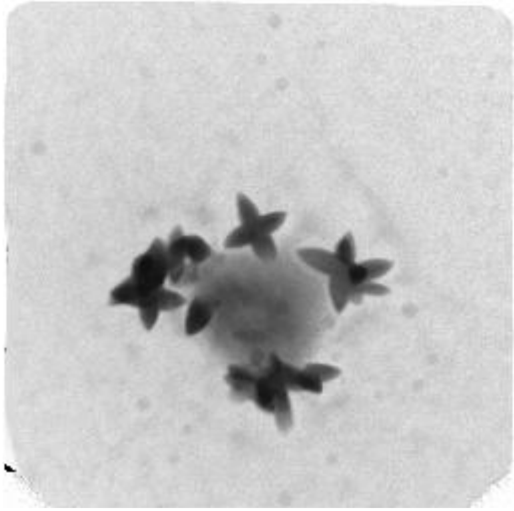
In Sediments

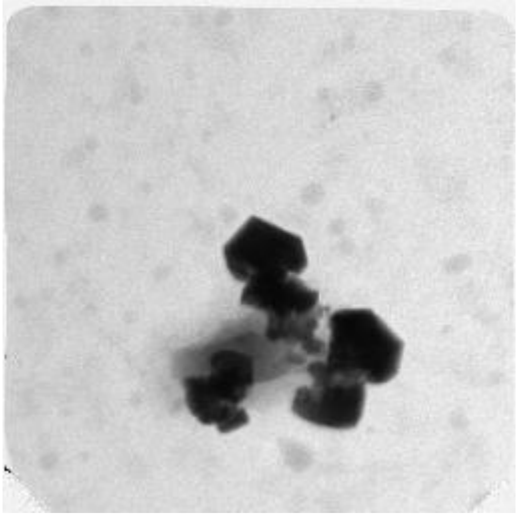
Microbes are pretty good at making nanoparticles



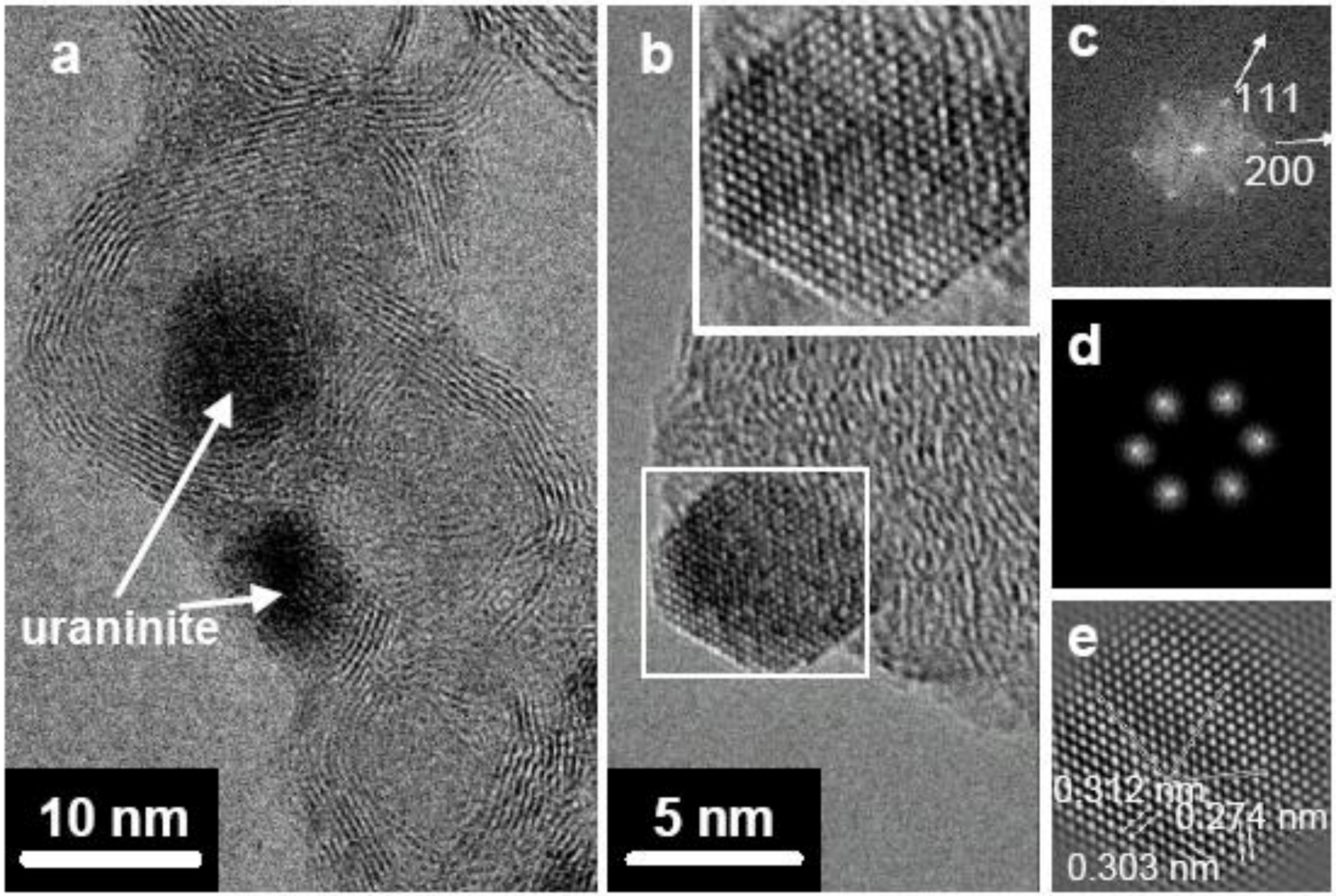
Cement makes nanoparticles





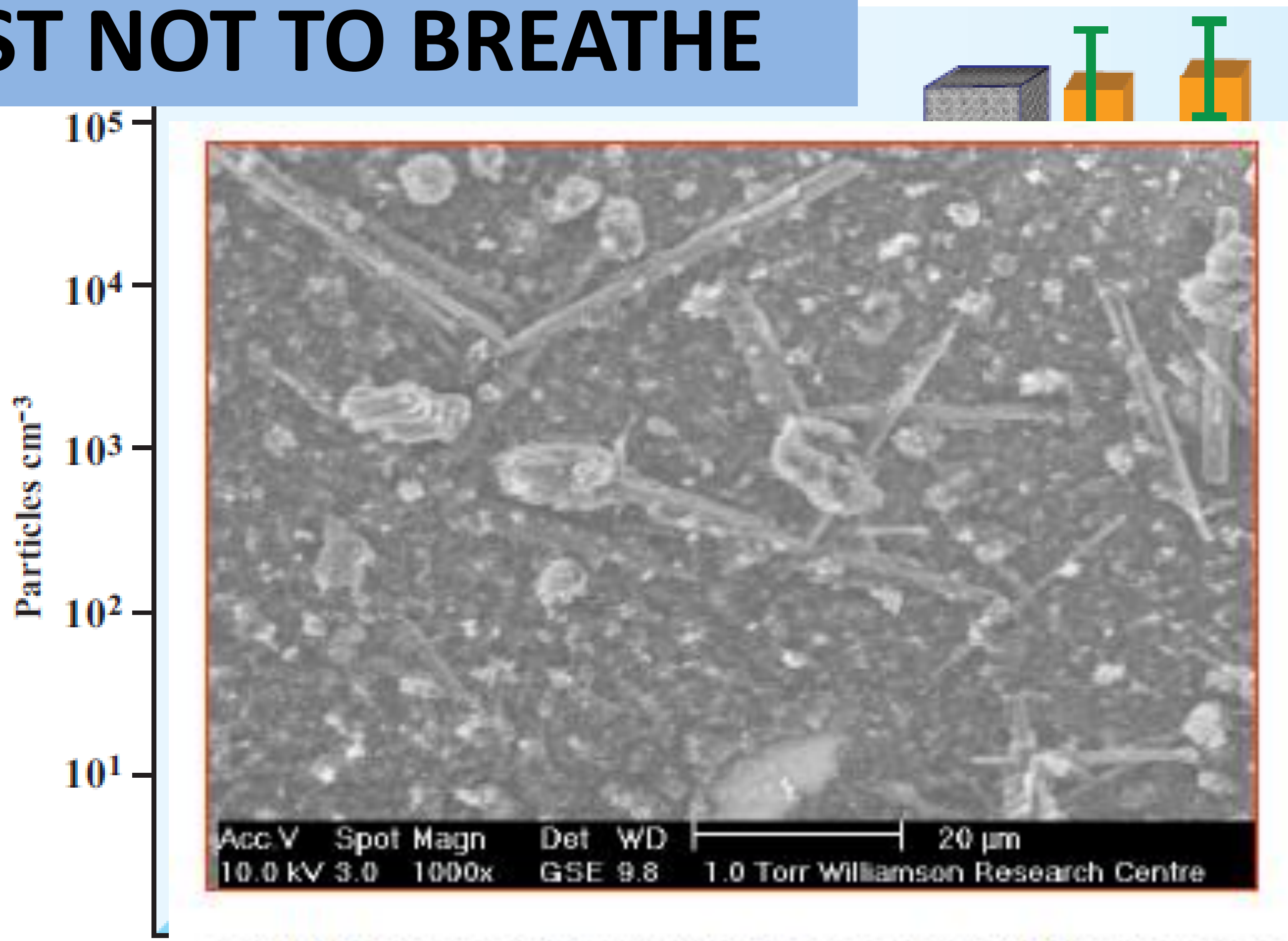


Forest Fires make nanoparticles



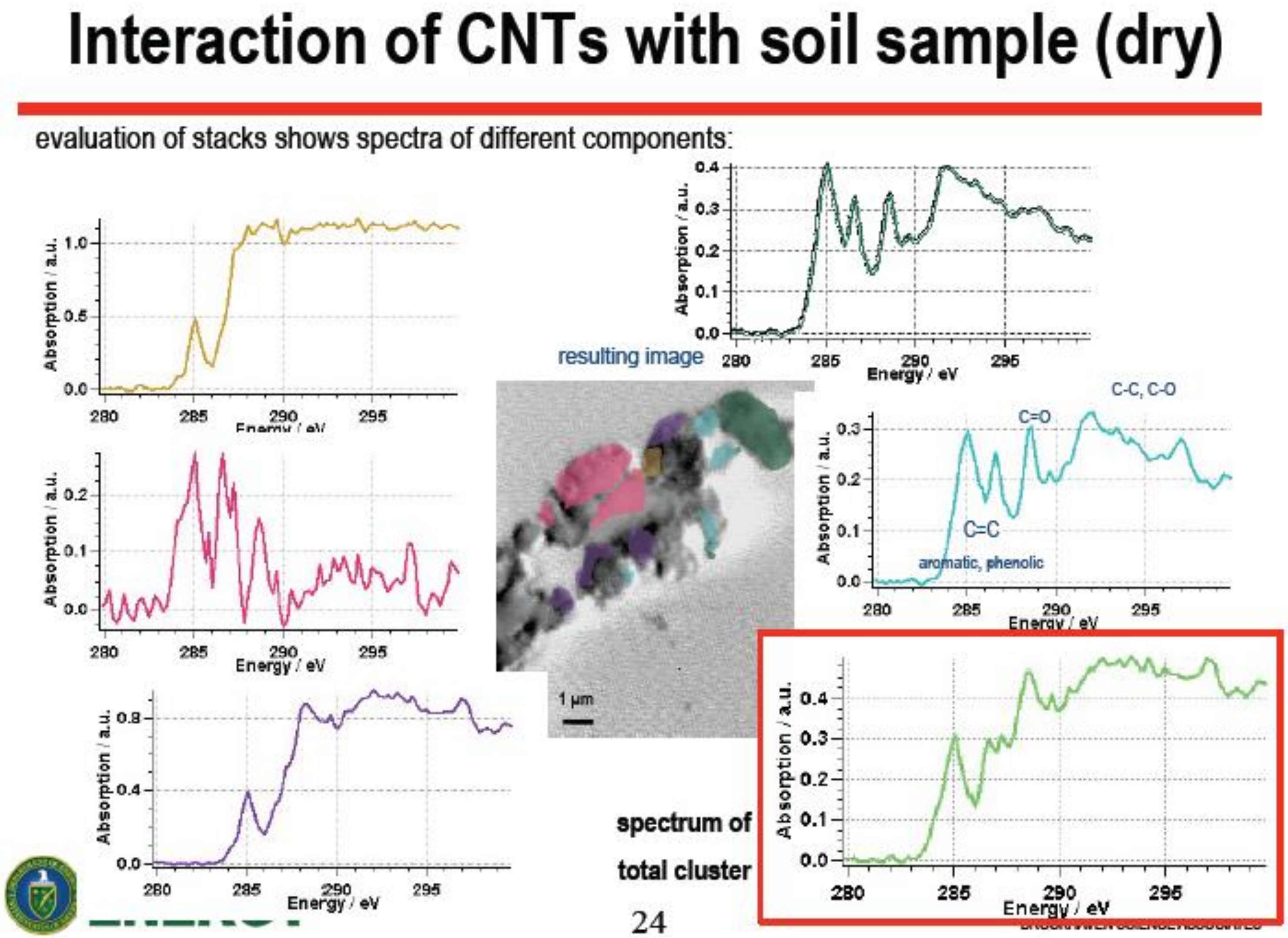
In Fact, if we want to avoid nanoparticles

BEST NOT TO BREATHE



ESEM image of material from central Manchester

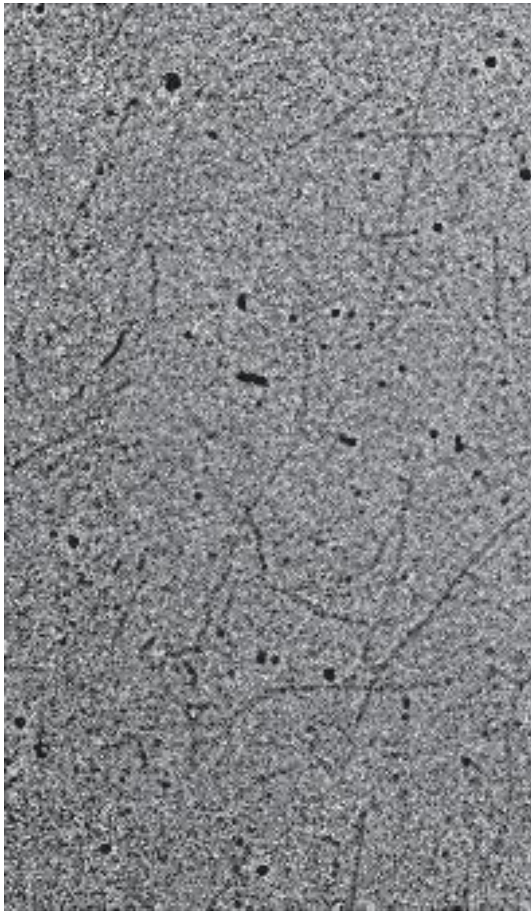
So the challenges are many!



Some major challenges

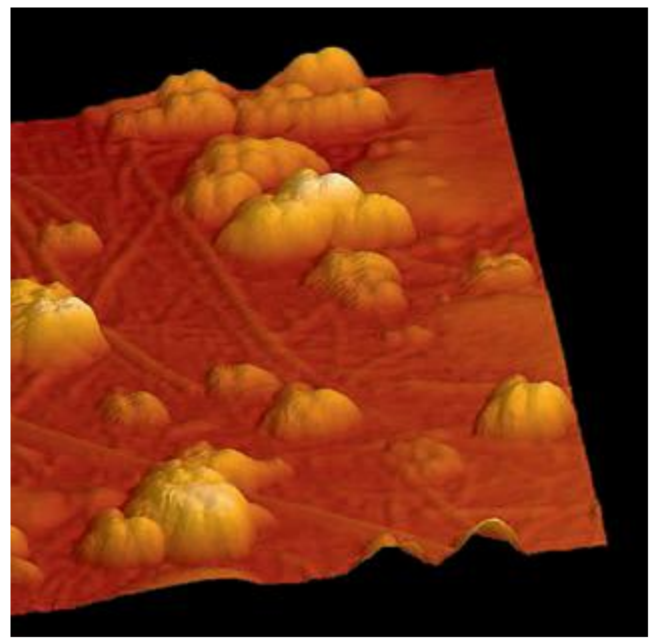
1) How do we track anthropogenic nanoparticles (engineered nanoparticles)?
2) What effects do they have on Earth systems – photocatalysis, oceanic phytoplancton growth, ocean carbonate formation and carbon cycling, river transport of minerals and pollutants, cycling of organic matter, rainfall seeding, etc.
3) How do we find that needle in a haystack?

Also best not to drink anything!



70 000 000 000 particles per litre (size 15 nm)

Ralf Kaegi, environmental scientist, is head of the Particle Lab at Eawag. Co-author: Brian Sinnet



Are there some positive developments?

BUSINESS

Purifying Water with Nano-particles

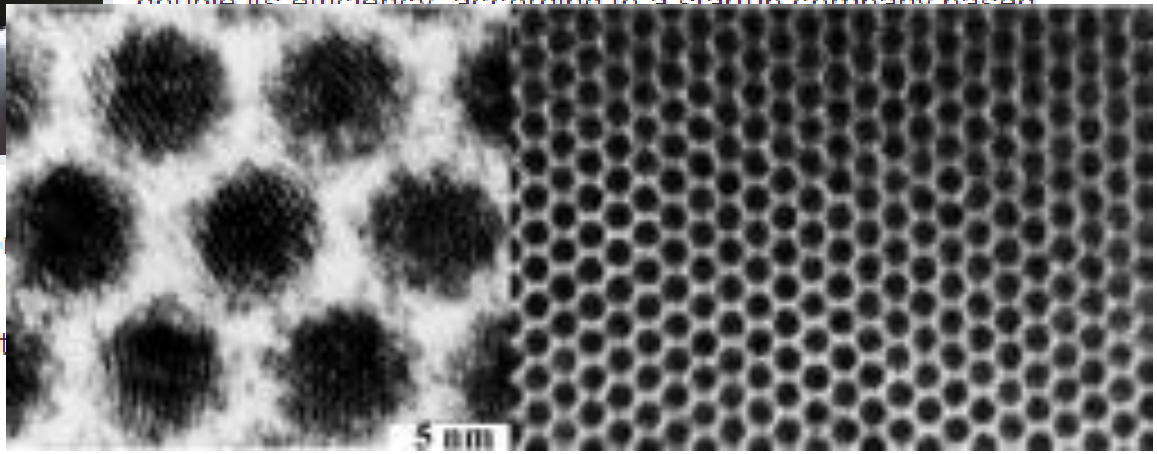
A company says 3-D nanoparticles boost the efficiency of water purification.

MONDAY, SEPTEMBER 29, 2008 | BY DUNCAN GRAHAM-ROWE

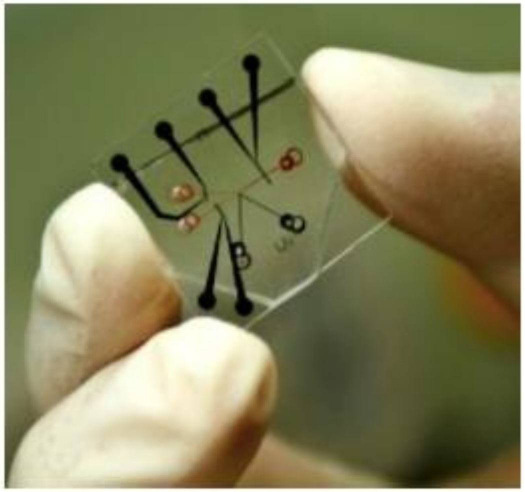
Audio »

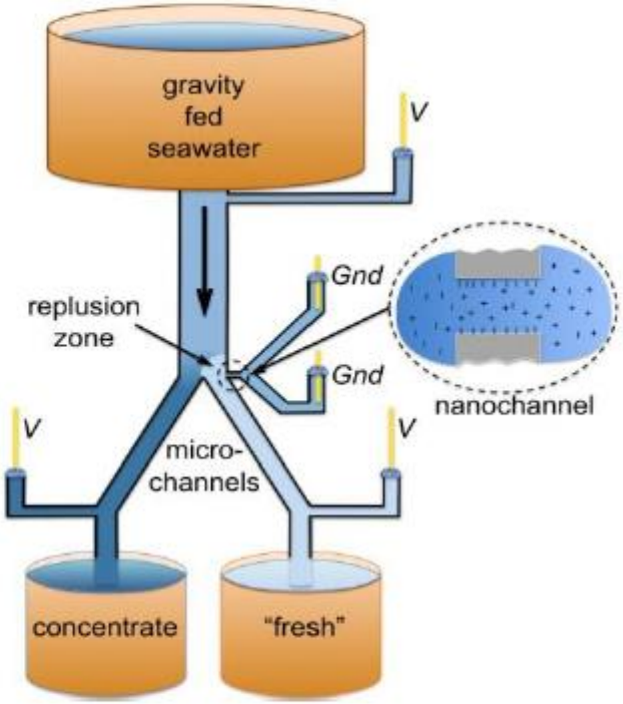
Adding nanoparticles to a water purifying membrane can
double its efficiency, according to a startup company based

Under pressure: The membrane
developed by NanoH2O allows mo
to filter through under for the same
of pressure. This reduces energy
requirements by around 20 percent
CEO Jeff Green.
Credit: NanoH2O



Small channels in membranes or fluidics

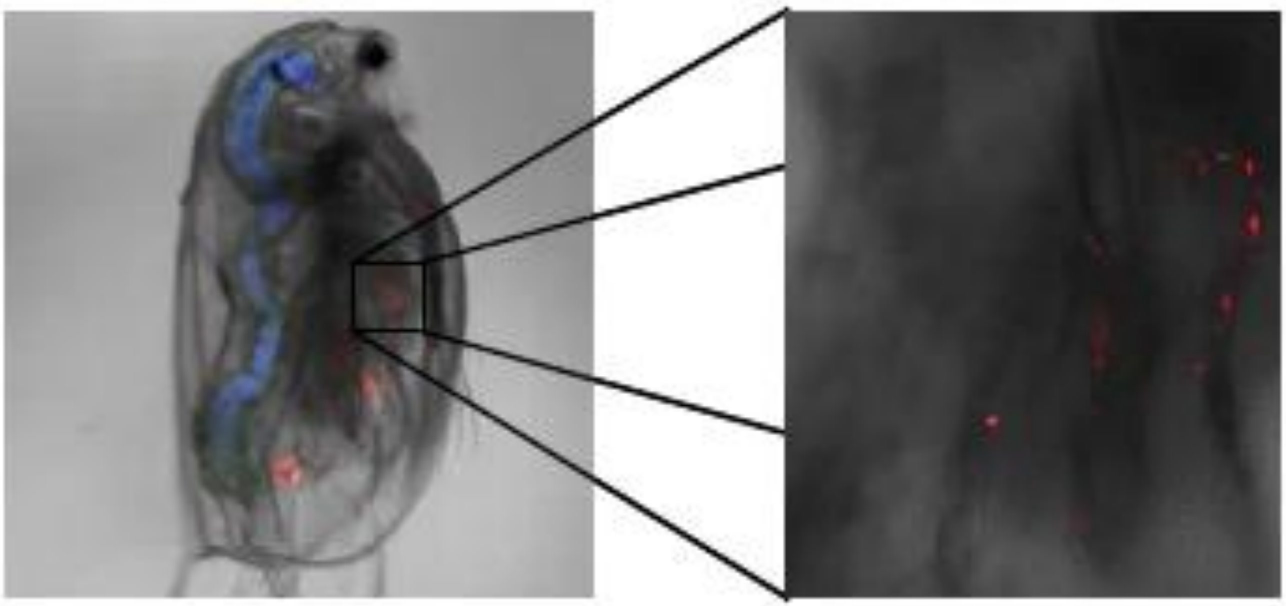




Kim et. al. (2010) nanofluidic device for desalination

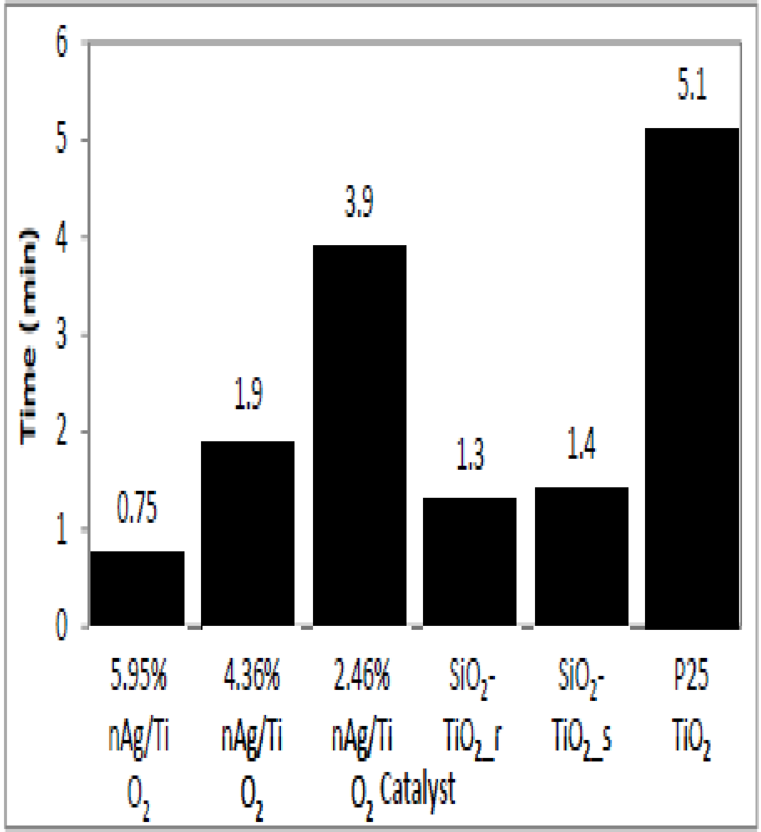
Risk assessment combining new and old

Can we take data from existing models while at the same time look at interactions of new particles to build a risk profile?



WRC Projects

- Zeolites, mesoporous carbons, modified nano-titanium oxides
- Electrospun mats, point of use detection, low energy microbicidal cloths
- Nano Zero Valent Metals
- Nano-based electrode systems



New materials

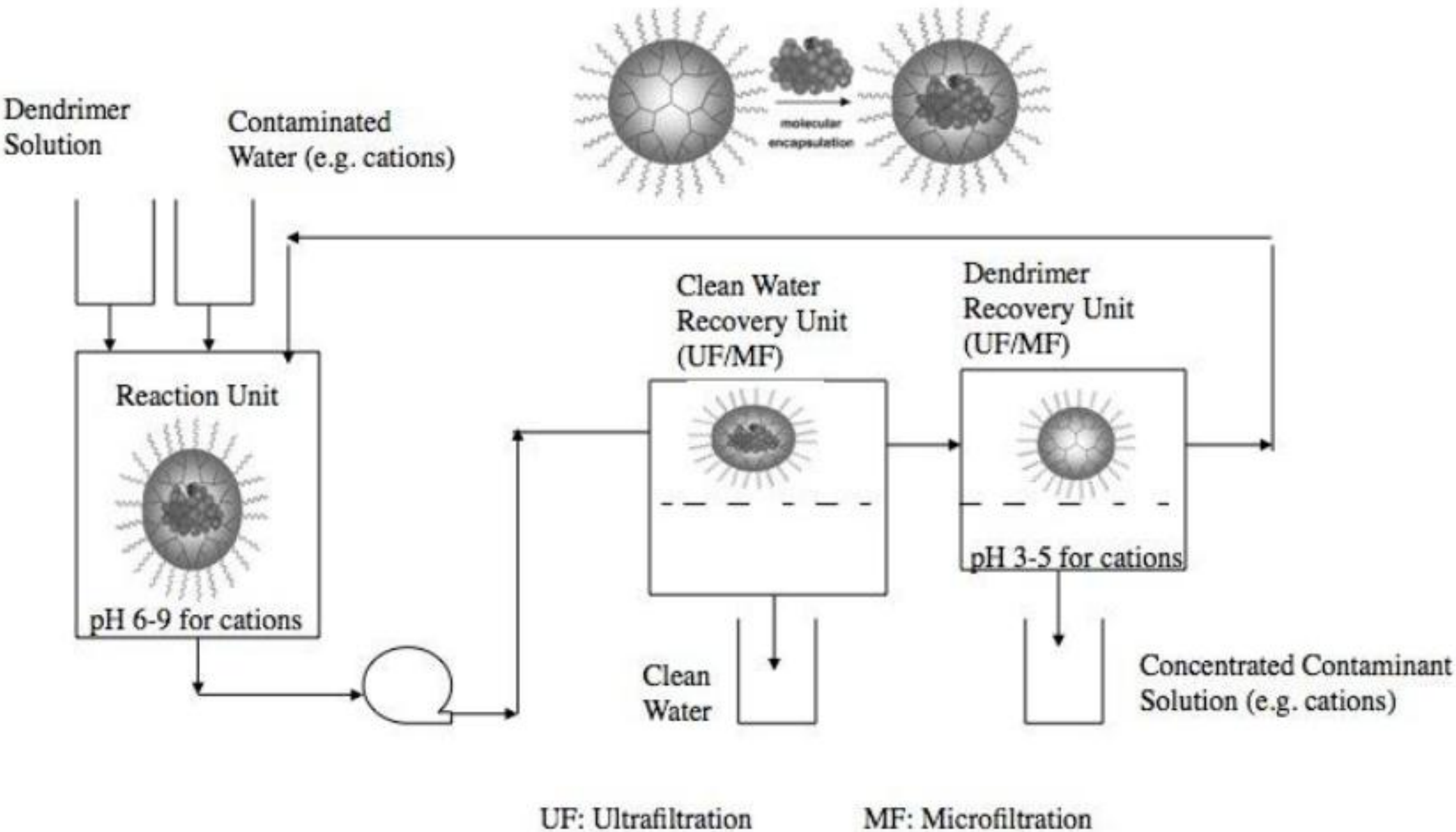
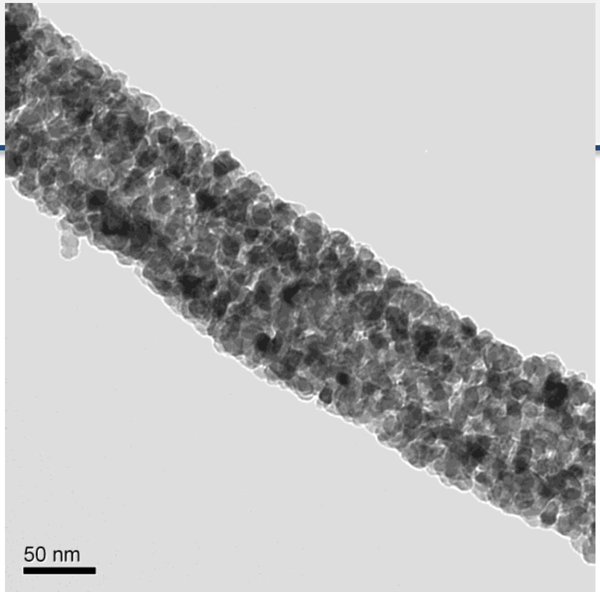
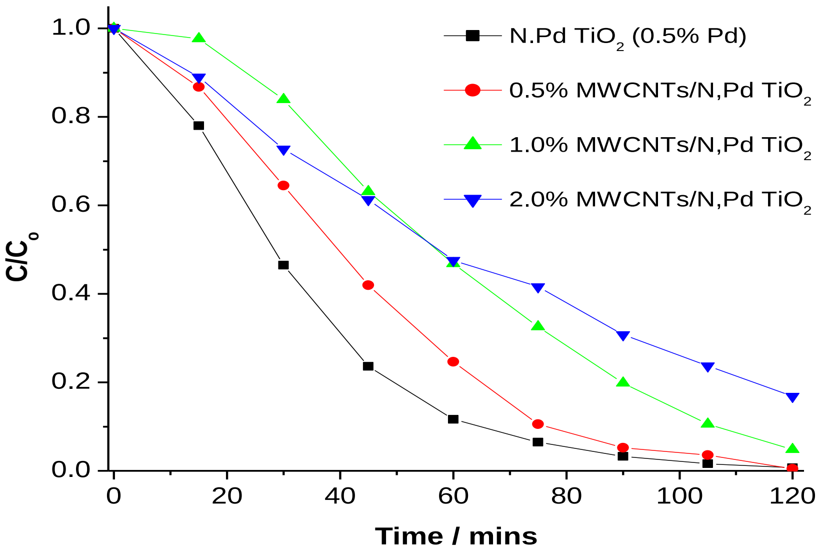


Figure 5.12. Recovery of metal ions from aqueous solutions by dendrimer filtration (adapted from Diallo 2008).

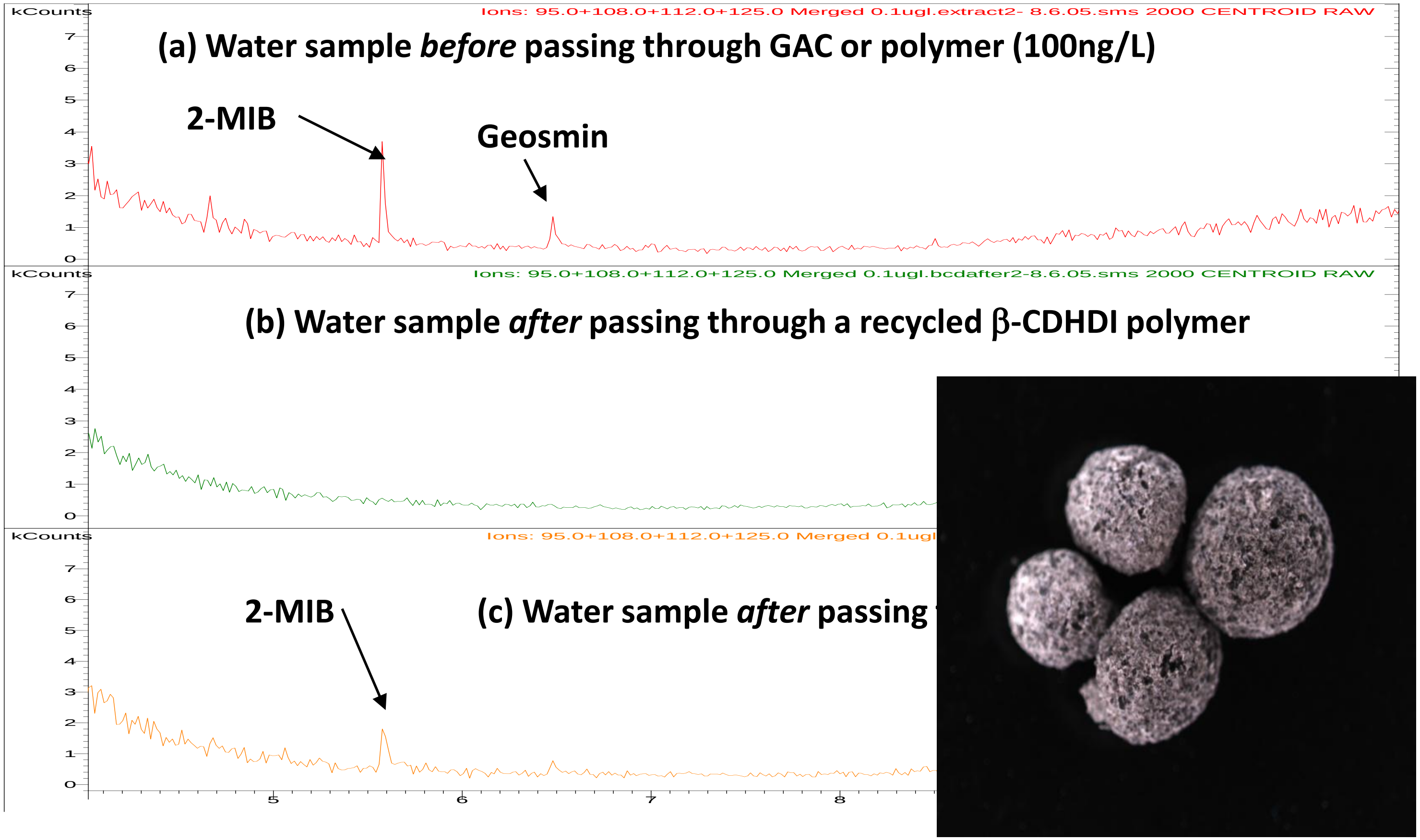
Photocatalysis

TiO_2 is already a good photocatalyst. Using nanomaterials allows us to improve the kinetics and find more efficient ways to look at degradation of pollutants in visible light.





Nano-Polymer adsorbent - WRC Project

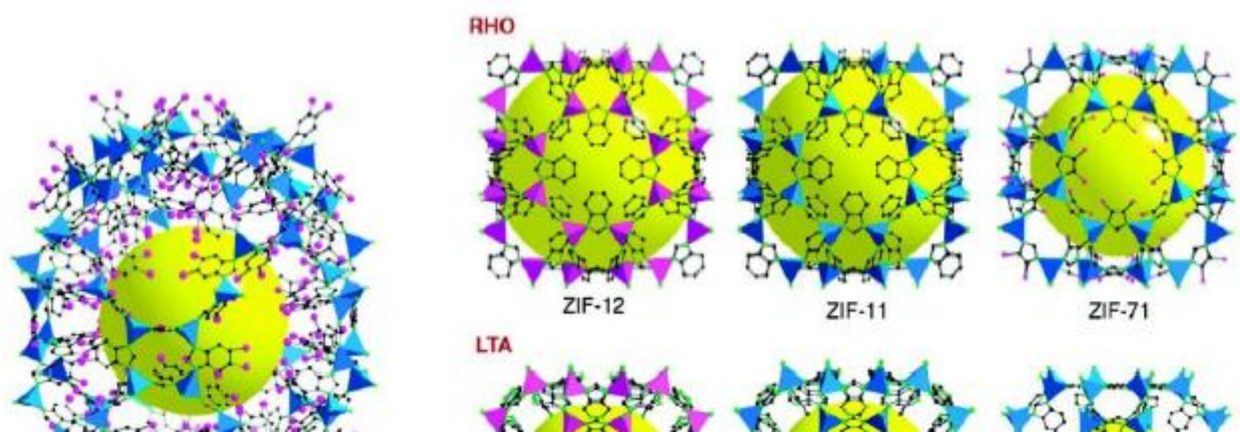


A major advantage - polymers can be recycled without loosing their efficacy.

SeasSwarm

A robot based on adsorbents to clean oil spills

. "Seaswarm" is a nanotechnology-enabled oil-spill-cleaning robot developed by a group of MIT engineers (*TechNews Daily*, August 25, 2010). The conveyor belt of the robot is coated with a mesh of superhydrophobic nanowires developed by Yua et al. (2008).



Thanks

First to WRC for the support throughout the years, taking a chance on "out there" ideas.

University of Johannesburg
Alex, Soraya, Hilary, Ephraim, Jude, Thabile, Lungile

NSF, Mihail Roco, Chad Mirkin, Mark Hersam, "NSF REPORT on PERSPECTIVES in NANOTECHNOLOGY"
J Thieme, Brookhaven National Laboratory,
Center for Biological and Environmental Nanotechnology
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QUESTIONS?