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Nanomaterials: friend or enemy?

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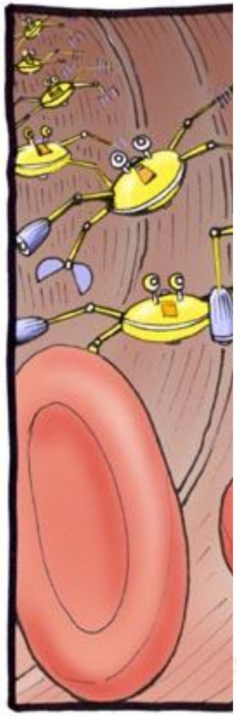
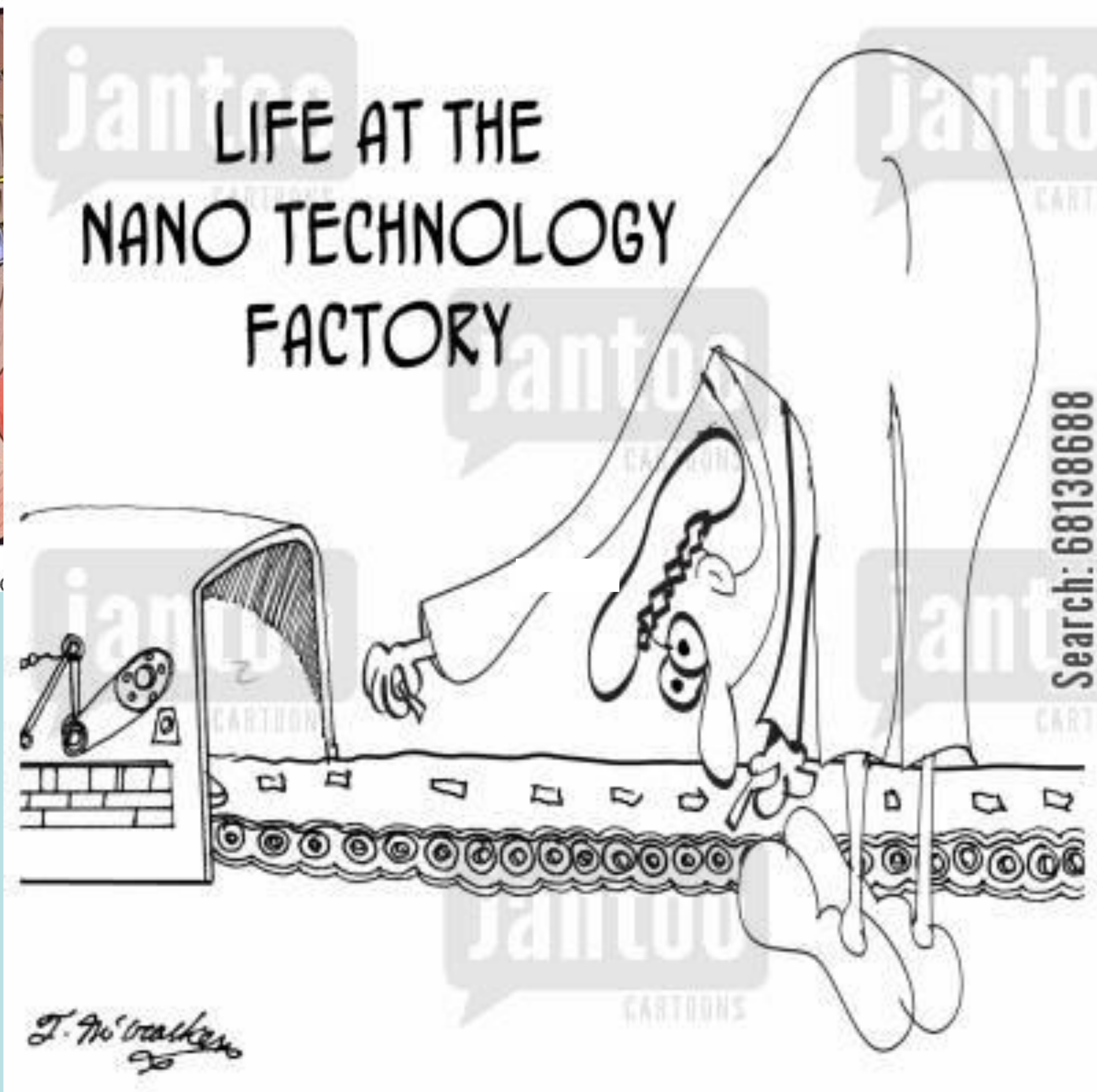
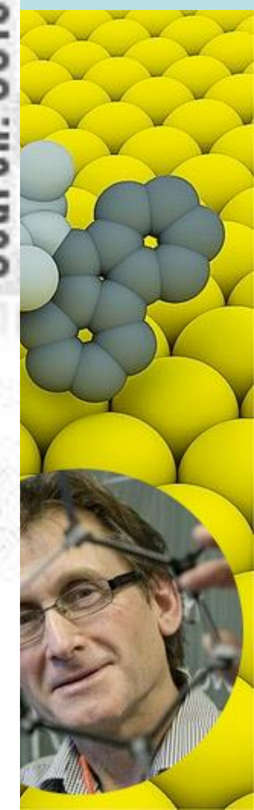


“Okay nanobo





Overview

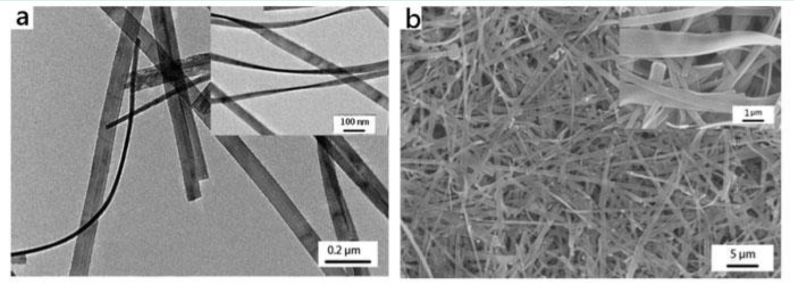
- Introduction
  - Nano?
    - Definition
    - Use?
- Important Physico-chemical parameters?
  - Size
  - Dissolution
  - Shape
  - Crystal structure & more
  - Surface characteristics (Protein corona & charge)
- Conclusions

Definition

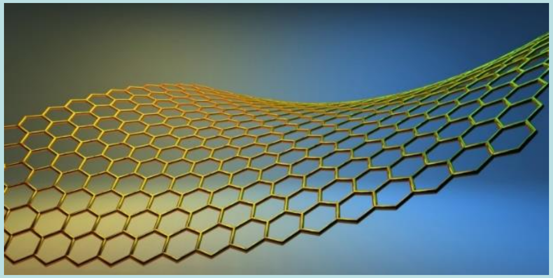
Nanomaterial = at least one dimension <100 nm, including biological nanomaterials, ambient ultrafine particles (UFP) and engineered nanomaterials.

(**Nanoparticle** = all dimensions <100 nm)

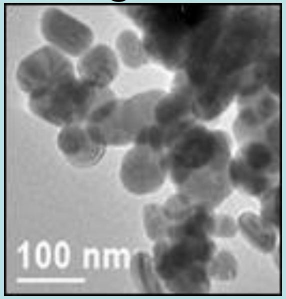
Nanotubes

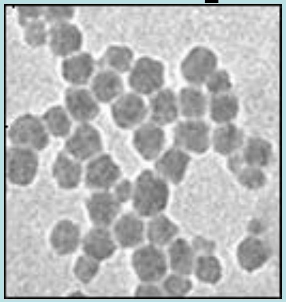


Nanoplates

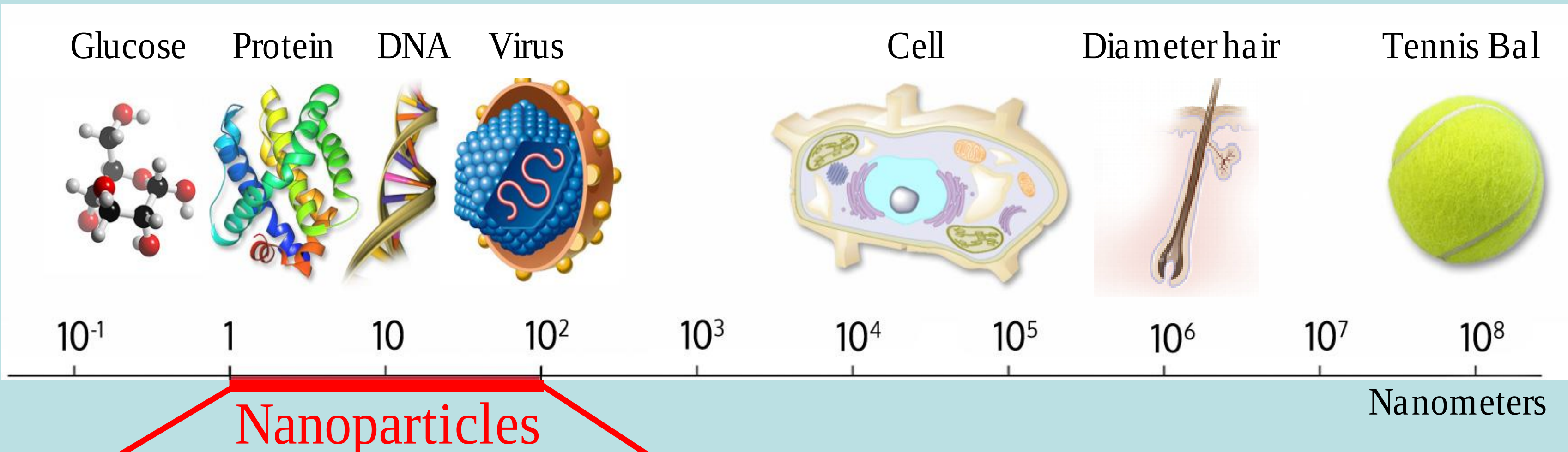


Ag **Nanopaticles** **SiO_2**

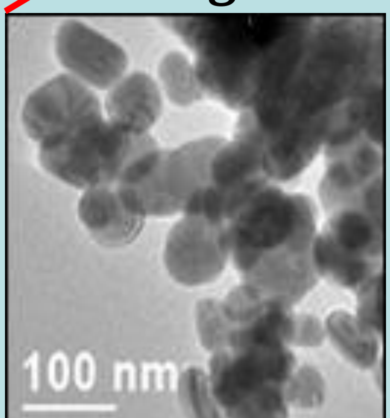




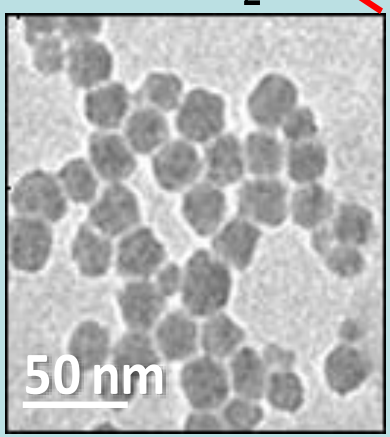
The size of nano



Ag



SiO_2



Applications of nanomaterials

Applications/Examples	**Effect**
• Sports equipment's (bikes, rackets, …)	➢ Improved strength, durability, lightness
• Ketchup	➢ Flow enhancing agent
• Food packaging, textiles	➢ Antimicrobial
• Solar cells, batteries	➢ Enhanced reactivity
• Sun creams, cosmetics	➢ Anti-UV effects
• Medicine (cancer therapy, imaging, drug delivery, …)	







Added value of Nanomaterials?

Effects and applications due to the reduced dimension

Effect		**Examples of application**
Enhanced reactivity	→	Catalysis, solar cells, batteries
Changing optical properties	→	Quantum dots
Higher resistivity	→	Electronics
Wear resistance	→	Hard coatings, tools

⇔ Nano is more than small size

Engineered nano particles/materials

= manufactured nanomaterials that are designed to achieve particular physico-chemical properties that relate to the product application

Important physico-chemical properties

- Size & size distribution
- Agglomeration / aggregation state
- Shape
- Crystal structure
- Chemical composition – including spatially averaged (bulk) and spatially resolved heterogeneous composition
- Surface area
- Surface chemistry
- Surface charge
- Porosity
- *Dissolution*

Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy Oberdorster et al ; PFT 2005

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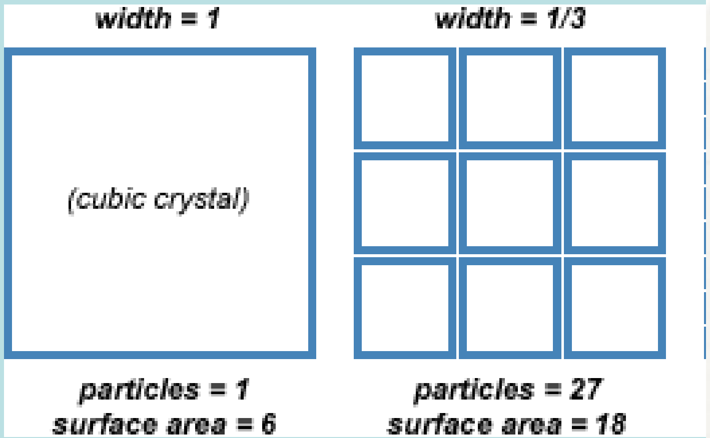
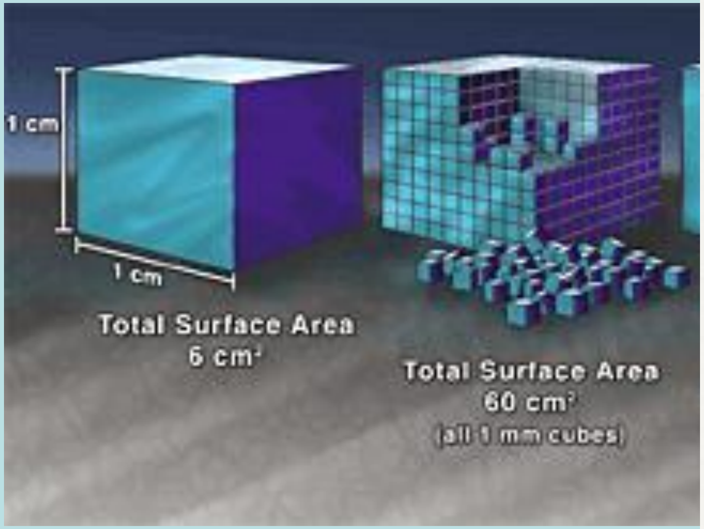
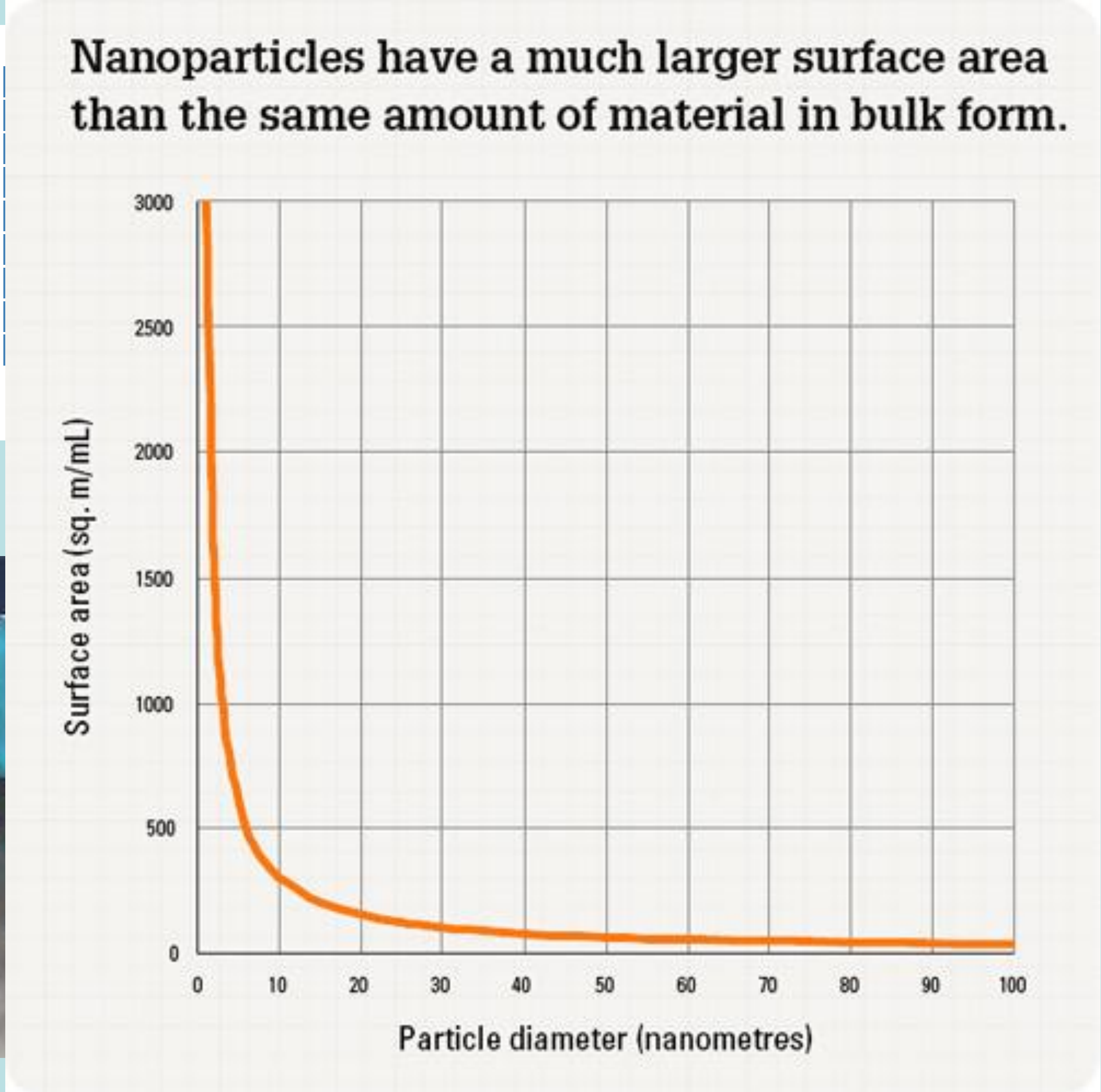
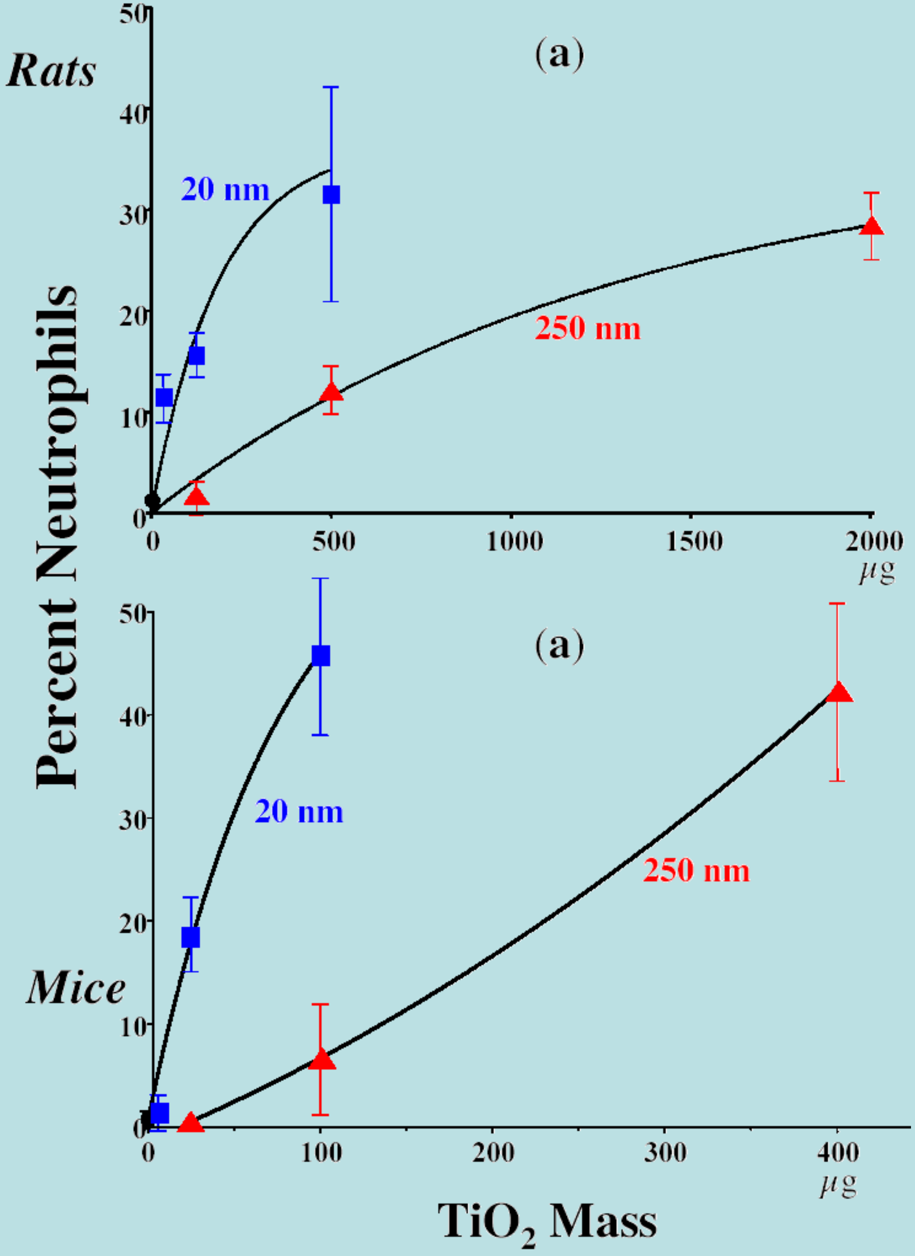
Size & surface area





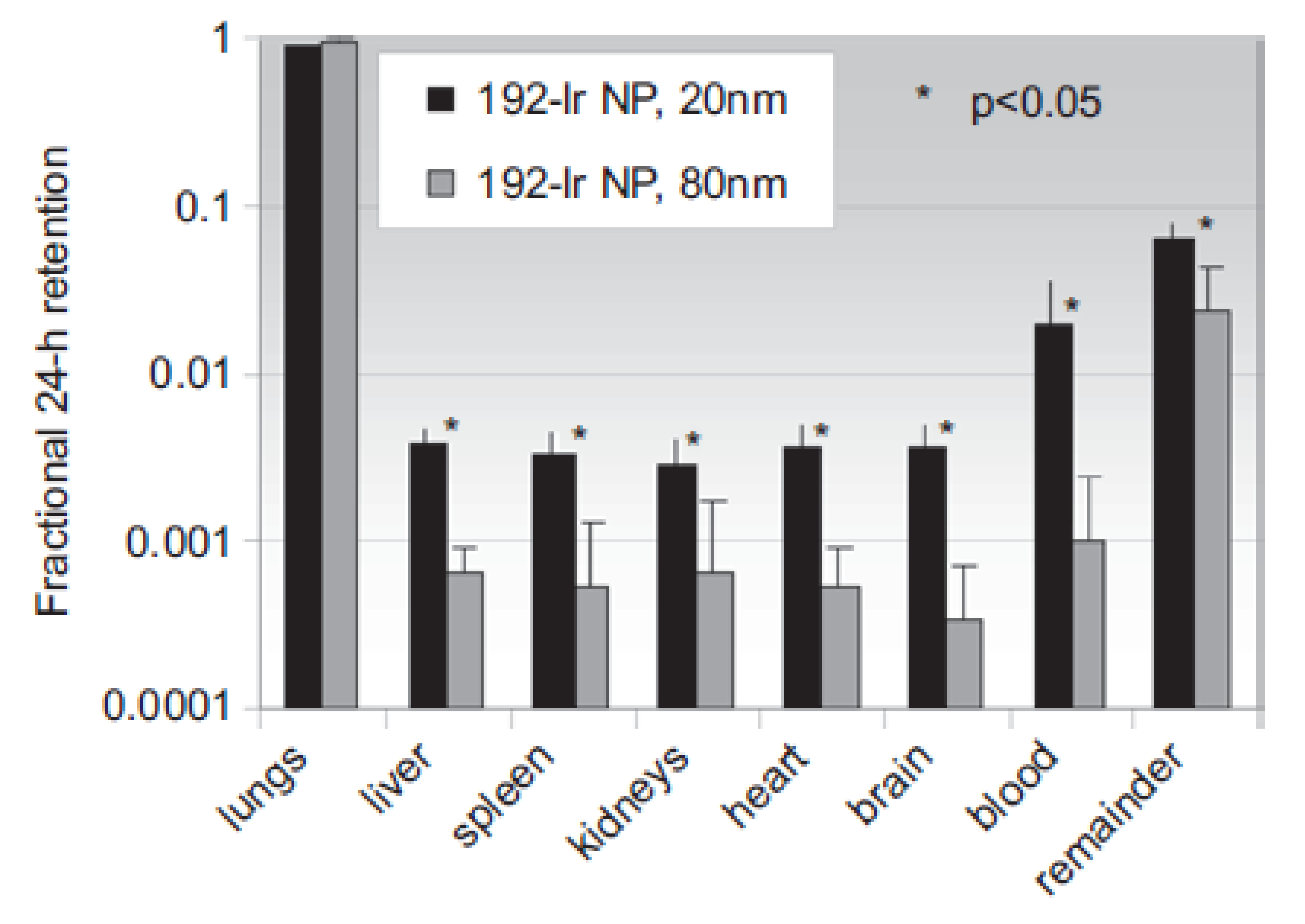


Size & surface area



Oberdörster et al Environmental Health Perspectives , 113, 2005

Size & Systemic uptake of nanomaterials



Kreyling et al *Inhalation Toxicology, 2009; 21(S1): 55–60*

SIZE : Conclusion

New risks/hazards?

- Probably Yes

Why?

- Different (more) toxicity
    - Surface area?

- Systemic delivery
    - Higher/different internal exposure/dose

Important physico-chemical properties

- Size & size distribution
- Agglomeration / aggregation state
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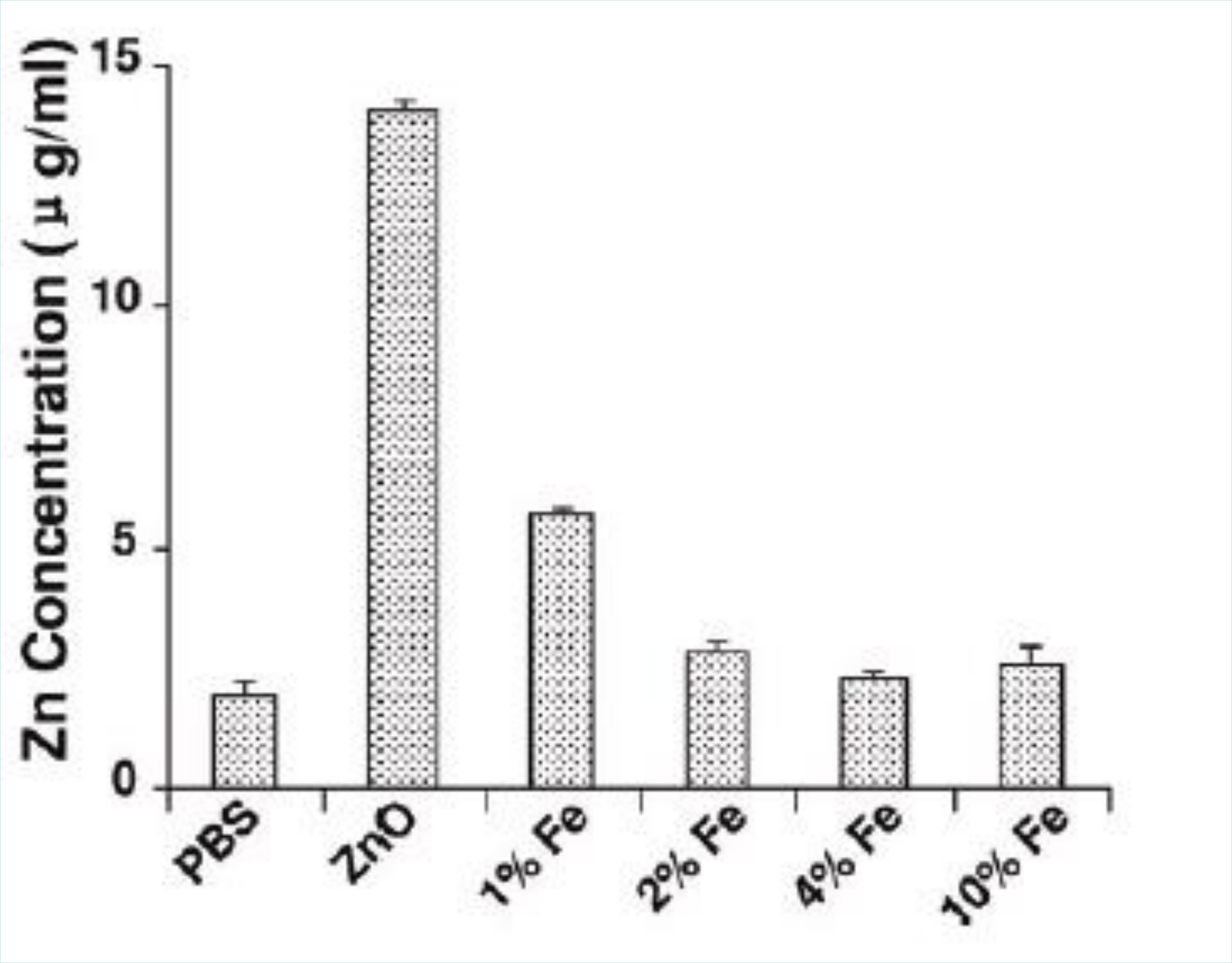
- Porosity

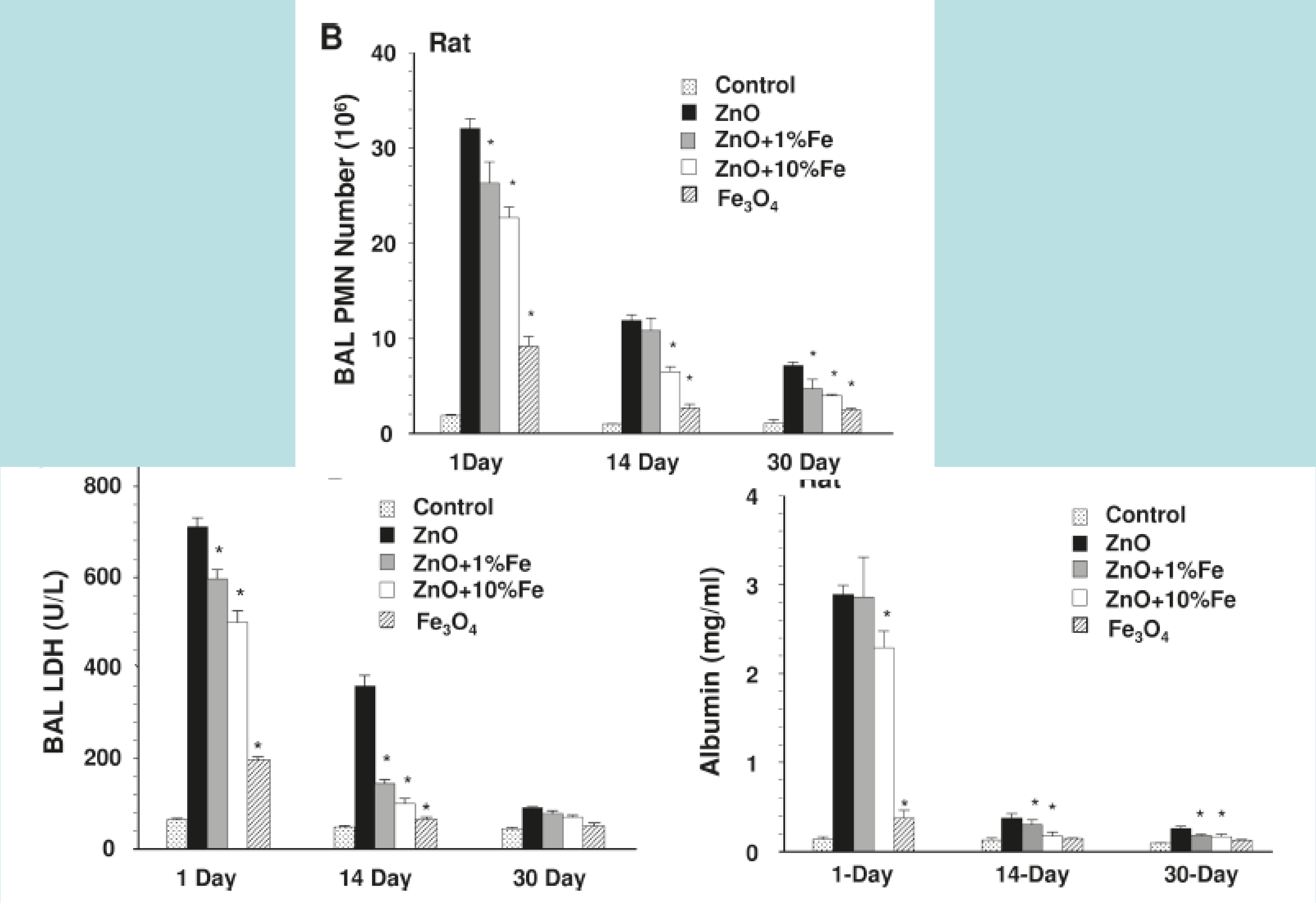
- ***Dissolution***

Decreased Dissolution of ZnO by Iron Doping Yields Nanoparticles with Reduced Toxicity ….

Xia et al. ACSNano 2011



Decreased Dissolution of ZnO by Iron Doping Yields Nanoparticles with Reduced Toxicity ….
Xia et al ACSNano 2011



Dissolution

- Metal (-oxides) NP's can release significant amount metal ions

➔ toxicity not necessarily depending on NP but on ions

+ Dissolution can generate oxidative stress.

Remark:

- In some instances NP & ions have additional effect
- Biodistribution of ions ≠ NP's (Trojan horse effect)

Recommended physicochemical properties to be characterized

- Size & size distribution
- Agglomeration / aggregation state
- Shape
- Crystal structure
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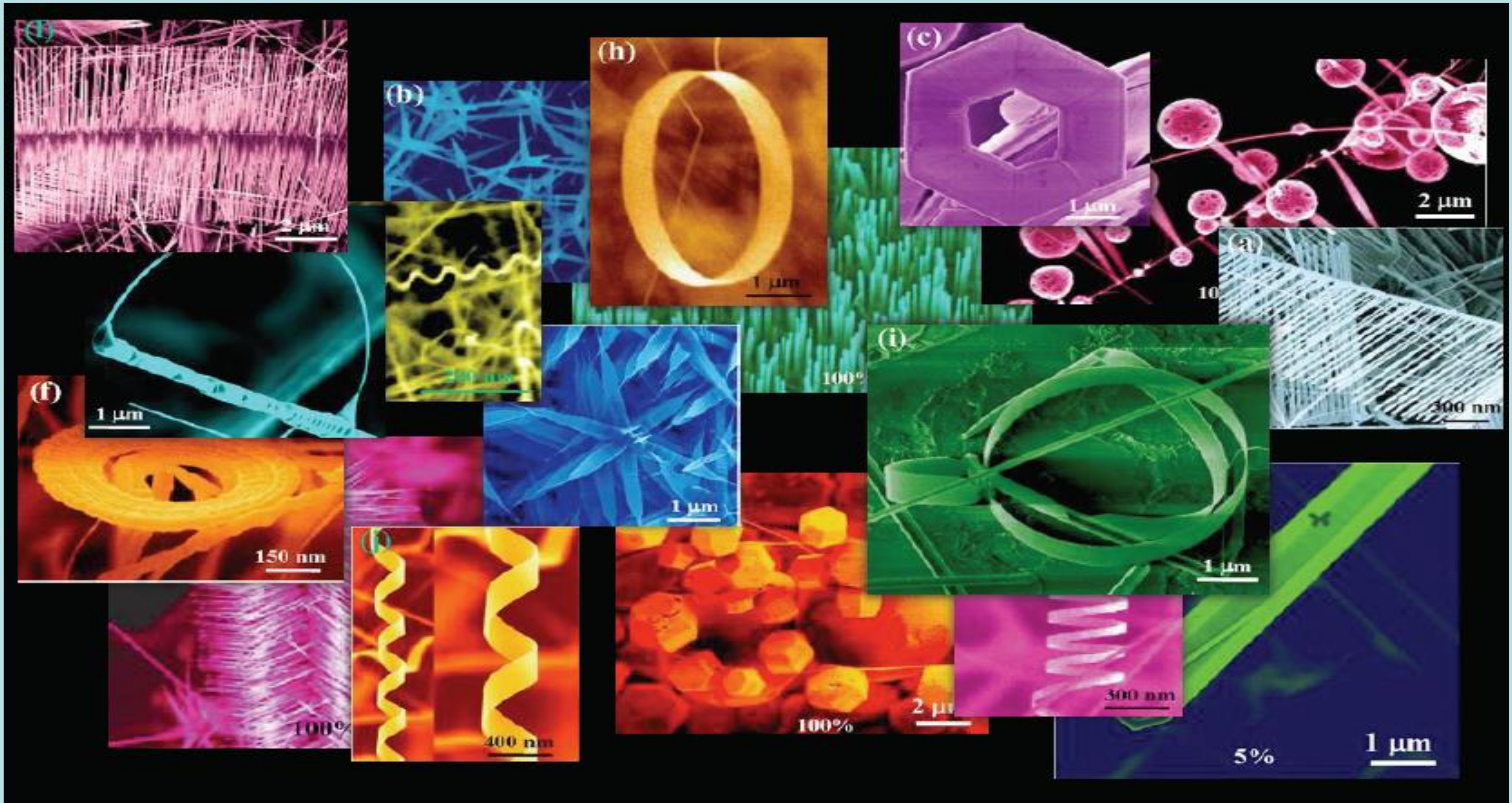
- Porosity

- *Dissolution*

SHAPE



Nano-ZnO: One chemistry, many shapes

Courtesy of Prof. Z.L. Wang, Georgia Tech

SHAPE

Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study

CRAIG A. POLAND[1], RODGER DUFFIN[1], IAN KINLOCH[2], ANDREW MAYNARD[3], WILLIAM A. H. WALLACE[1], ANTHONY SEATON[4], VICKI STONE[5], SIMON BROWN[1], WILLIAM MACNEE[1] AND KEN DONALDSON[1]*

Nature Nanotechnology May 20 2008

Specific properties
Carbon nanotubes

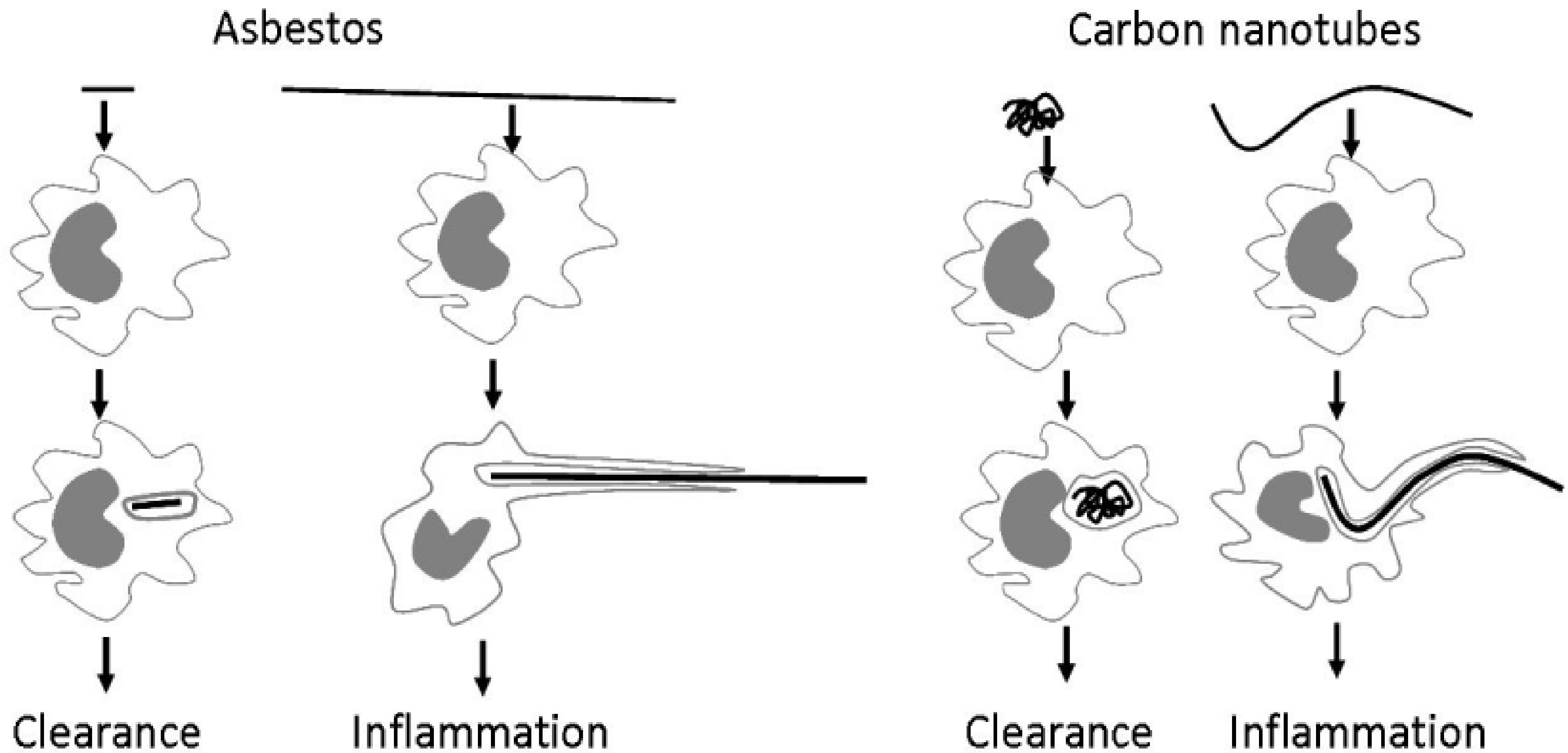
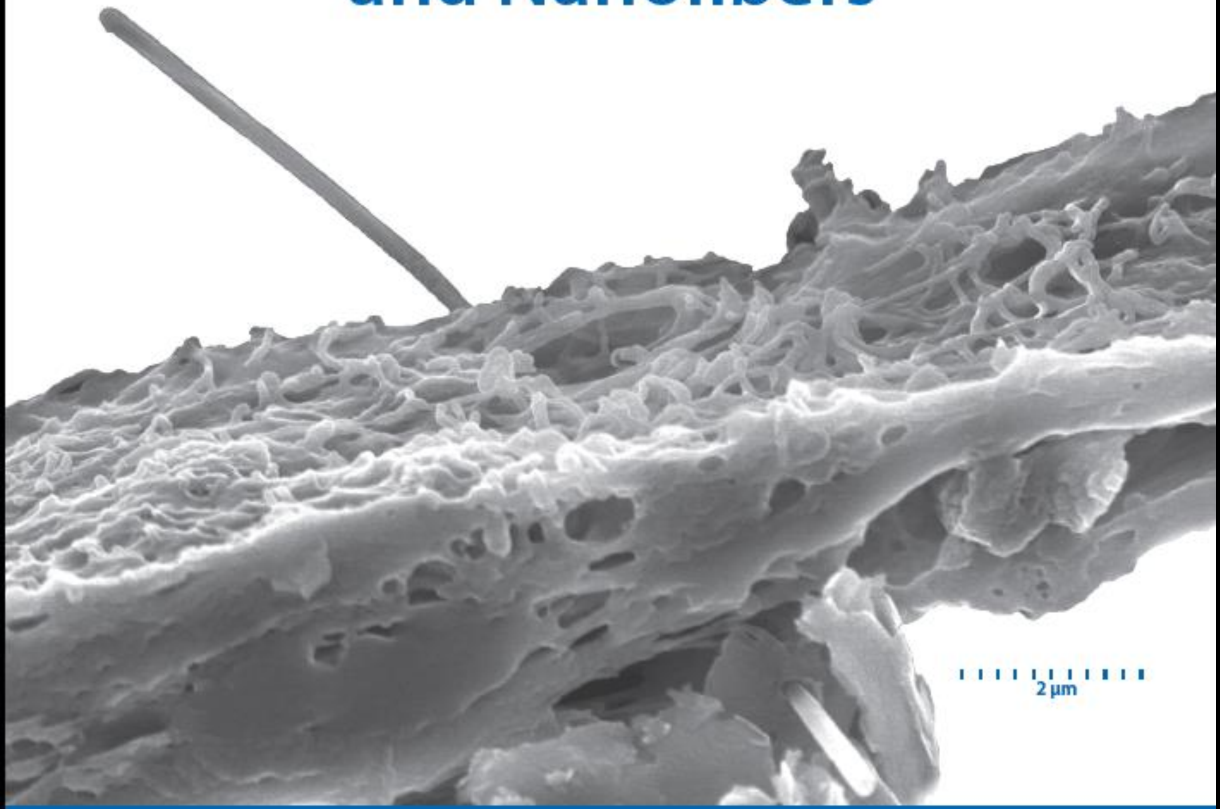


Figure 2 The frustrated phagocytosis paradigm as it relates to long and short fibres of asbestos (left) and various forms of carbon nanotubes (right). When confronted by short asbestos fibres or tangled, compact carbon nanotube 'particles' the macrophage can enclose them and clear them. However the macrophage cannot extend itself sufficiently to enclose long asbestos or long nanotubes, resulting in incomplete or frustrated phagocytosis, which leads to inflammation.

Donaldson et al. Particle and Fibre Toxicology 2010, 7:5

CURRENT INTELLIGENCE BULLETIN 65

Occupational Exposure to Carbon Nanotubes and Nanofibers



DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

SHAPE plays a role

- Delivery - bioavailibility
  - Inhalation & clearance
  - Cellular uptake
- Mechanical damage
  - Needle vs spheres
- Time of exposure
  - Excretion & Biopersistent

Recommended physicochemical properties to be characterized

- Size & size distribution
- Agglomeration / aggregation state
- Shape
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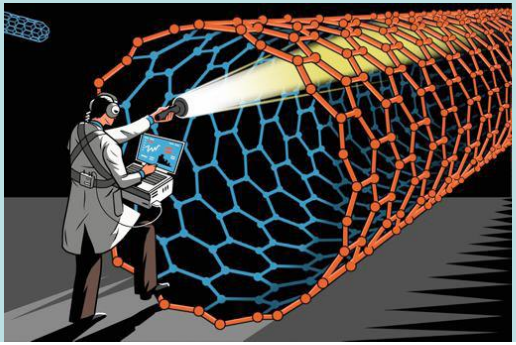
- Dissolution

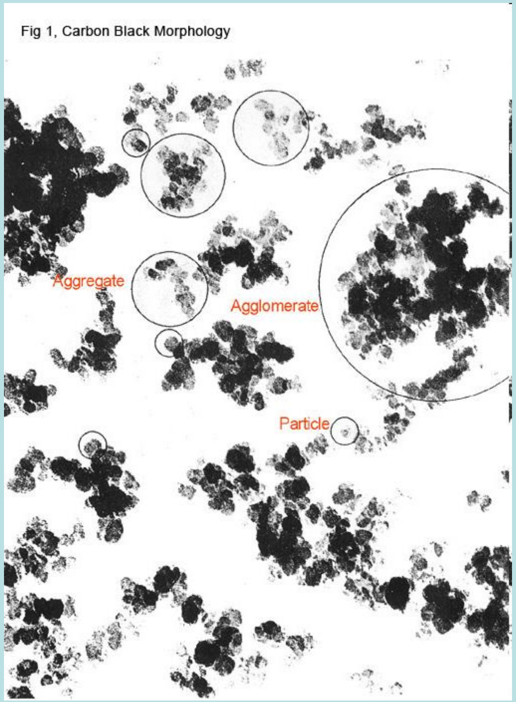
Principles for characterizing the potential human health effects from exposure to nanomaterials: elements of a screening strategy Oberdorster et al ; PFT 2005

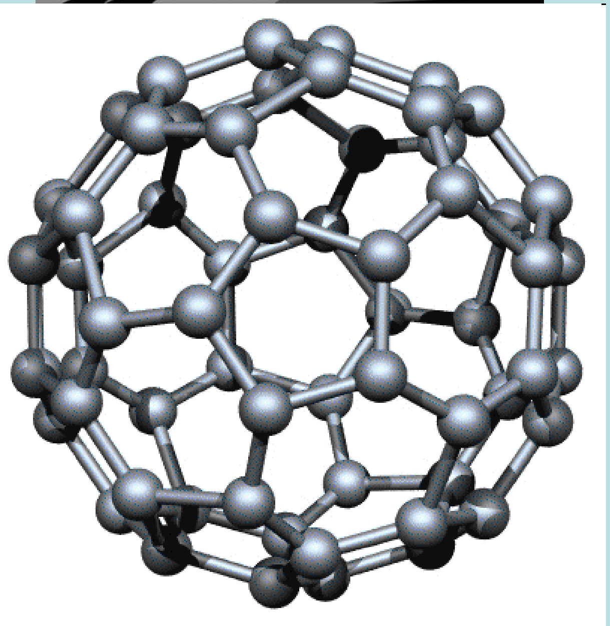
Crystal structure

- Carbon based materials (all “pure” C)

  Existing material:
  - [Carbon Black: filling material – “toner” ink]
  - Fullerenes (filling - lubricating)
  - Carbon nano tubes (filling – electronics?)







Crystal structure

- Crystal structure (or absence) is important
- Structure defects (lattice defects)
  - *Crystalline Silica (µm)*
  - *Carbon nanotubes*
- Impurities

Recommended physicochemical properties to be characterized

- Size & size distribution
- Agglomeration / aggregation state
- Shape
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- Surface chemistry
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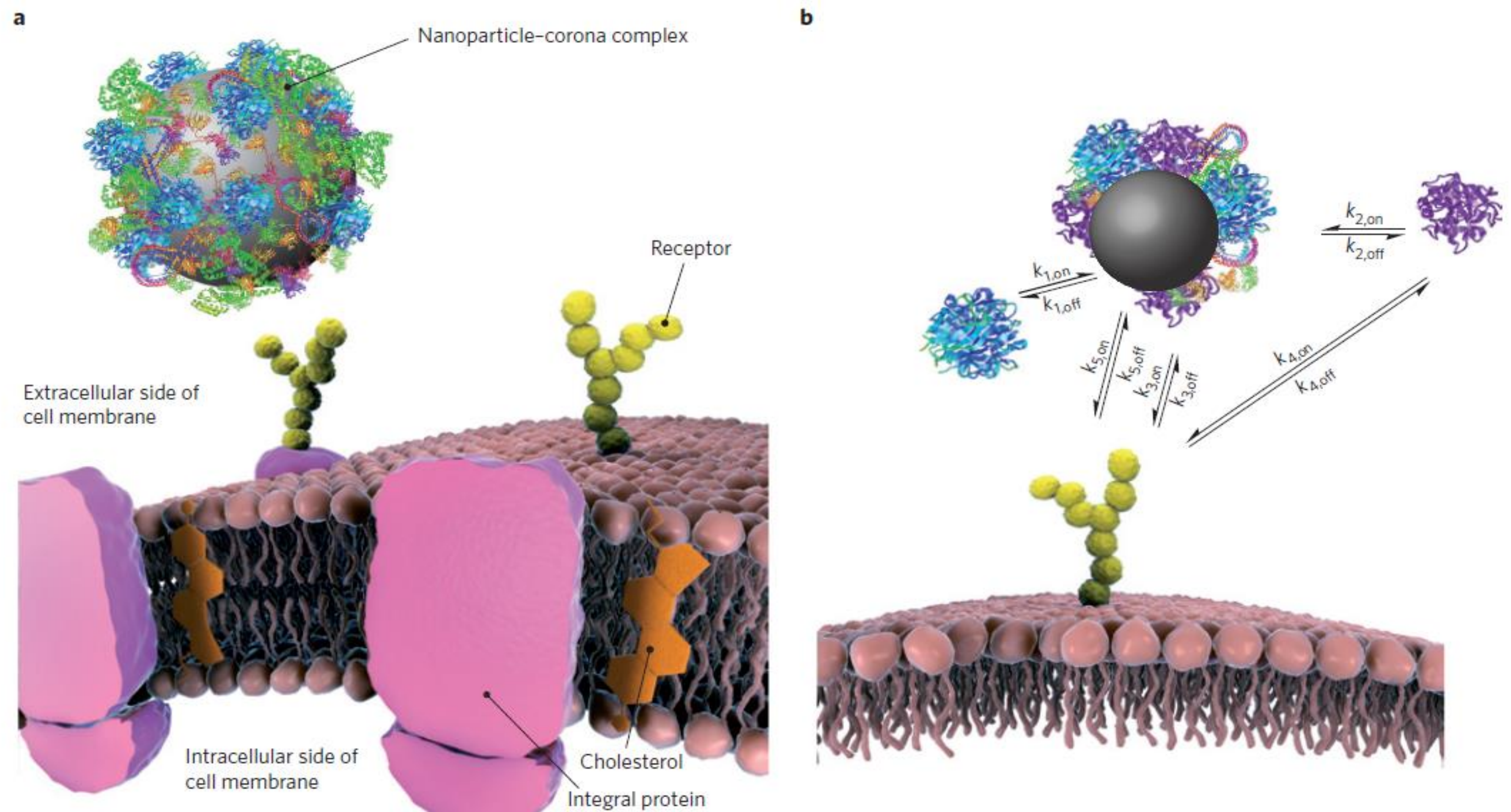
- Porosity

- *Dissolution*

nature nanotechnology
REVIEW ARTICLE
PUBLISHED ONLINE: 5 DECEMBER 2012 | DOI: 10.1038/NNANO.2012.207

Biomolecular coronas provide the biological identity of nanosized materials

Marco P. Monopoli[1,2], Christoffer Åberg[1], Anna Salvati[1,2] and Kenneth A. Dawson[1*]

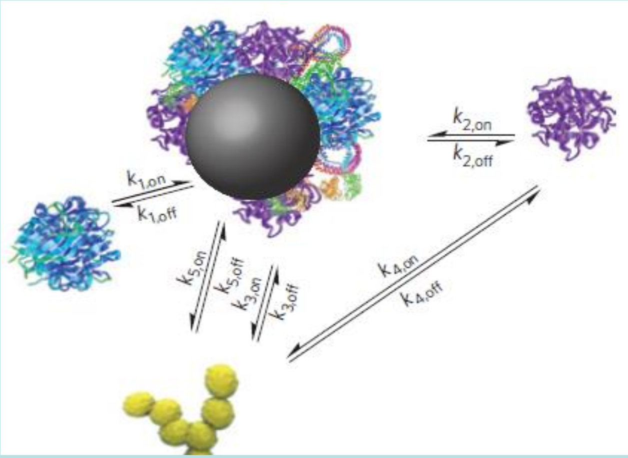


Surface Charge & Chemistry Conclusions

- Biodistribution/health effects depends (partly) on surface and **corona** formation

Corona

- Dependent on characteristics of NP & milieu (tissue…)
- Dynamic system
- Use to deliver compounds
- Use to suspend NP
  - Pulmonary surfactant, serum proteins…
- Changes characteristics of NP
  - Size, surface charge, …
- Corona can be used to identify the potential toxicity?



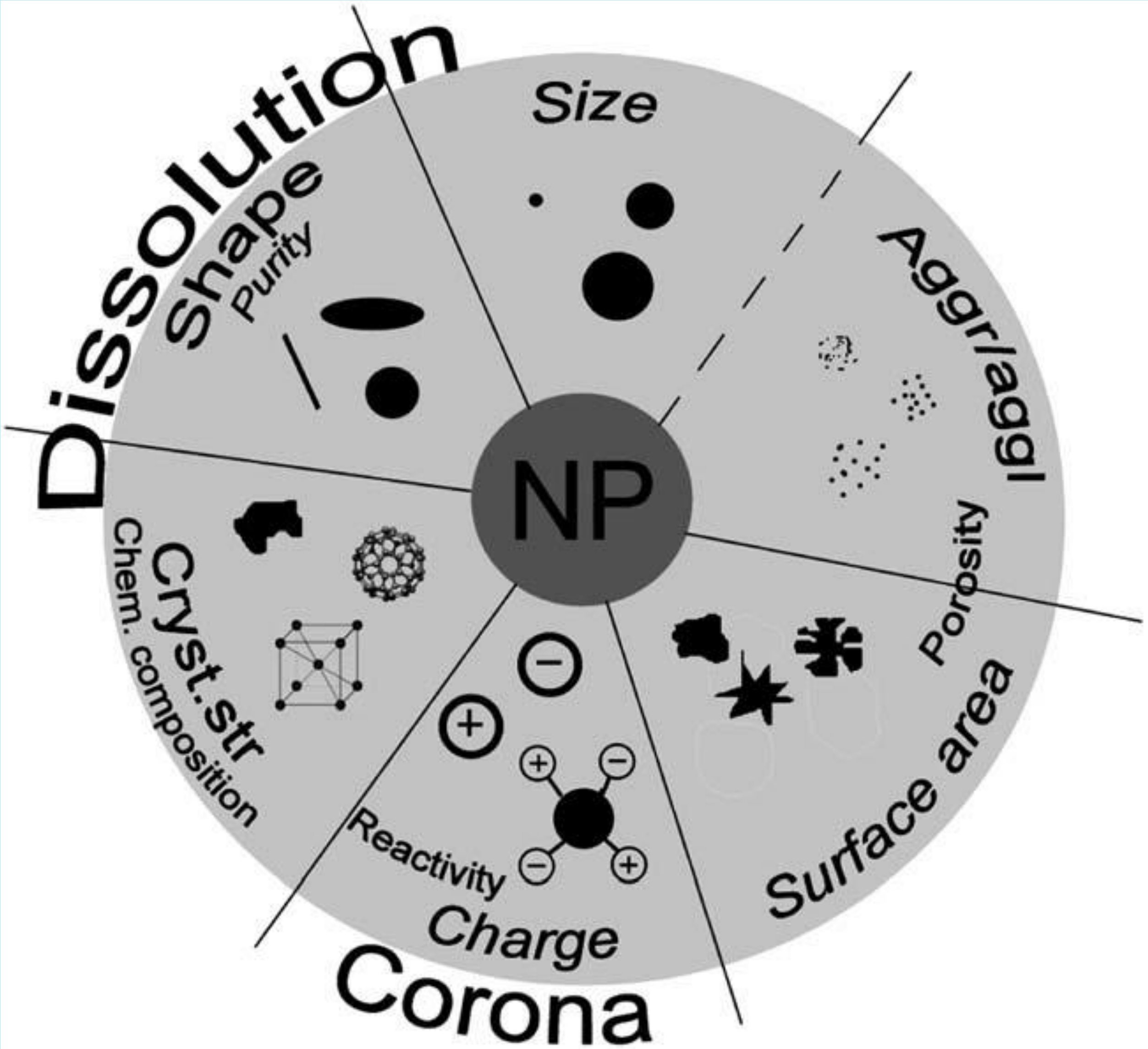
Recommended physicochemical properties to be characterized

- Size & size distribution
- Agglomeration / aggregation state
- Shape
- Crystal structure
- *Chemical composition*
- Surface area
- Surface chemistry
- Surface charge
- Porosity
- Dissolution

➔All affect biological effects

But not in all circumstances in the same extend

Interrelated effects

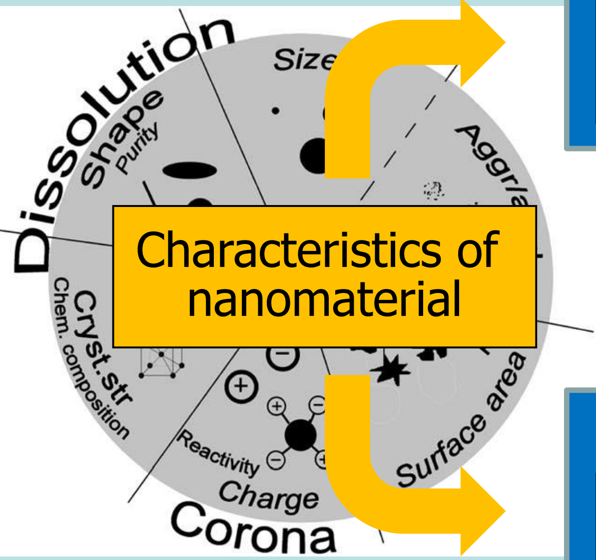

Dissolution
Size
Shape
Purity
Aggr/aggl
NP
Porosity
Cryst.str
Chem. composition
Surface area
Reactivity
Charge
Corona

KATHOLIEKE UNIVERSITEIT LEUVEN

Part 2: Risk assessment


NANO · PARTICLE
SAFETY TEST

Risk Characterisation/Assessment



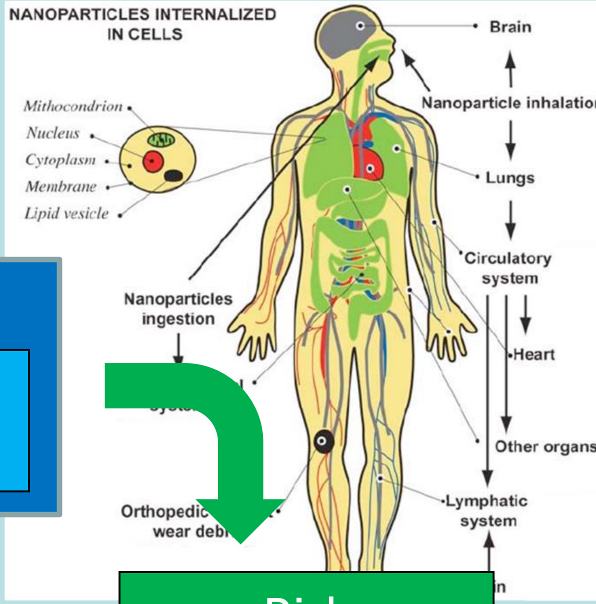
Characteristics of nanomaterial

Hazard assessment

Hazard identification	Dose response assessment

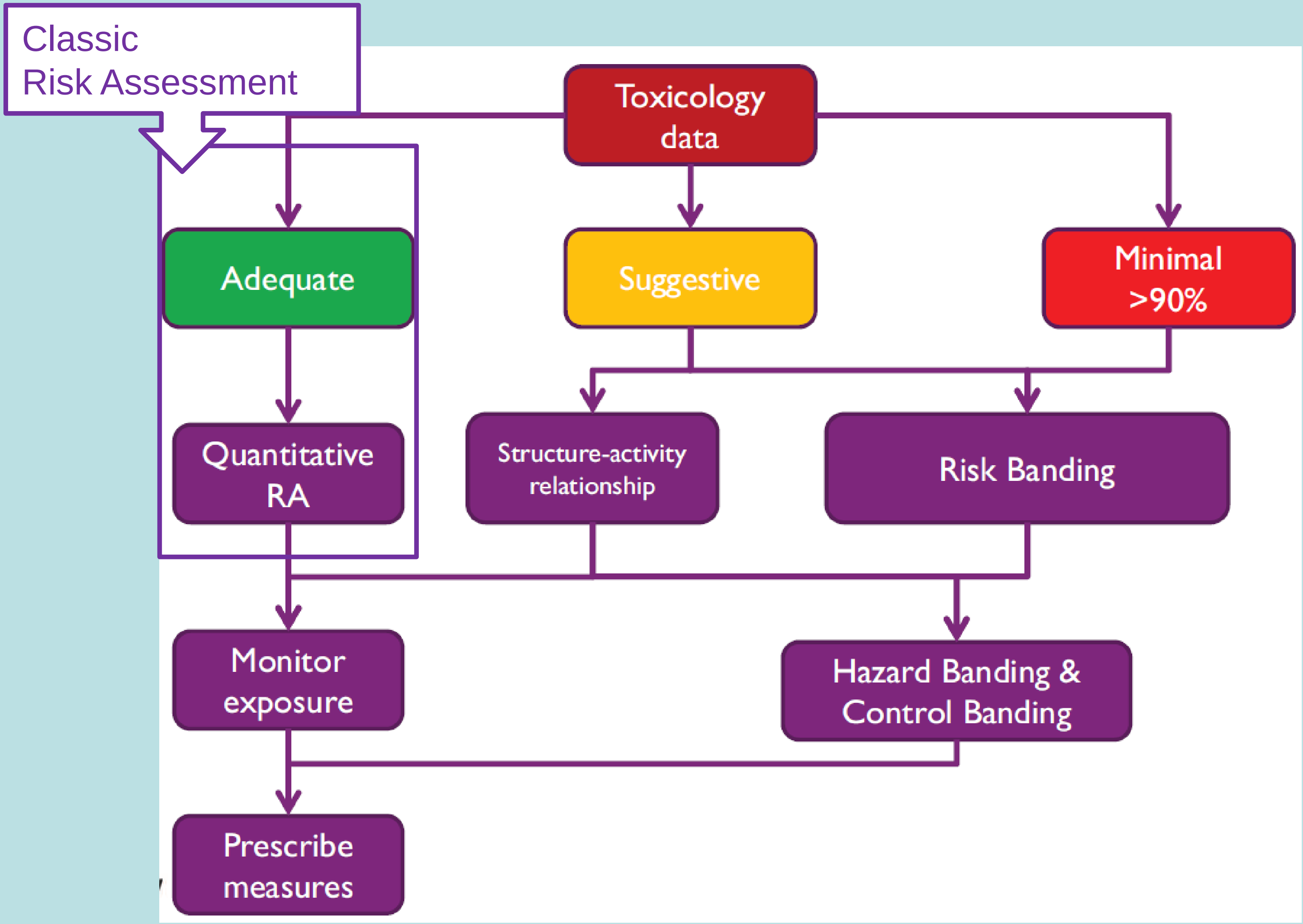
Exposure assessment

External dose	Internal dose



Risk characterisation

Is Hazard sufficient assessed



Control Banding respecting precautionary principle

Generic risk evaluation technique & control of those risks

Exposure/Hazard	**Low**	**Moderate**	**High**
Low			
Moderate			
High			

Consists of:

- grouping the health hazards=toxicity (risk bands),
- exposure potential (exposure bands)

➔ combining these elements to generate a set of controls (control bands)

Typical Control Bands Approach (as defined for chemicals)

1-General Ventilation
A good standard of general ventilation and good work practices.

2-Engineering Control
Typically local exhaust ventilation, but also includes other types of engineering controls, but not containment.

3-Containment
Completely contain or enclose the hazard, such as inside a glovebox.

4-Special
Expert advice is needed in selecting appropriate control measures.

ASSESS HAZARDS for NanoMaterials
Possible hazard criteria

HIGH Hazard

solubility and dispersion capacity

- Water insoluble material
- Biopersistant material
- Material with high dispersion capacity

size and shape.

- Powders with diameter < 10 nm
- High aspect ratio material
- Fibre/needle shaped material

toxicity of the (parent) material used?

- toxic parent material (carcinogenic, mutagenic, repro-toxic)
- contains transition metals (parent or surface treatment, catalyst)
- is functionalized with toxic, mutagenic, repro-toxic …
- tends to have highly reactive surface

ASSESS EXPOSURE for NanoMaterials
Nature of the work?

HIGH exposure potential:

Proximity & duration of manipulation.

- Manipulations within breathing zone < 0,5 m
- Duration manipulations = every day / whole day

Nature of the activity.

- Manipulations can disrupt the material (scraping, cutting, slicing, polishing, ...)
- Spraying of aerosols containing NM
- Mechanical cleaning (scraping, blasting, vacuum cleaning)
- Cleaning of dust collection systems to capture NM

Conclusions

- Exposure ~ natural (environmental NPs) but specific exposure at work & in consumer products
- Nanotechnology = use nano-specific features → specific physico-chemical characteristics
- Risk not well enough know

  →Careful handling / avoid exposure
- Risk banding can be used including the necessary caution

Thank You For Your Attention

Lung Toxicology (KULeuven)

- Ben Nemery
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