Why nanoparticles are different…

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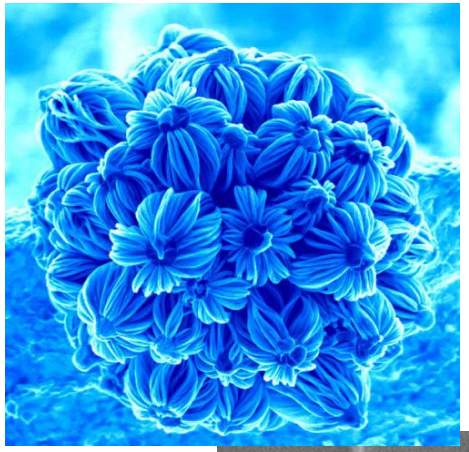
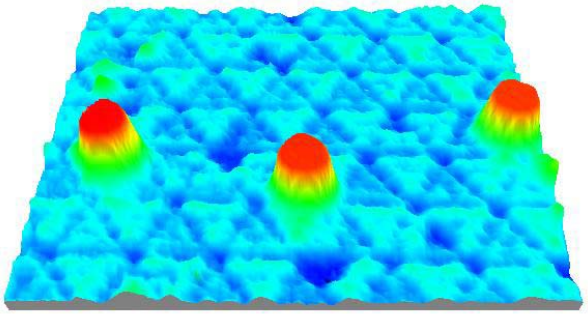
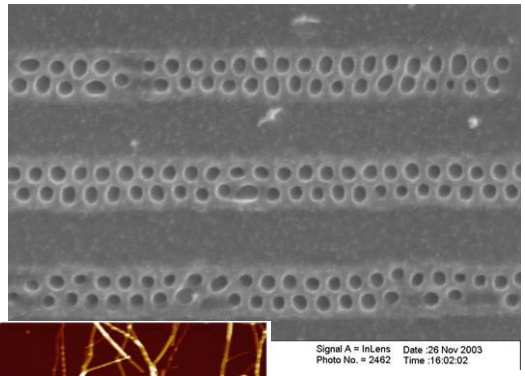
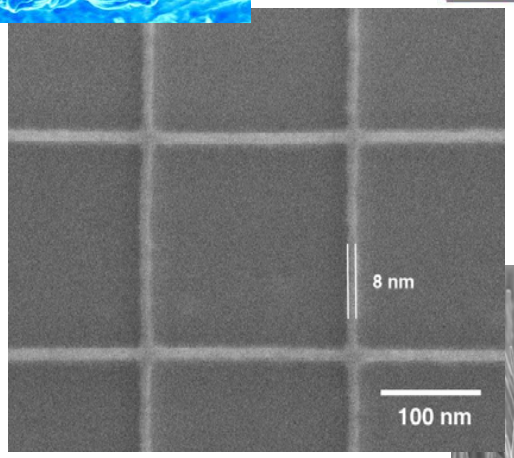
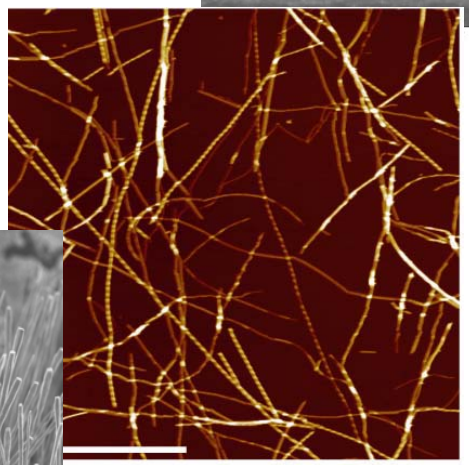
Nanostructures

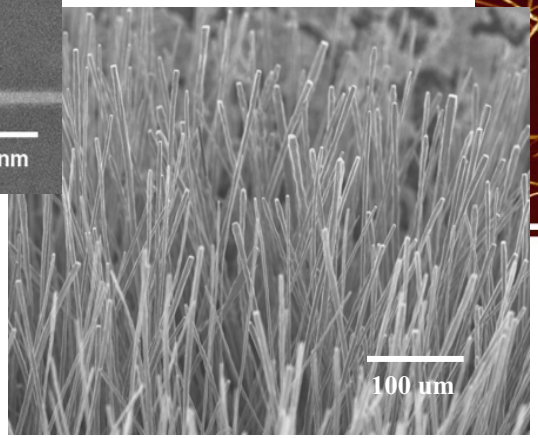












Scaling

- Surface area proportional to 1/size:

  Given $1cm^3$ of material

$1cm^3$ cube	$6cm^2$
$1\mu m^3$ cubes	$6m^2$
$1nm^3$ cubes	$6000m^2$

- Proportion of surface atoms:

$1cm^3$ cube	1 in 10^7
$1mm^3$ cube	1 in 10^3
$1nm^3$ cube	80%

Consequences

- Surface properties dominate:

  Adsorption, catalysis, chemical activity and reactivity

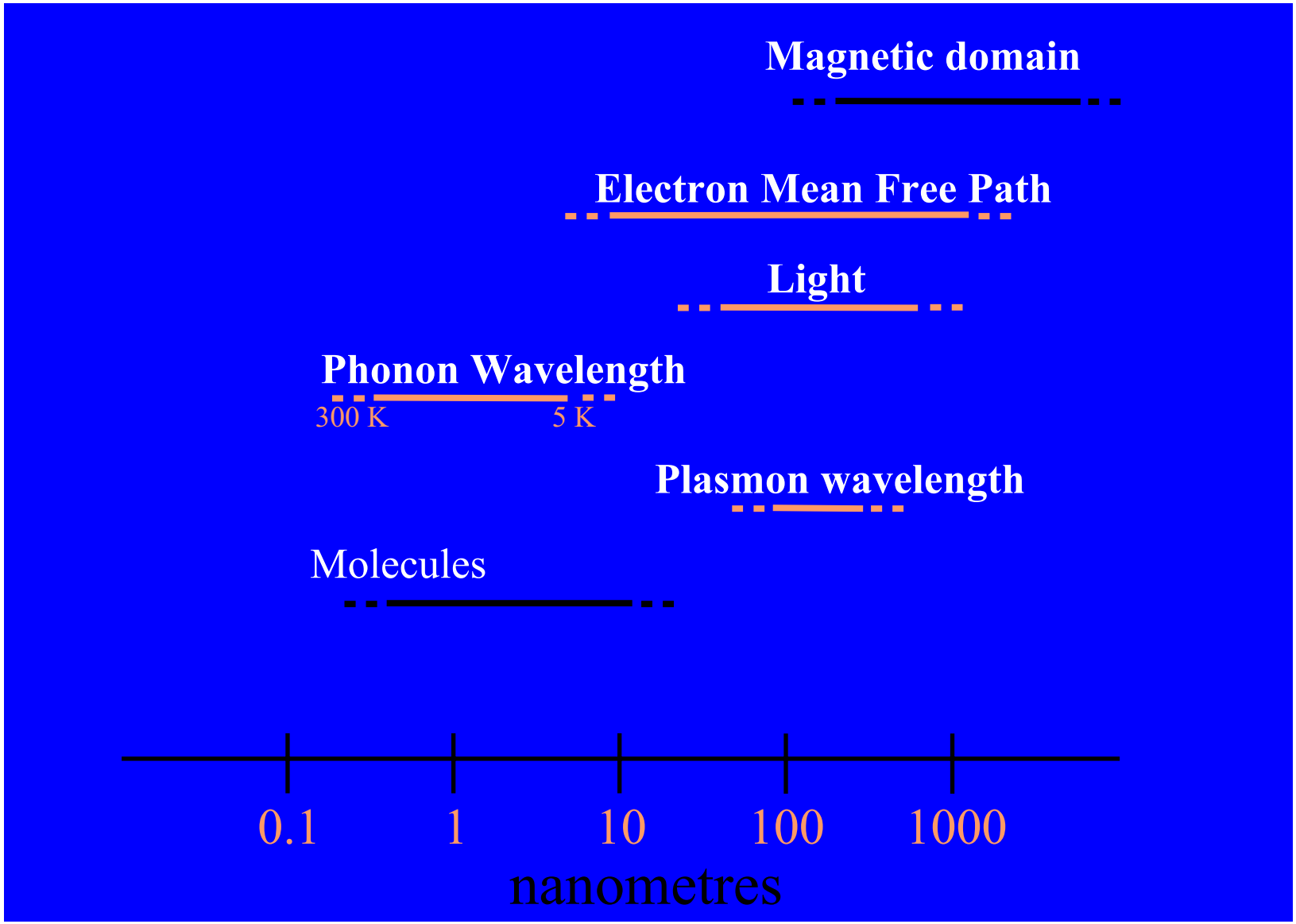
- Bulk properties mediated by surface in two ways:

  Coupling to surface states or properties.

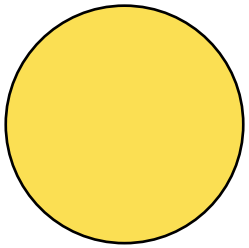
  Surface defines boundary conditions on quantised physical properties

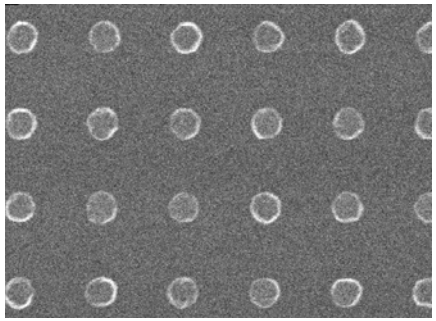
Properties depend upon size and shape

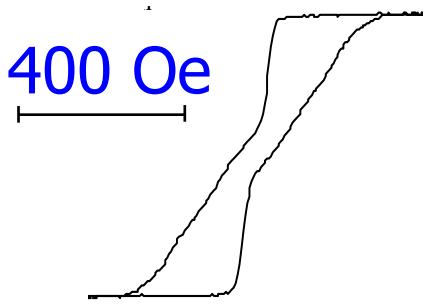
Length scales

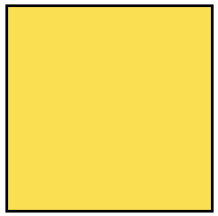


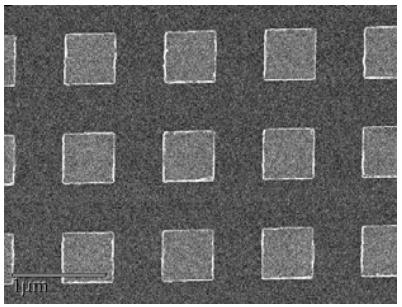
Shape, size and magnetism

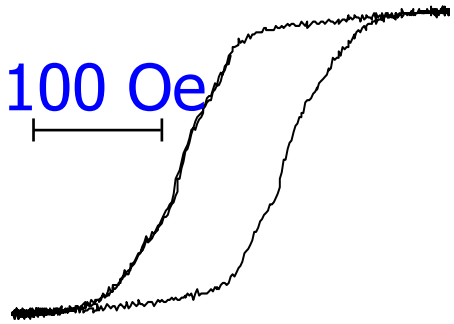


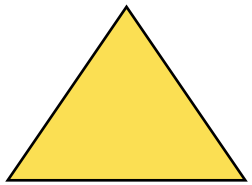




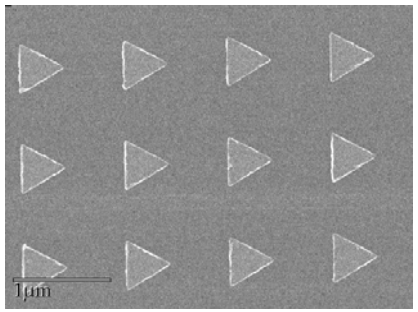


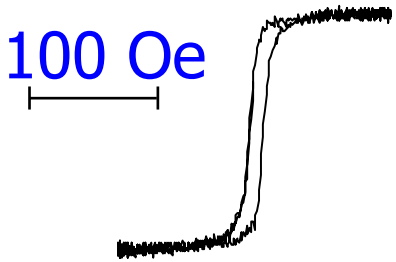






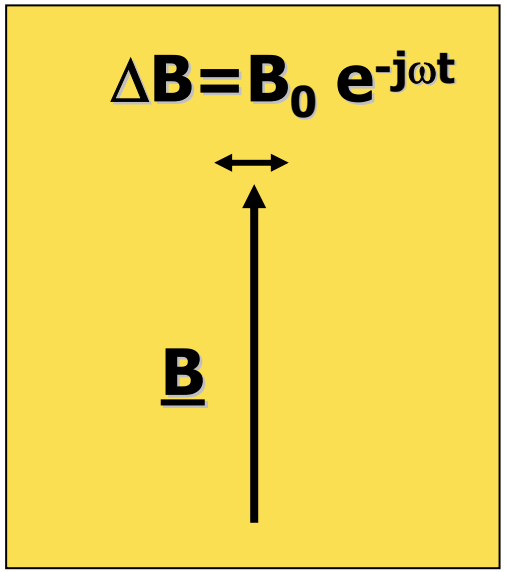
300nm

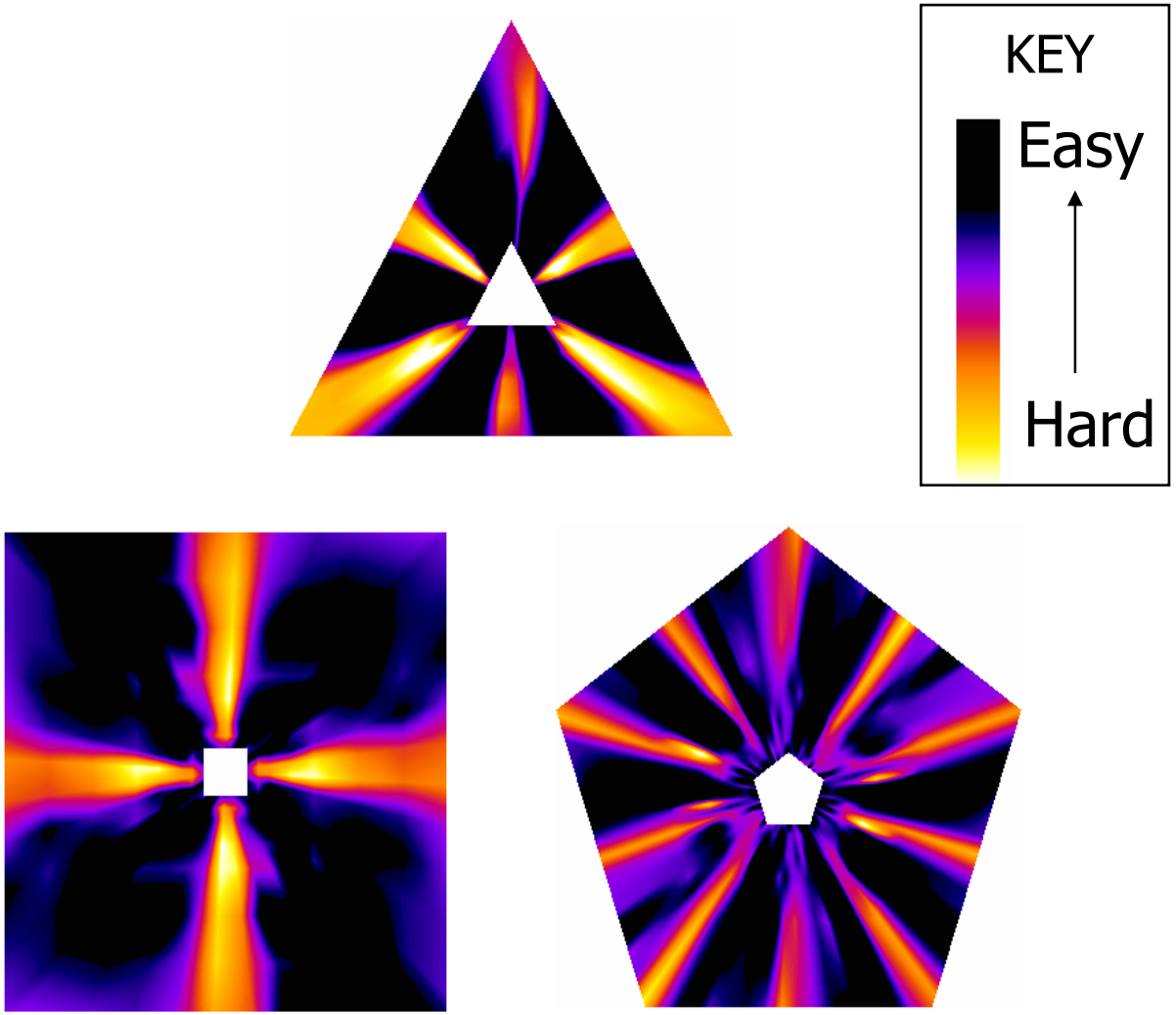




2.5nm thick Permalloy

Magnetic anisotropy





Optical emission from Ag particles

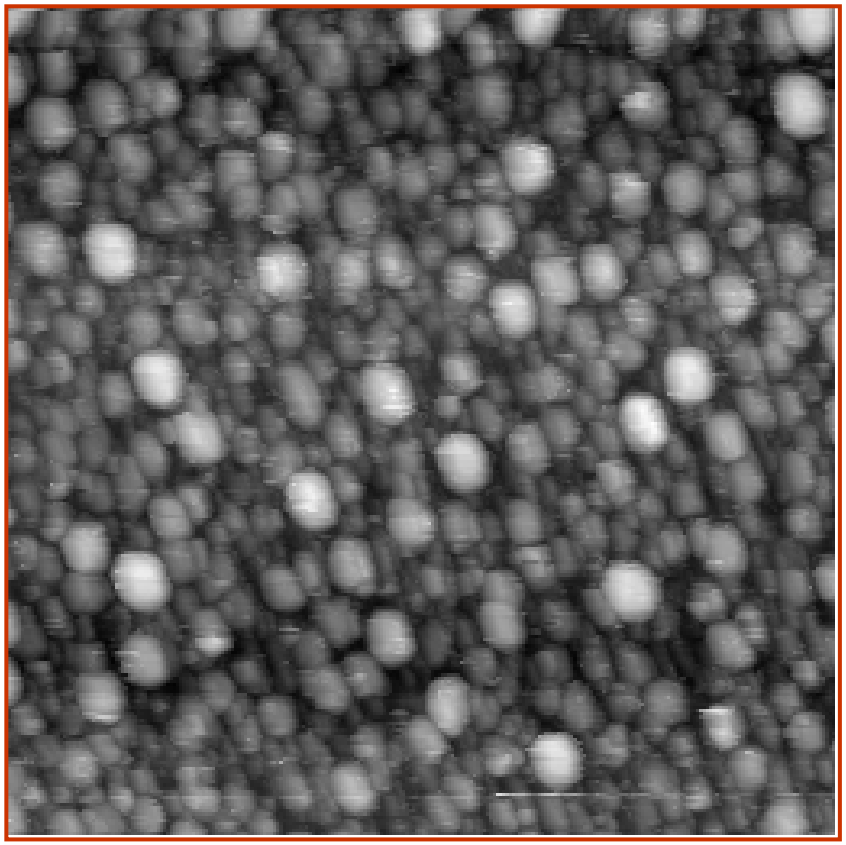
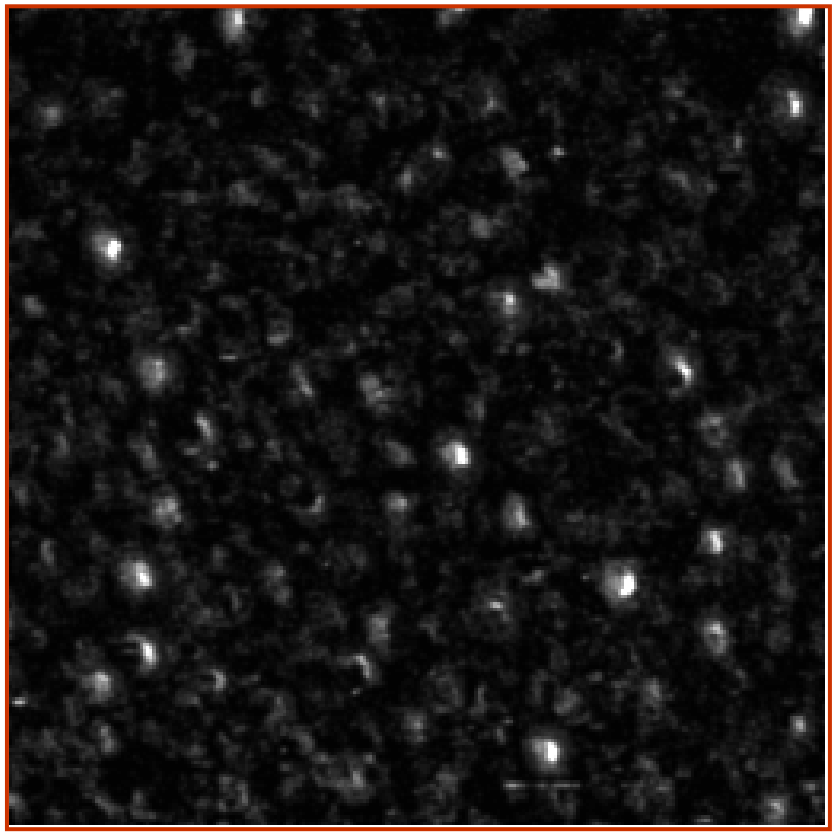


Image size: 1500Å
Height range: 38Å.
Current: 10nA, tip bias: -3.1V



Photon map: quantum efficiency 0 - 3.0×10^{-5}.
Tip radius -40Å,
particle heights: up to 30Å.

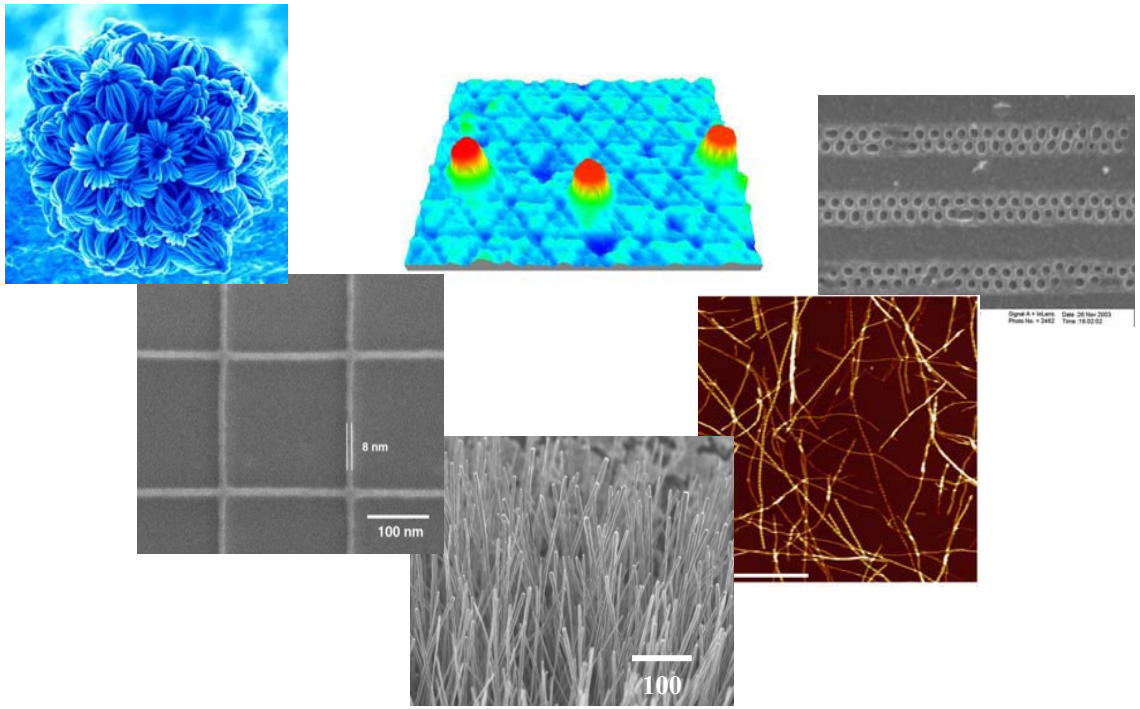
Physical properties

- Physical properties can change with shape and size where there is some fundamental relevant length scale commensurate with scale.

- For singular dependence upon shape and size, coupling with nearest neighbours or matrix must be controlled.

Challenges

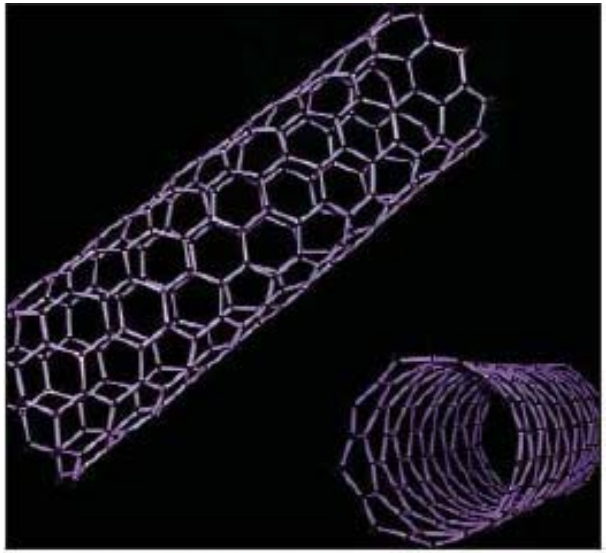
- **Characterisation/metrology**
- **Nomenclature**
- **Standards**
- **Toxicity**

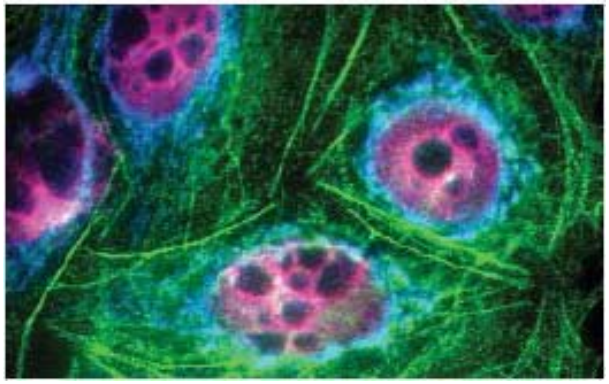


Issues in Nanotoxicology

- Total surface area presented to the target organ
- Chemical reactivity of the surface
- Physical dimensions
  - Allow to penetrate, prevent removal
- Solubility

- All vary with particle size





Quantum dots inside cells

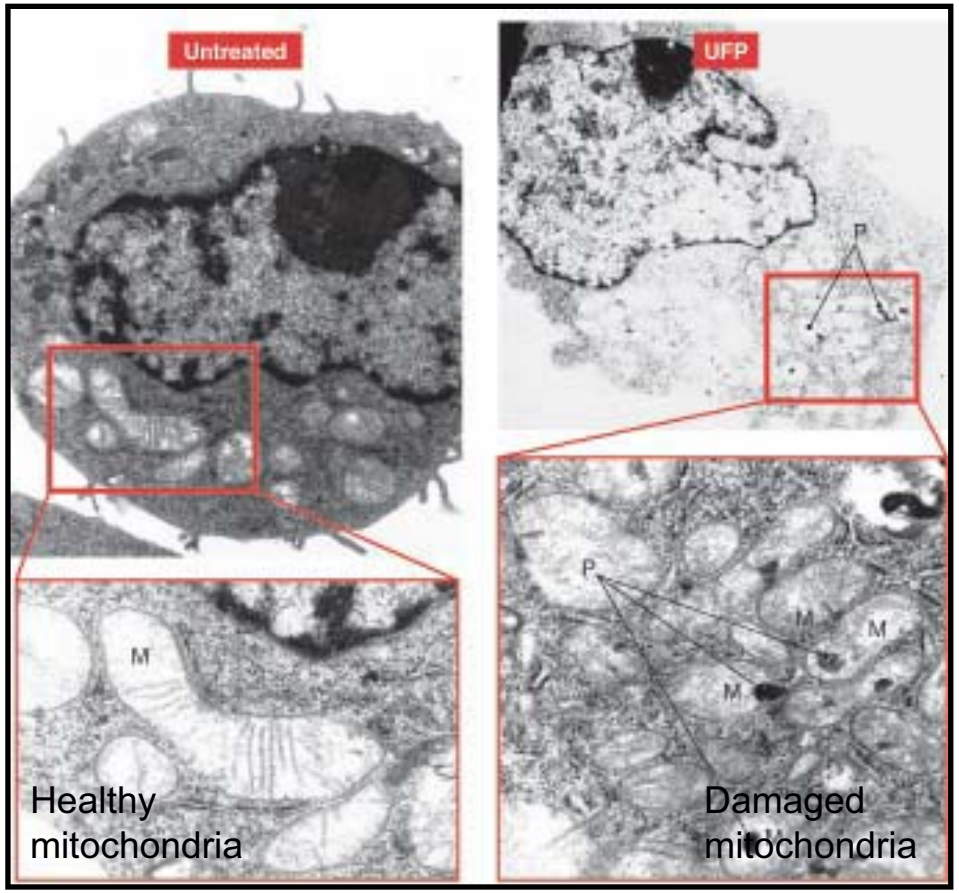
Evidence for Nanotoxicity

•nC_{60} causes lipid peroxidation in the brain of Sea Bass Oberdorster *et al*., 2004

•Ultrafine pollution particles damage mitochondria in human macrophages Nel et al., 2005

•Exposure of human keratinocytes and bronchial epithelial cells to a mixture of carbon nanotubes and iron particles increases levels of cell damage and apoptosis Shvedova et al.

•Mechanisms remain unclear



Nel *et al*., *Science*, May, 2005