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Nanotechnology: Is it Safe?

What are nanomaterials?
Why should we care about them?
Why an expert panel assessment?
What do we know about the risks?
What should be done?

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Chair: Council of Canadian Academies
Assessment of Nanotechnology Risks

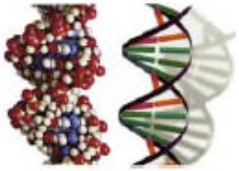
11 February 2010

What Are Nanomaterials?

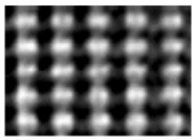
- The nanoscale world
  - We live in a world of mm, metres, km
  - Cells: μm (10^{-6} m)
  - Molecules: nm (10^{-9} m)
  - Atomic nuclei: fm (10^{-12} m)
- Nanomaterials* are:
  - Objects with at least one dimension between 1 &100 nm

Ant
~ 5
mm

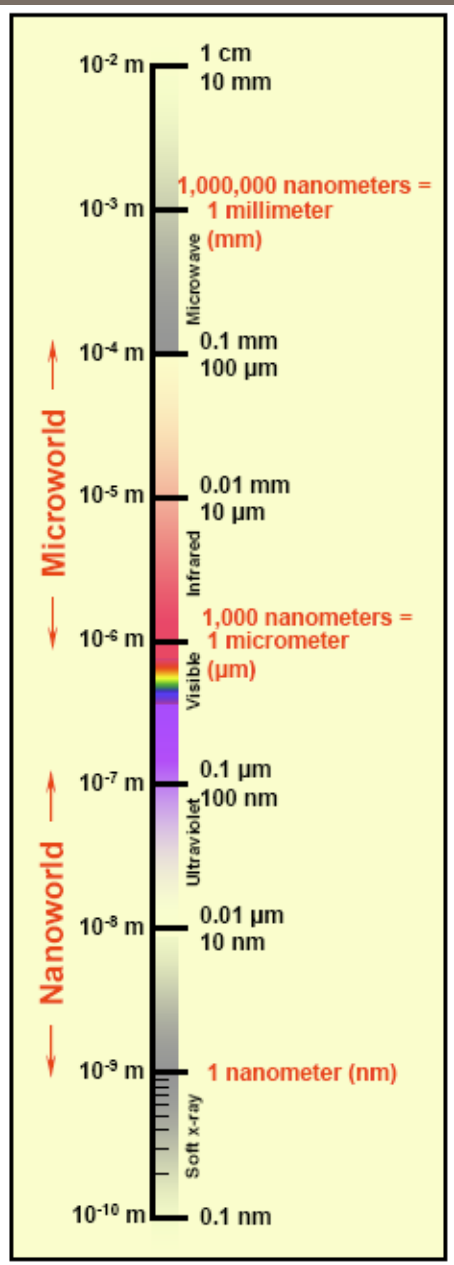
Red blood cells
(~7-8 μm)



DNA
~2.5 nm diameter



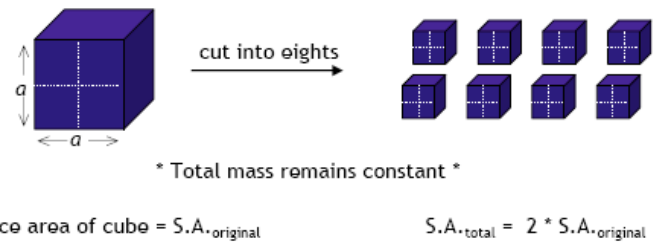
Atoms of silicon
spacing 0.078 nm



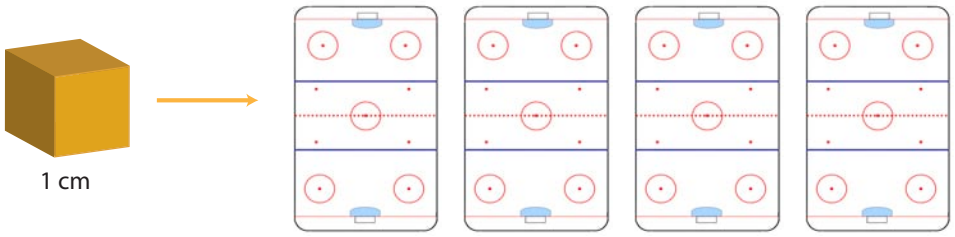
* Lots of definitions – this is often used

Properties of Nanomaterials

- Properties of objects come mostly from
  - Physical interactions
  - Chemical interactions
- Most “action” at surface
  - More surface – more reactivity
  - Especially chemical & biological properties



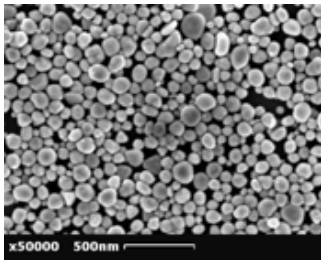
- Split up a 1 cm cube into “nanocubes”
  - Area of 4 hockey rinks



  - Huge change in properties

Some Nano Behaviour "Magical"

- Ordinary elements change behaviour
  - Nano-silver powerful microbicide
  - Nano-gold changes colour depending on size



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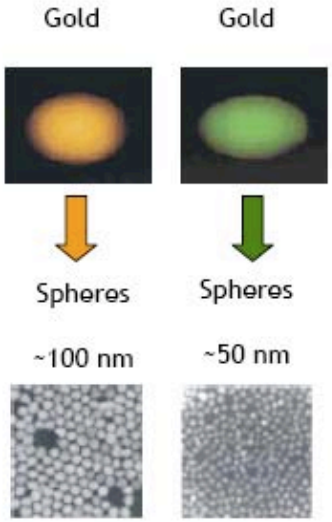
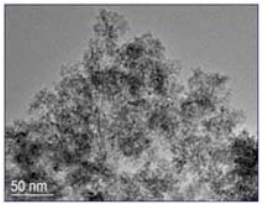
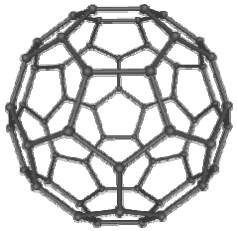


- Chemicals also change
  - TiO_2 good example
  - Nano-TiO_2 absorbs UV, good microbicide
    - Find it in suntan lotions, cleaning agents



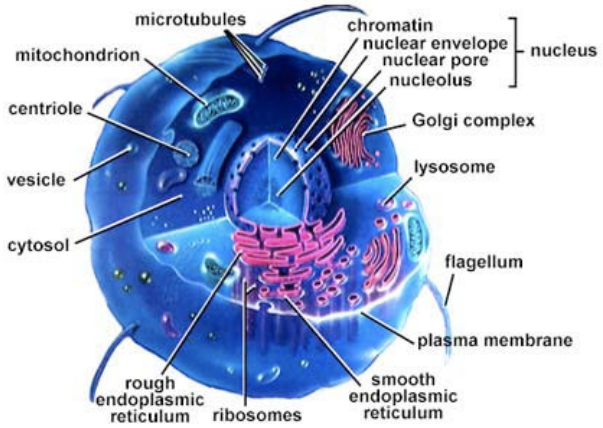
And Some Nano Behaviour Frustrating

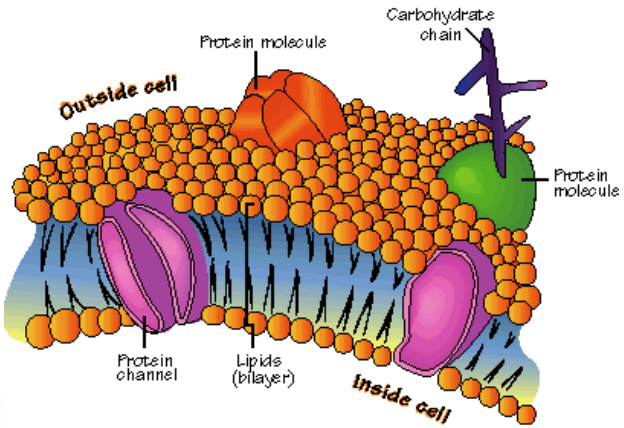
1. Enormous range of different types
   - Literally 100's of different materials
   - No agreed upon classification
2. Difficult to measure properties
   - Hard to handle – measurement techniques in infancy



3. Properties can change!
   - Nanoparticles can cluster, change properties
   - No standards for manufacture
4. Very limited knowledge base
   - New ones being invented daily
   - No coherent research effort

So, What's the Problem?





- Biological effects not well-understood for nanomaterials
  - What sort of exposure matters?
  - How does a nanomaterial interact with a cell?
  - What are the long-term biological effects?
  - How do nanomaterials enter and leave environment?

And There are Many "Nano-Products"

- One source estimates >800 products with nanomaterials
  - Some of them have been assessed for potential risks
    - E.g. nano-silver in wound dressings
- Most have not undergone any formal risk assessment

David Hawxhurst for the Project on Emerging Technologies http://penmedia.org/stock/products/

The "Small is Different" Expert Panel

- Federal government requested expert advice
  - Asked the Council of Canadian Academies to create an "expert panel"
  - Requested CCA to look into what science can tell us about nanomaterial risks

- *"What is the state of knowledge with respect to existing nanomaterial properties and their health and environmental risks, which could underpin regulatory perspectives on needs for research, risk assessment and surveillance?"*

Expert Panel Members

- **Pekka Sinervo** (FRSC) (Chair) Dean, Faculty of Arts and Science, University of Toronto (Toronto, ON)
- **Sabin Boily** Président, LithChi Inc. & Chairman, Société pour la promotion de la science et de la technologie (Montréal, QC)
- **Conrad Brunk** Professor of Philosophy & Director, Centre for Studies in Religion and Society, University of Victoria (Victoria, BC)
- **David Castle** Canada Research Chair in Science and Society & Director, Institute for Science, Society and Policy, University of Ottawa (Ottawa, ON)
- **Warren C. W. Chan** Assistant Professor, Institute of Biomaterials and Biomedical Engineering, University of Toronto (Toronto, ON)
- **Meng-Dawn Cheng** Distinguished R&D Staff Member and Group Leader, Atmospheric and Aerosol Science Group, Environmental Sciences Division, Oak Ridge National Laboratory (Oak Ridge, TN)
- **Richard Gold** Director, Centre for Intellectual Property Policy & Associate Professor, Faculty of Law, McGill University (Montréal, QC)
- **Peter Grütter** (FRSC) Professor, Department of Physics, McGill University (Montréal, QC)
- **Christopher Haarmann** Senior Vice-President, Global Liability Line of Business Head, Zurich Insurance Companies (New York, NY)
- **Andrew D. Maynard** Chief Science Advisor, Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars (Washington, D.C.)
- **Günter Oberdörster** Professor, Environmental Medicine, School of Medicine & Dentistry University of Rochester (Rochester, NY)
- **Jo Anne Shatkin** Author, *Nanotechnology: Health and Environmental Risks* & Managing Director, CLF Ventures (Boston, MA)
- **Lorraine Sheremeta** Research Officer, National Institute for Nanotechnology & Research Associate, Health Law Institute, University of Alberta & Special Advisor, Strategic Development, Alberta Ingenuity Fund (Edmonton, AB)
- **Robert Slater** Adjunct Professor, Carleton University & President, Coleman, Bright and Associates (Ottawa, ON)
- **Nigel J. Walker** Deputy Program Director for Science, National Toxicology Program, National Institute of Environmental Health Sciences (NIEHS), National Institutes of Health (NIH) (Research Triangle Park, NC)

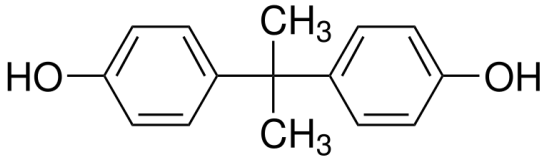
How Do We Assess Risk?

- Risk assessment is well-understood process
  - Identify hazards
  - Identify potential exposure
  - Manage the risks, e.g.
    - Eliminate exposure
    - Provide information on use and/or safe handling
    - Regulate use (or entry into "trade and commerce")

- Each country has its own regulatory "culture"
  - Canada has a culture somewhere between Europe and US
  - Public has high degree of confidence
- Some contrasting cases
  - Genomically modified organisms (GMO)
  - Exposures to chemicals

Risk Assessment & Uncertainty

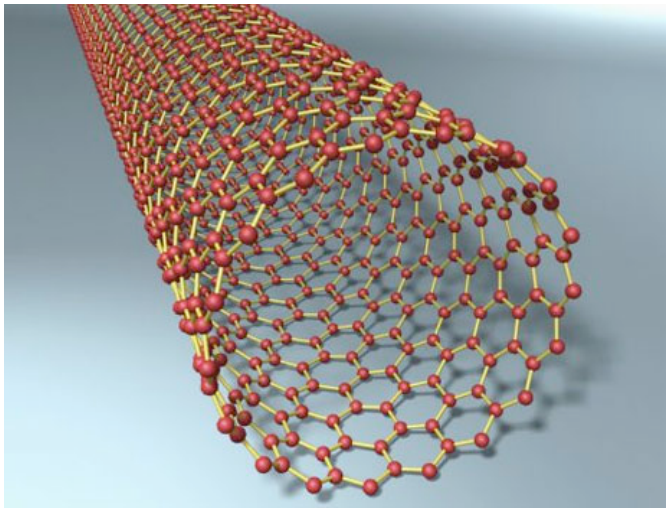
- Risk assessment does not give “yes/no” types of answers
  - Often uncertainty
    - Lack of knowledge
    - Conflicting knowledge
  - Risk vs benefits
    - Different people have different risk tolerance
  - Often, resort to “precautionary principle”



- Case study: Bisphenol A
  - Plastic used in many containers
    - Trace amounts “leach” into liquids, causing exposure
  - Shown to cause biological effects in large exposures
    - But results are scientifically “marginal”, “may be increased risk”
  - Health Canada banned BPA in baby bottles

Risks of Nano?

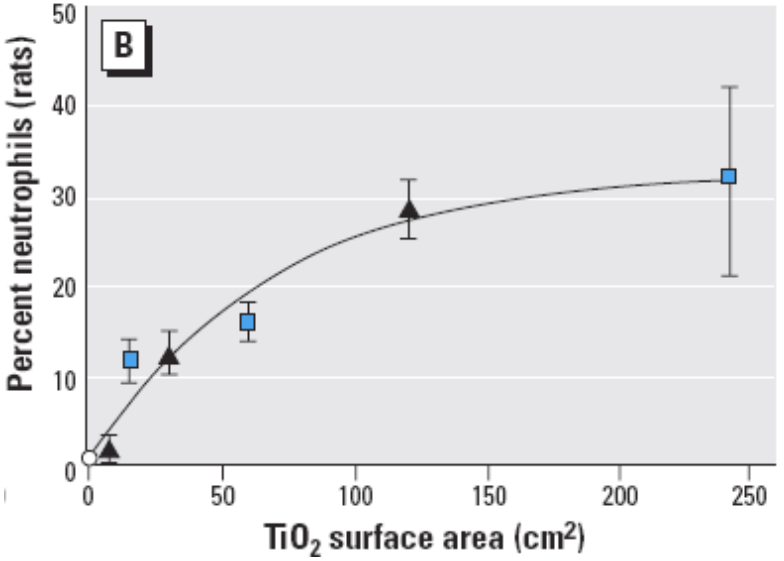
- What are the known hazards?
  - Biological effects of nanoparticles in cells
    - Long-term toxicity?
    - How long do they reside?
  - Exposure through inhalation
    - Carbon nanotubes, eg. – do they create long-term lung damage?
  - Absorption through skin
    - Not much is known about the potential mechanisms
    - What happens once inside human body?



More Research is Needed

- Have to understand effects of exposure
  - Understand range of biological effects
  - Determine dose-response for each nanomaterial
  - Understand behaviour in environment
    - Where do nanomaterials end up?
    - What are the biological effects

- Some questions are still of a fundamental kind
  - Example here are various measurements on TiO_2 exposure



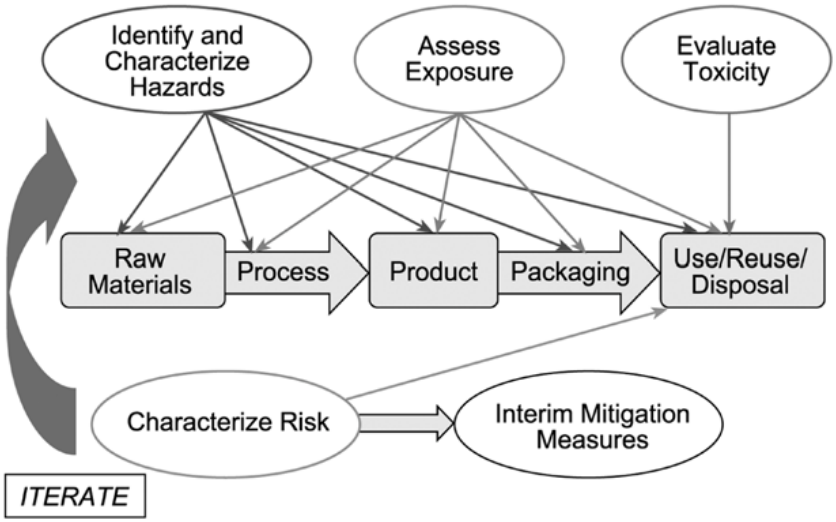
So What Does the Science Really Say?

- To date, no unique biological effects associated with exposure to nanomaterials
  - But there is still a poor understanding
- Risk assessment frameworks robust, but requires
  - New ways for measuring exposure, dose and response
  - Better understanding of biological effects
- Nanomaterials can cause harm at different stages in life cycle
  - Require a life cycle approach to risk assessment
- Inadequate data to inform quantitative risk assessments
  - Only qualitative risk assessments are feasible, given the current state of knowledge

So What To Do Now?

- In face of uncertainty over health & environmental risk
  - "Precautionary principle" is the preferred approach
    - Give priority to ensuring health and safety of environment
- Doesn't mean a "ban" on all nanomaterials
  - Does mean that caution has to be exercised

- Example approach:
  - Adaptive risk management (Shatkin)



So Why Take the Risk?

- What risk?
  - Some nanomaterials in use for a long time, and no problems!
- Expected to be $1T in nanomaterials sold by 2015*
  - Estimate criticized, but reality is that nanomaterials are part of market place
  - Canada should be engaged in product innovation

* Roco & Bainbridge (2001)

- Some real benefits, e.g.:
  - New products to improve standard of living
  - Assist in solving difficult problems
    - Environmental remediation
    - Drug delivery

Expert Panel's Advice

1. Develop an interim classification of nanomaterials
   - OECD working on this, but very slowly
   - Canada should take interim steps
2. Review current regulatory "triggers"
   - Many triggers are based on weight!
3. Make sure workplace exposure is controlled
   - Worker's need to be protected when handling nanomaterials
4. Improve ability to measure & characterize nanomaterials
   - Invest in research

Summary

- The scientific knowledge on which one can **quantitatively** assess the risks associated with nanomaterials is limited, especially given their potential applications
- Uncertainties associated with risk assessment and risk management are **not** unique to nanomaterials, but have been present in the introduction of other new technologies
- Taking a precautionary approach is appropriate, giving priority to ensuring the safety of health and the environment
- The existing Canadian regulatory approaches and risk management strategies are appropriate to this new challenge, provided:

  1) that a greater investment is made in strategic research associated with the risk assessment of these materials,
  2) that attention is paid to addressing issues of classification, regulatory triggers and regulatory capacity, and
  3) that regulatory agencies coordinate their activities with each other, between federal and provincial levels of government and with the regulatory efforts in other countries

Learn More?

- Lots of resources, e.g.
  - Full report of Expert Panel
    - http://www.scienceadvice.ca/documents/(2008_07_10)_Report_on_Nanotechnology.pdf
  - Recent paper article
    - http://www.torontosun.com/news/canada/2009/01/09/7972131.html
  - Environment Canada and Health Canada proposal
    - http://www.ec.gc.ca/substances/nsb/eng/nanoproposition_e.shtml