



Institute of Actuaries of Australia

XIth Accident Compensation Seminar 2007

Nanotoxicology and Implications for OH&S

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A Definition of “Nanotechnology”

“ – the manipulation, precision placement, measurement, modelling or manufacture of sub-100 nanometre scale matter.”

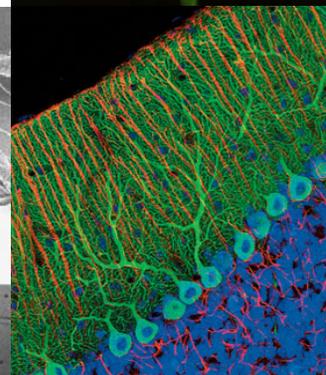
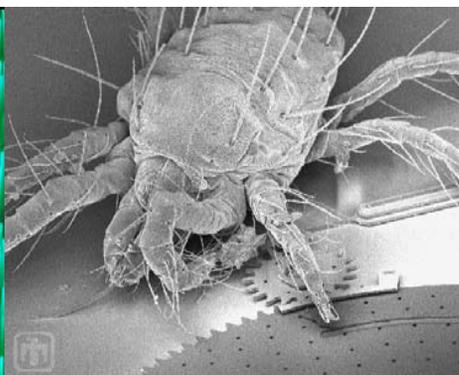
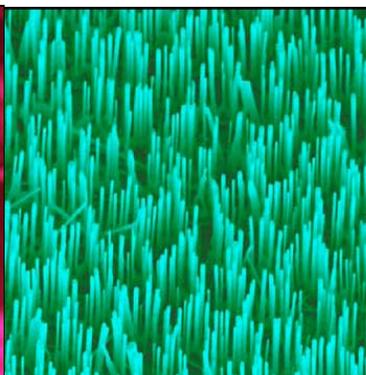
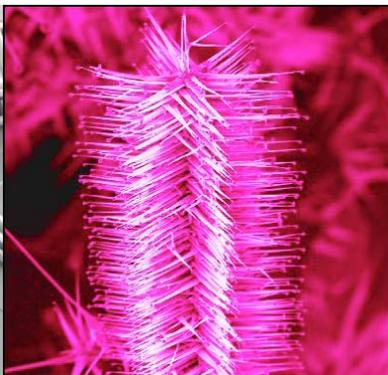
[.....at least in one dimension]

(Borm et al, 2006)

– ORIGIN from the Greek nanos meaning ‘*dwarf*’.

The “*real*” definition of nanotechnology

- new and unexpected properties
- the next “*industrial revolution*”
- will have a broad impact on our lives
- is already here !!



For example,
nanoparticle-based
products are already
reaching the
marketplace.

In North America,
and, more generally

....



“.. by 2014, a whopping \$2.6 trillion worth of manufactured goods will incorporate nanotechnology.”

(Service, 2006).

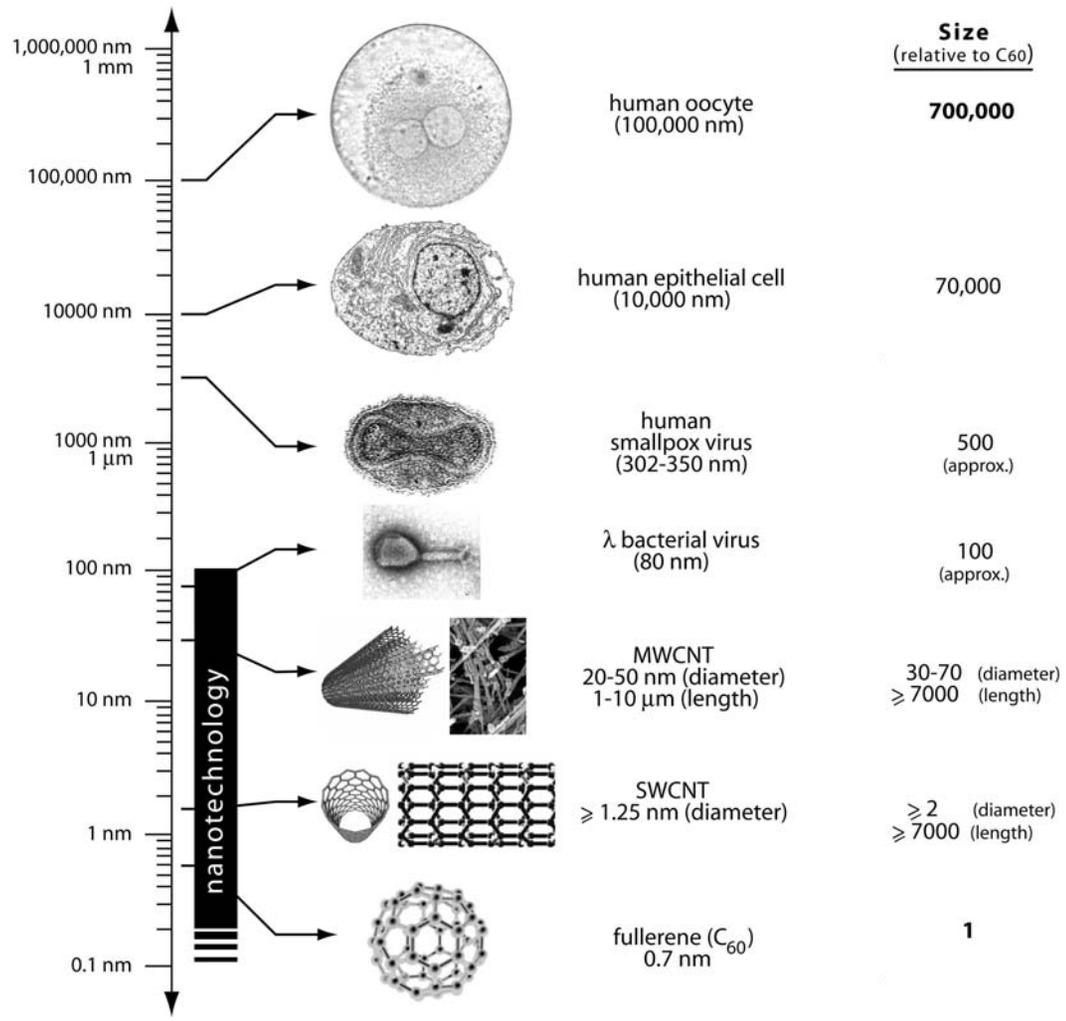
- stain-free clothing
- sunscreens and cosmetics
- longer-lasting tennis balls
- lightweight, stronger tennis racquets & bicycles
- scratch-proof and glare-reducing coatings
- corrosion and radiation-resistant paints and coatings
- specialist technical applications (e.g. medical diagnostics & imaging).

Some reality checks:

- nanotechnology's commercial applications are still relatively limited.
- nanoparticles are mostly combined with traditional materials to improve existing properties.
- major commercial advances will come with new functionalities.

(Innovest 2005).

Relative Scales



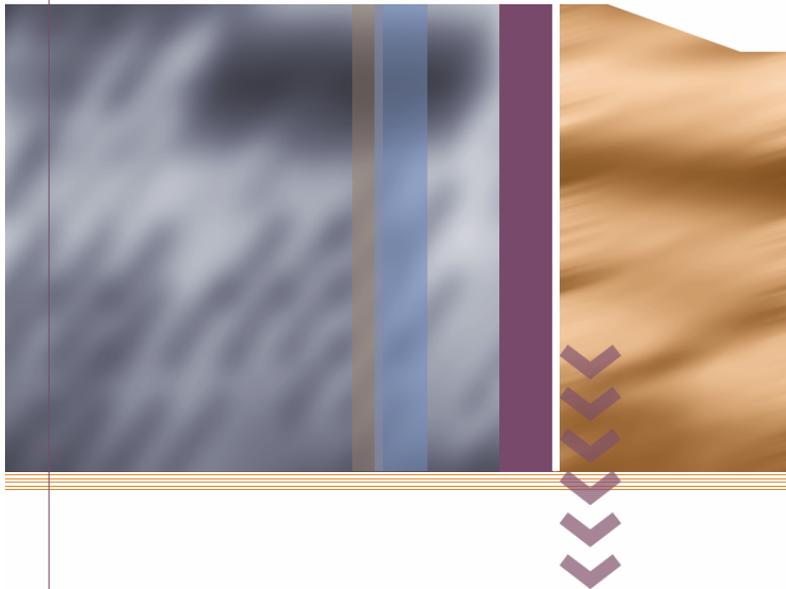
(An analogy to illustrate these sizes will be given)

Consequently, “***Nanotoxicology***”
becomes:

- *the study of the adverse health effects of nanoscale materials.*

A REVIEW OF THE POTENTIAL OCCUPATIONAL HEALTH & SAFETY IMPLICATIONS OF NANOTECHNOLOGY

July 2006



Australian Government
Australian Safety and Compensation Council

2006 Australian Safety and Compensation Council Report

<http://www.ascc.gov.au/ascc/AboutUs/Publications/ResearchReports/AReviewofthePotentialOccupationalHealthandSafetyImplicationsofNanotechnology.htm>

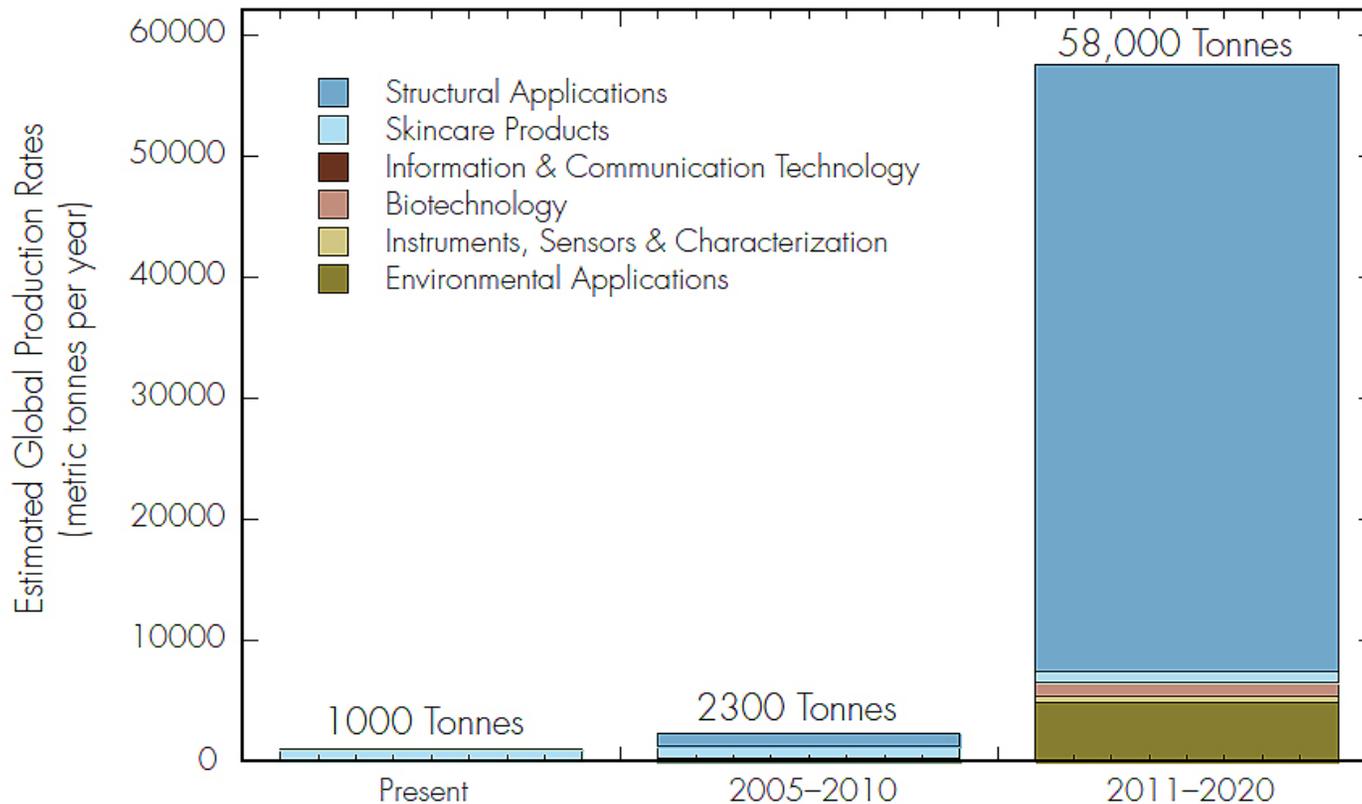
(Commissioned by Dr. Howard Morris, DEWR).

Major conclusions from this - *and other* - reports.

- Properties of NPs change as quantum scales are reached.
 - e.g. CNTs become stronger than steel.
- Production volumes are expected to rise (dramatically).
- Some “smoking guns” already.
 - e.g. CNT tumourigenesis?, QD ROS production, systemic uptake?
- *“For most manufactured NPs no toxicity data are available.”*

(Born et al., 2006)
- All reports recommend alterations to *status quo* practices of government regulatory agencies.

Predicted increases in global production of engineered NPs.



Nanoparticle Origins

- **Natural Nanoparticles:**
Viruses, bushfire smoke/ash, sea spray, volcanic ash
- **Incidental Nanoparticles (human):**
Cooking smoke, diesel & combustion exhausts, welding fumes, etc.
- **Deliberate Nanoparticles (engineered):**
Metal oxide nanopowders (e.g. TiO_2), nanotubes, dendrimers, nanocapsules, quantum dots, fullerenes.

Broad Nanoparticle Classifications

- Fullerenes, C_{60} , “buckyballs”
- Metal oxide nanopowders
- Carbon nanotubes (single- & multi-walled)
- Quantum dots
- Nanowires
- Nanocrystals
- Others
 - dendrimers, graphene sheets, “pea-pods” , nanostrand arrays, etc., etc.

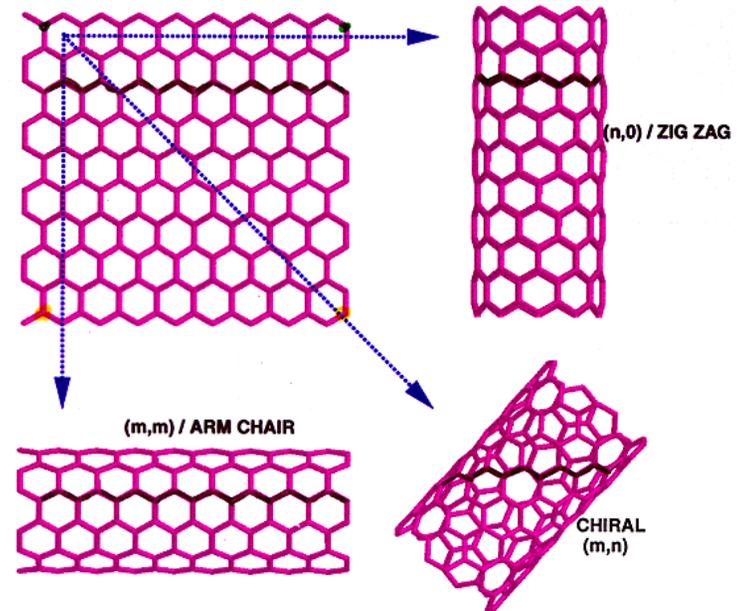
A Toxicologist's Viewpoint

- NP toxicity now depends on **size** and **shape**
 - as much as on the more conventional factors of chemical structure and composition.
- NP unique properties **may not** be easily predicted.
- These novel properties may be different to what humans and the environment have seen previously.
- The capability of our bodies to recognise - *and appropriately respond to* - NPs is mostly unknown at this stage.

Carbon Nanotube (CNT) Structures and Constituents.

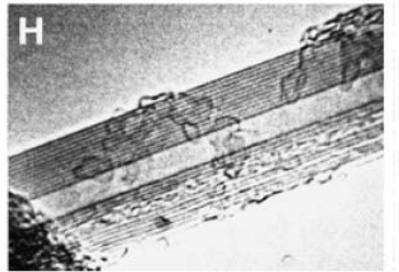
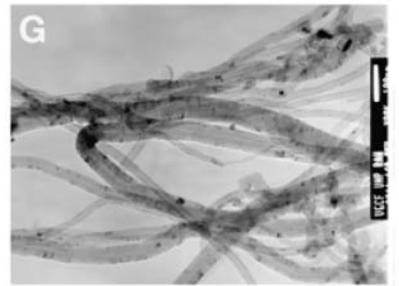
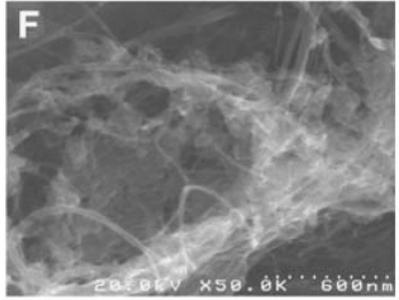
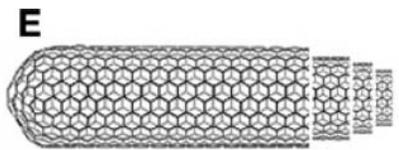
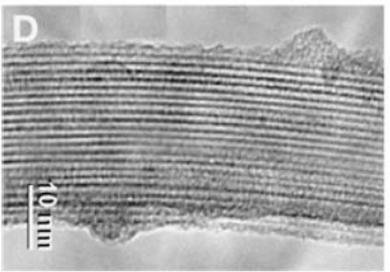
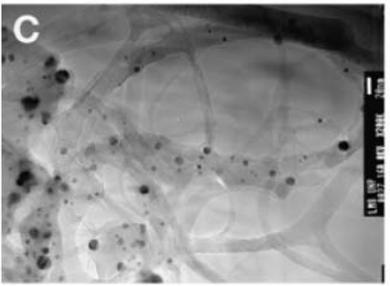
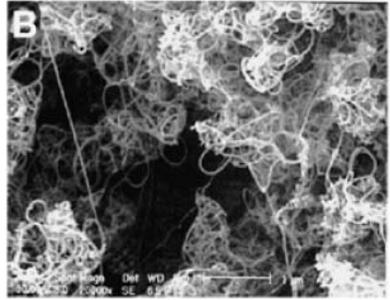
- CNTs are equivalent to a two dimensional graphene sheet rolled into a tube.
- Diameter as small as 1 nm.
- Length up to microns.
- CNTs have a high **aspect ratio**.
- Typically contain impurities such as toxic metal ions.

• STRIP OF A GRAPHENE SHEET ROLLED INTO A TUBE



SWCNT

single wall
carbon
nanotube



MWCNT

multi-wall
carbon
nanotube

(Lam et al, 2006)

A) to (D): SWCNTs; (E) to (H): MWCNTs. Scanning electron microscope (SEM) images show SWCNT (B) and

CNTs can be woven into fabric!

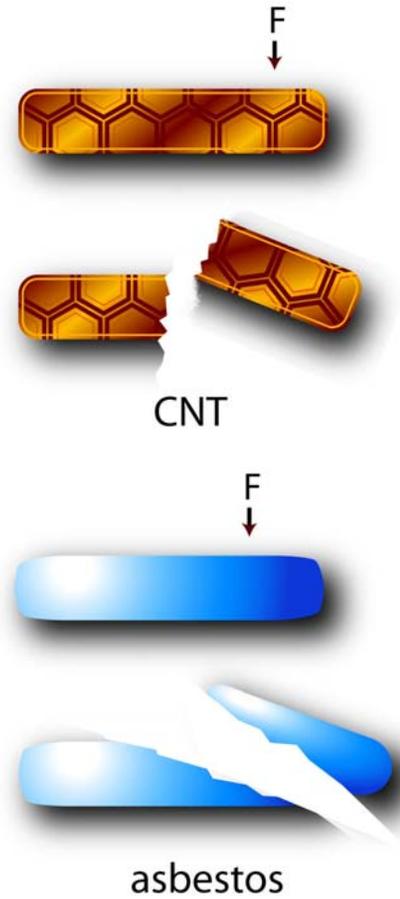
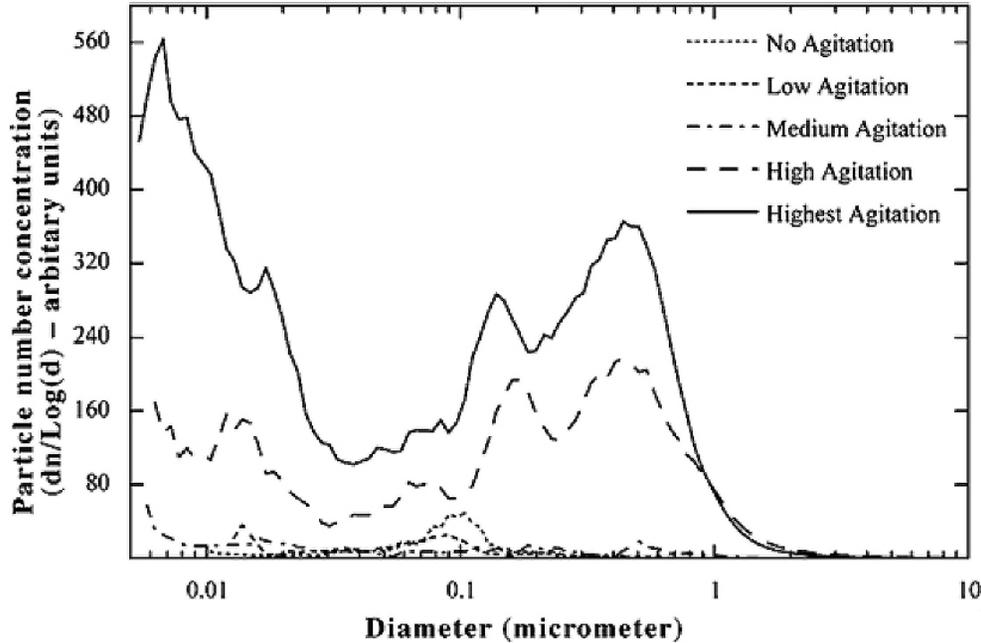
Snapshots From the Meeting >>



First nanotube textile. Not a bad way to get your career in science off the ground. Plano, Texas, high school student Diane Chen is shown here weaving the first ever carbon nanotube-based textile. For a summer research project



.... but can also break-down and aerosolise.



(Baron et al., 2003)

A Precautionary Note

- from asbestos.

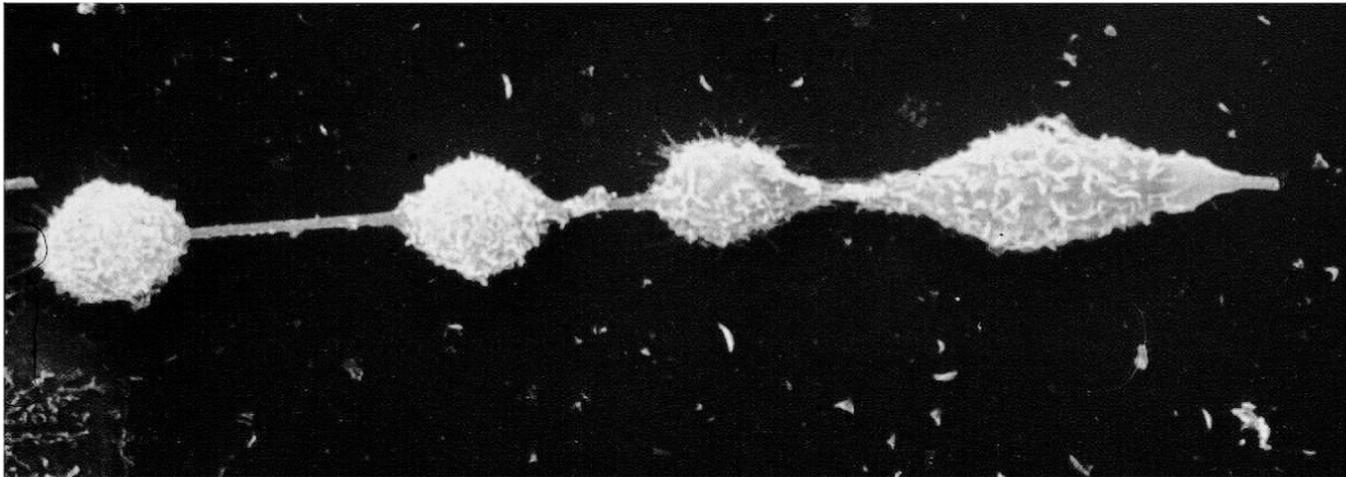


Figure 5.2 Four macrophages attempting to ingest an asbestos fibre (approximately 80 μm long). (Royal Society Report 2004; Professor Ken Donaldson, Edinburgh).

Particle size determines where deposited.

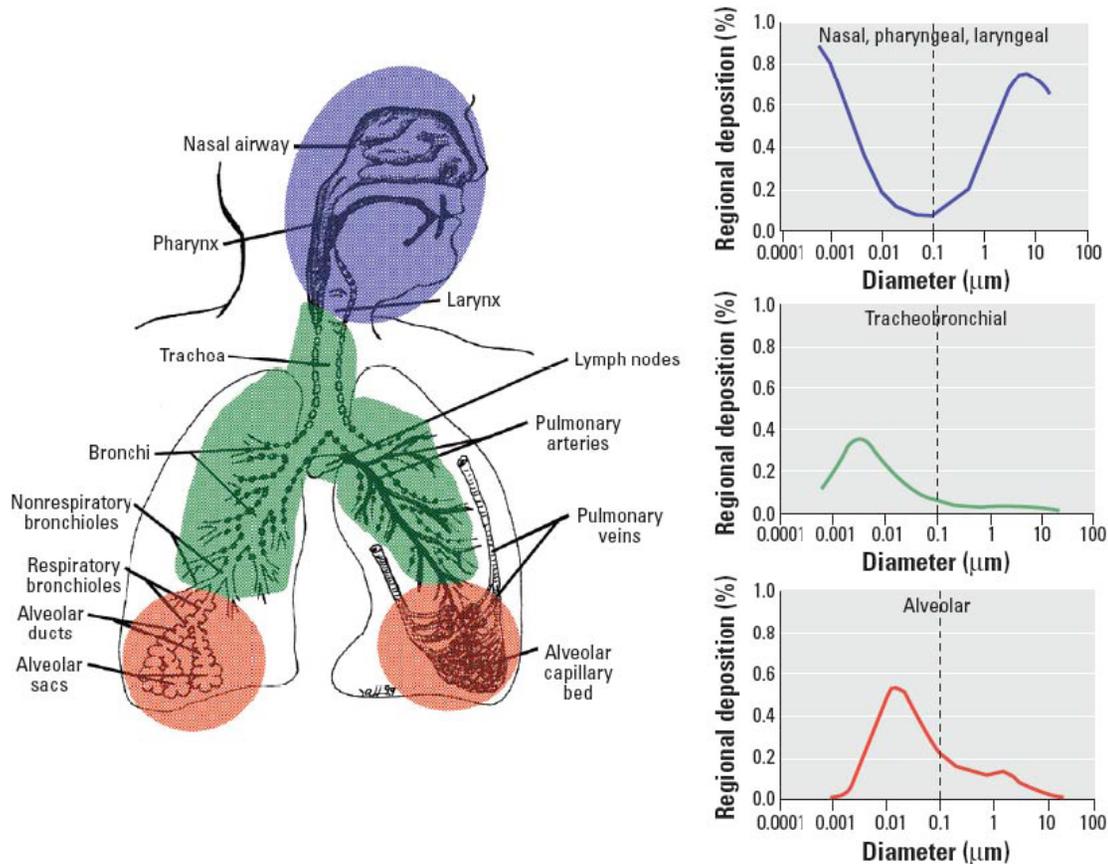
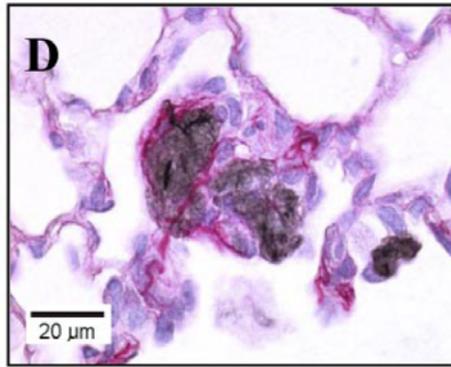
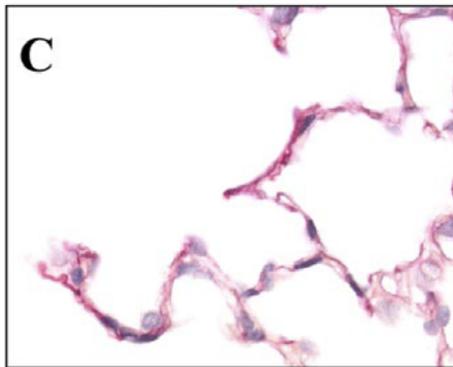
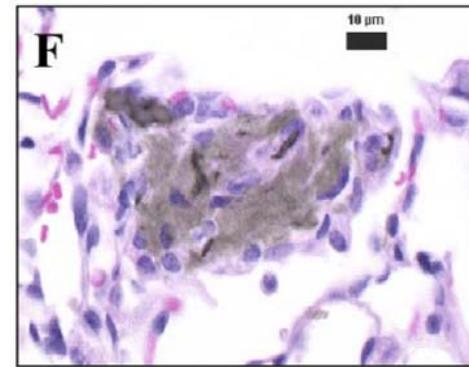


Figure 8. Predicted fractional deposition of inhaled particles in the nasopharyngeal, tracheobronchial, and alveolar region of the human respiratory tract during nose breathing. Based on data from the International Commission on Radiological Protection (1994). Drawing courtesy of J. Harkema.

SWCNTs can produce an unusual inflammatory and fibrogenic response in the mouse lung.

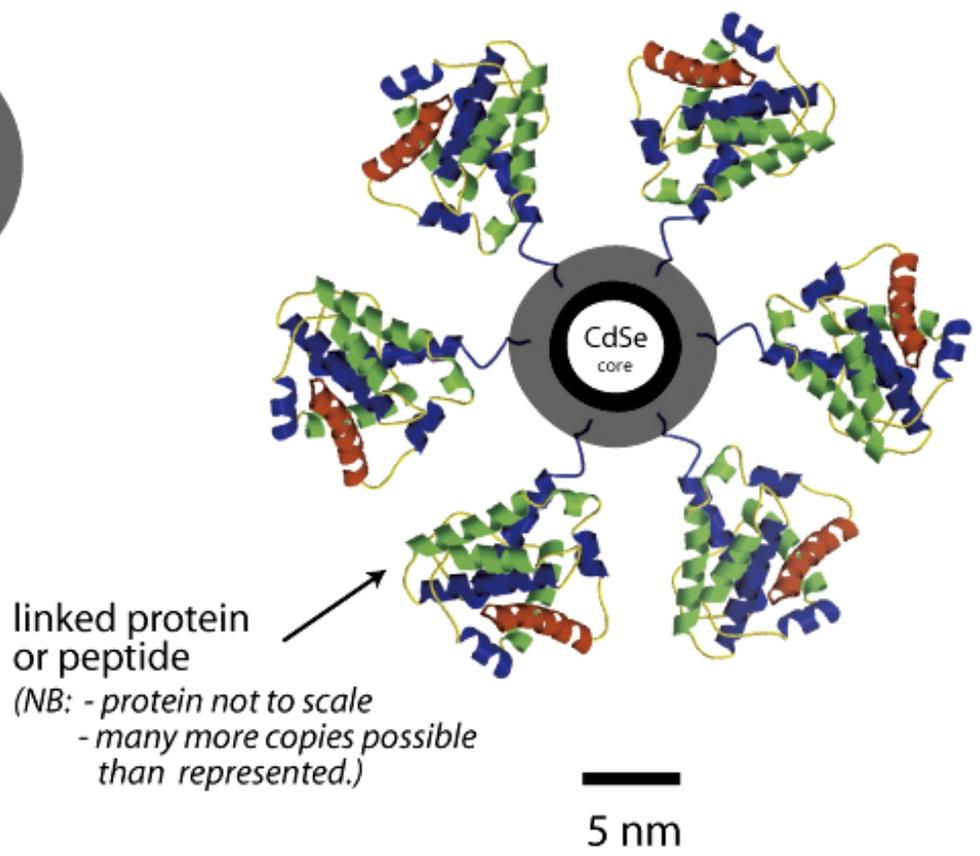
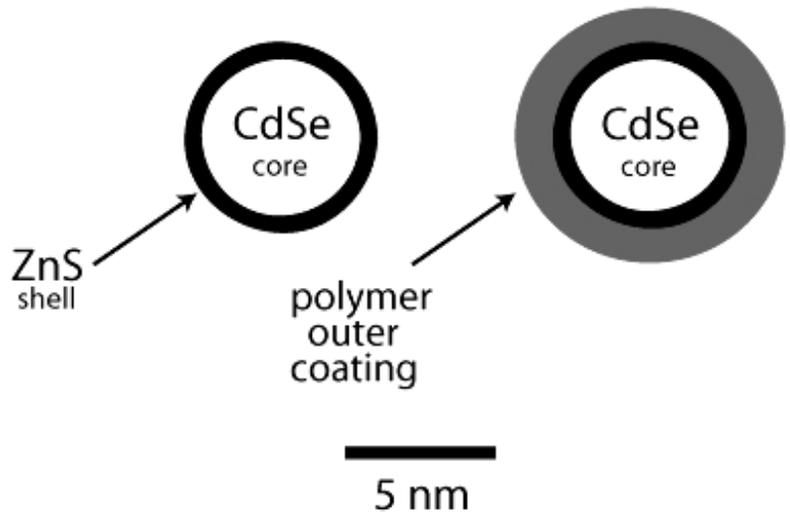


SWCNT-induce focal pulmonary granulomatous inflammation in mice....



... and, are **still** found in the lung 2 months after treatment.

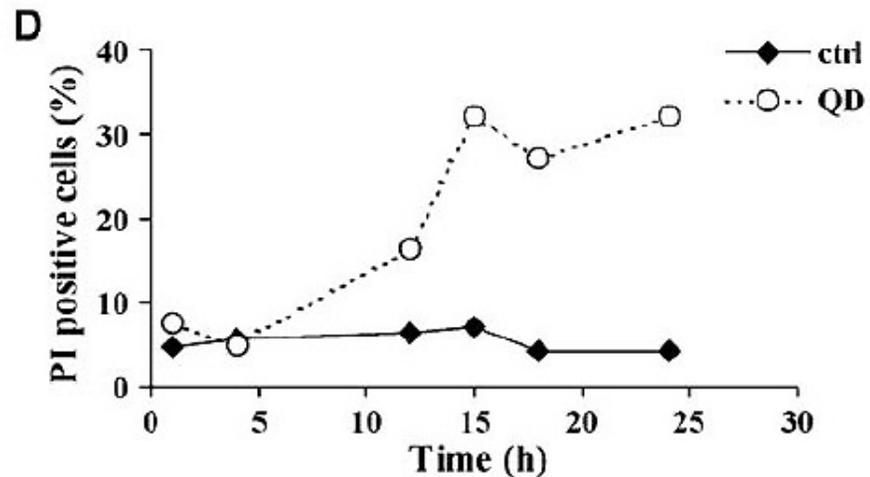
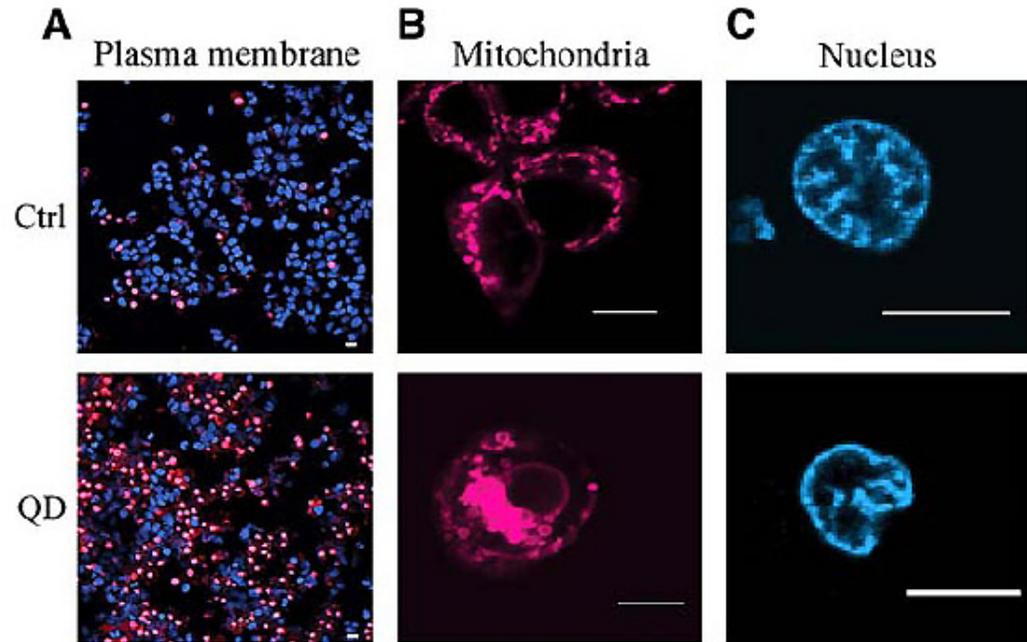
Representative Quantum Dot (QD) Structures.



Spectral Properties of Quantum Dots



QD-induced cytotoxicity.



(Lovric et al., 2005)

Nanoparticles and worker health

- All major reports highlight worker safety as one of the most important issues in nanotechnology risk assessment.
- Workers interact with substances directly and continuously.
- Especially true during materials transfer procedures.
- no information yet on long-latency effects of NPs (“the silent *H* in OHS”).

General OHS principles will still apply.



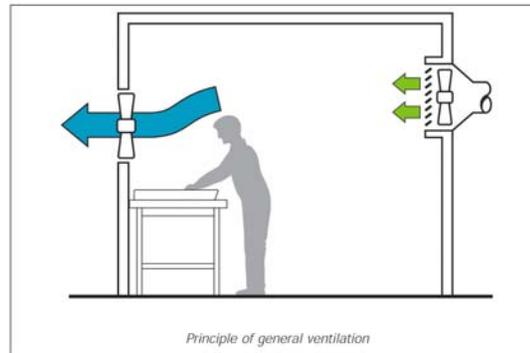
Selection of personal protective equipment



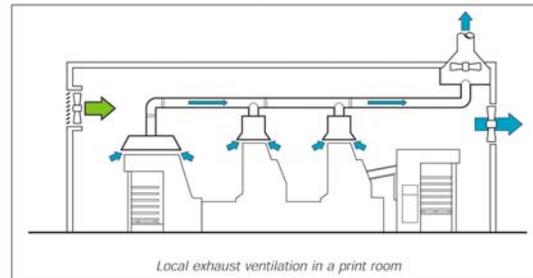
Chemicals causing harm via skin or eye contact

PPE

General ventilation

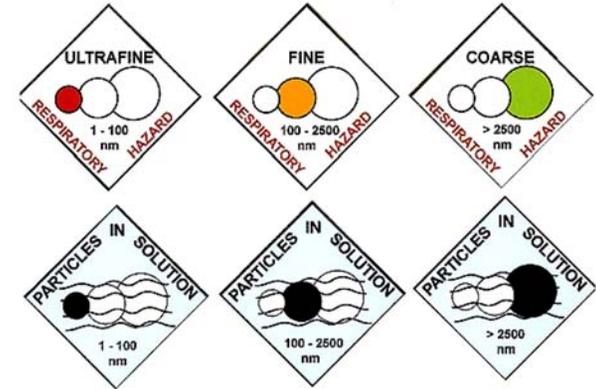


Enhanced engineering controls



Exposure controls

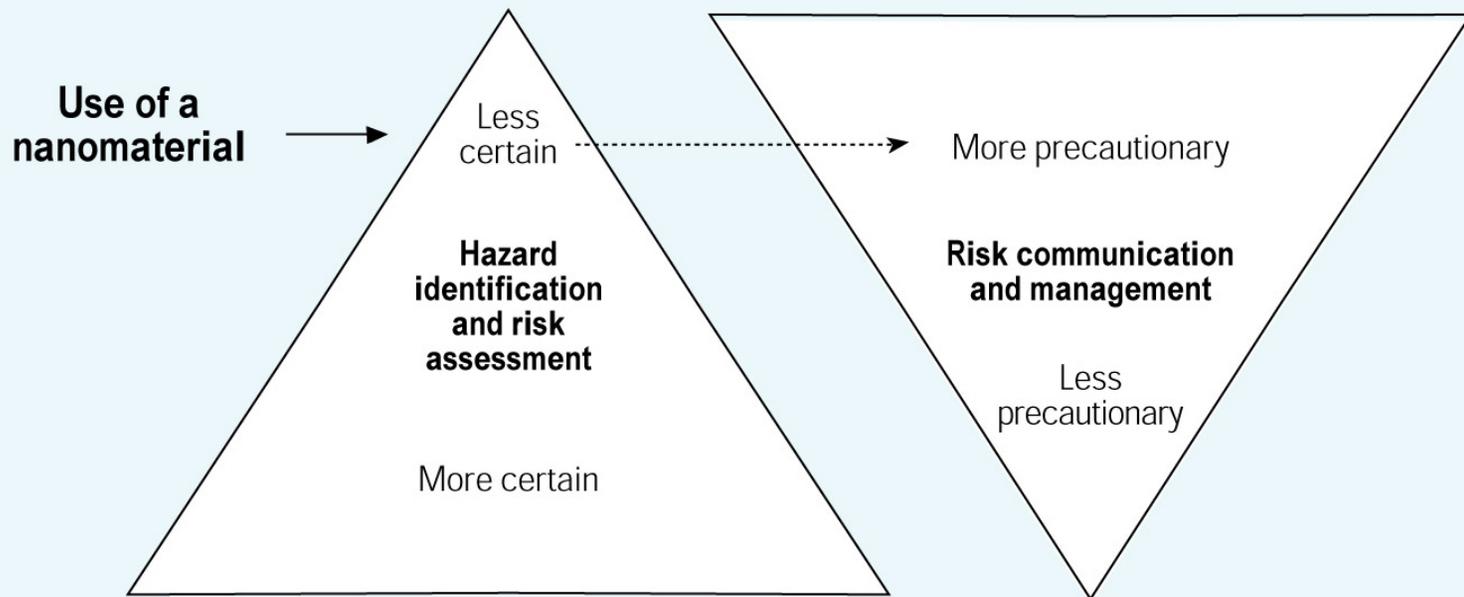
NANOPARTICLE SAFETY LABELS.



(labels from: Nanotechnology Victoria)

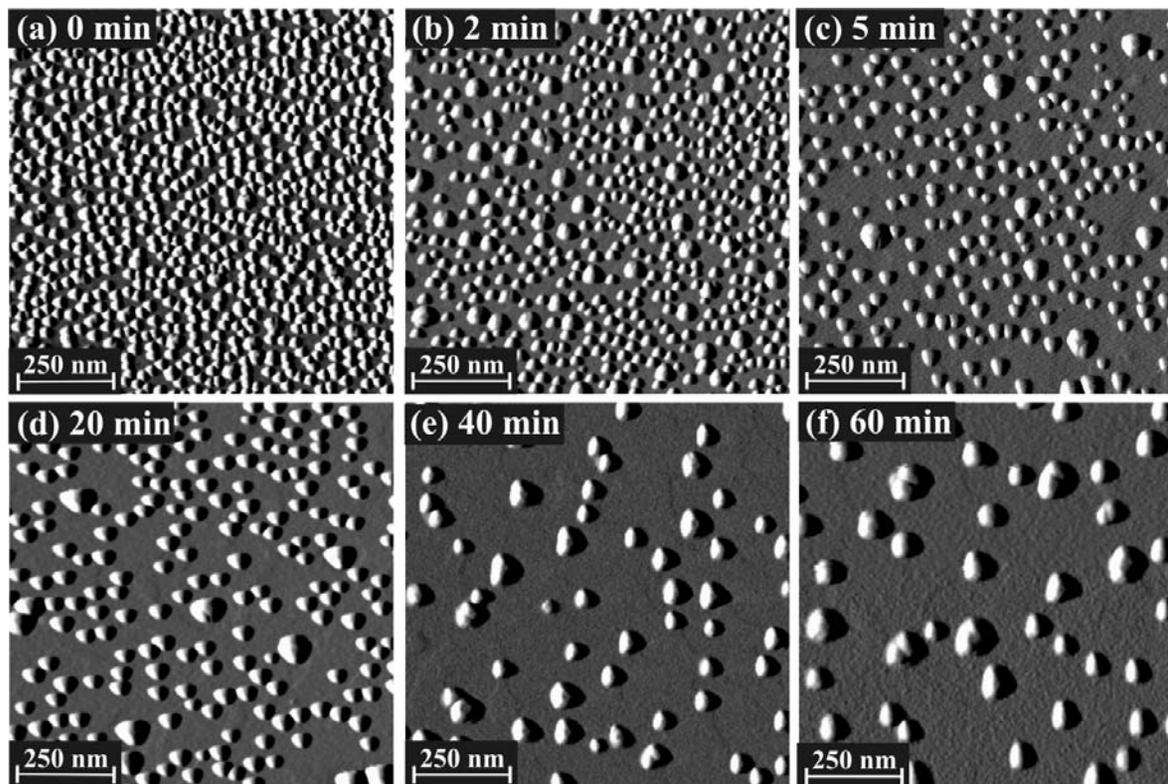
Education & communication of hazards and risks

A risk management framework for NP use in the workplace.



Real-time analysis of CdSe quantum dots.

Aggregation and agglomeration events

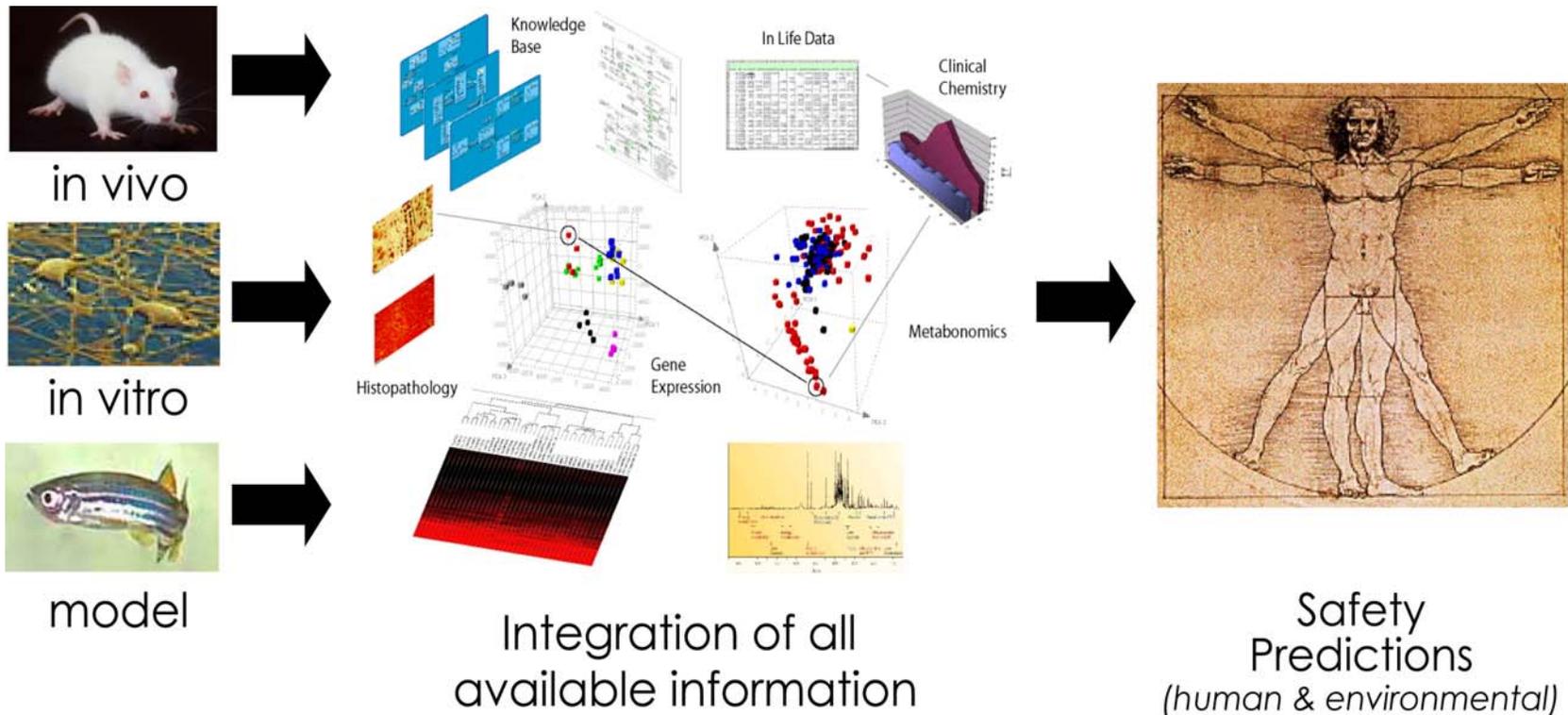


Data kindly provided by Dr. Gunter Springholz (University of Linz) - with permission.

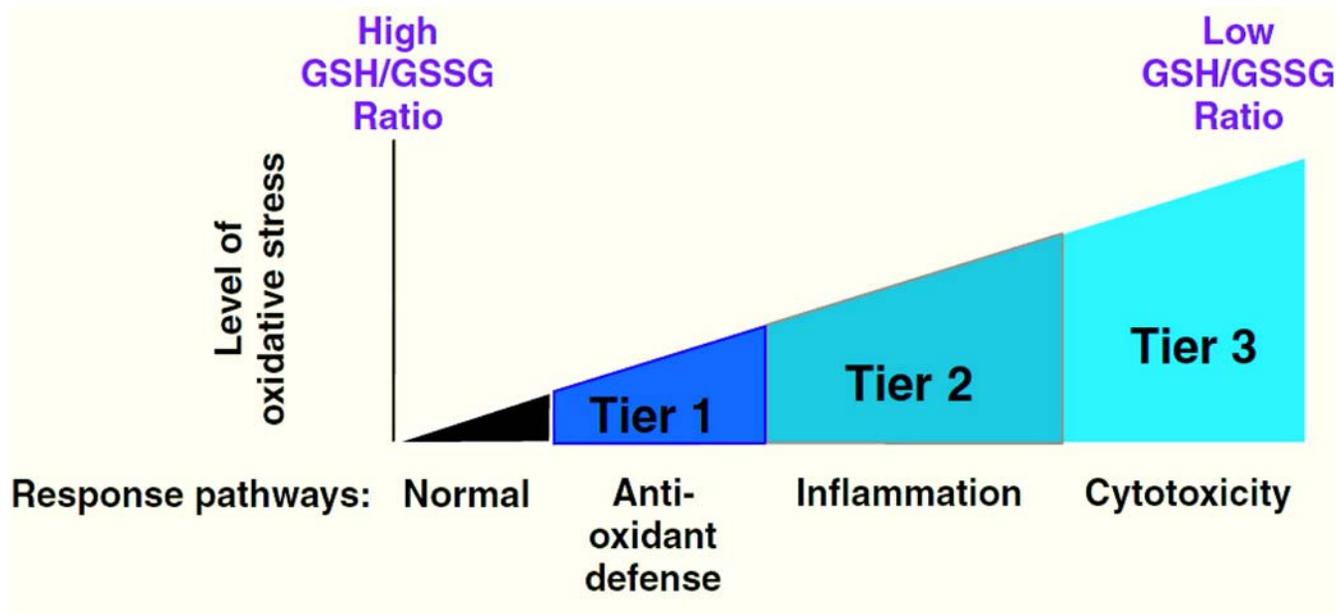
The future in human & environmental toxicology.

- All organisms present a hierarchical set of defences to combat foreign particles and maintain homeostasis.
- Any changes to the normal physiology of these defences are an indication that the body is under stress. Disease may result if repair pathways are overwhelmed.
- Nanoparticle-induced changes can occur at the level of a body's organs, cells and/or molecules.
- We will have the capability to test rapidly and quickly.

“Systems biology” in safety assessment.



A toxicology testing approach.



Conclusions

- Nanoparticles are set to become a prominent feature of mainstream commerce.
- Little is known regarding the stability, persistence and health effects of NPs to the environment and in humans.
- Available information - small as it is - suggests that NPs have the potential to induce damage.
- There are **strong, unified, international** and **urgent** appeals requesting that funds be directed to address the current lack of information.

Horizon Scanning

- Defined by the *UK Office of Science and Technology* (OST) as:
 - “the systematic examination of potential threats, opportunities and likely future developments, including (but not restricted to) those at the margins of current thinking and planning.”
- Horizon scanning may explore novel and unexpected issues as well as persistent problems or trends.

(An example of the possible
consequences of failing to
horizon-scan will be
presented)

Other “failures” in toxicological “horizon scanning”.

- PCBs (Rachel Carson’s “*Silent Spring*”).
- Ozone depleting CFC’s
- Lack of acceptance of GM foods.

The Last Word

(or, an insight – of sorts)