

The New Science of Sophisticated Materials

Nanomaterials and beyond

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University of Washington Seattle, Nov 8 2011



Deepwater Horizon spill, Gulf of Mexico

G-MARINE Fuel Spill Clean-UP!

These plant derived ingredients are processed to form a colloidal micelle whose small particle size (1-4 nanometers) enables it to penetrate and breakdown long chain hydrocarbons bonds in oils and grease and holds them in a colloidal suspension when mixed with water.

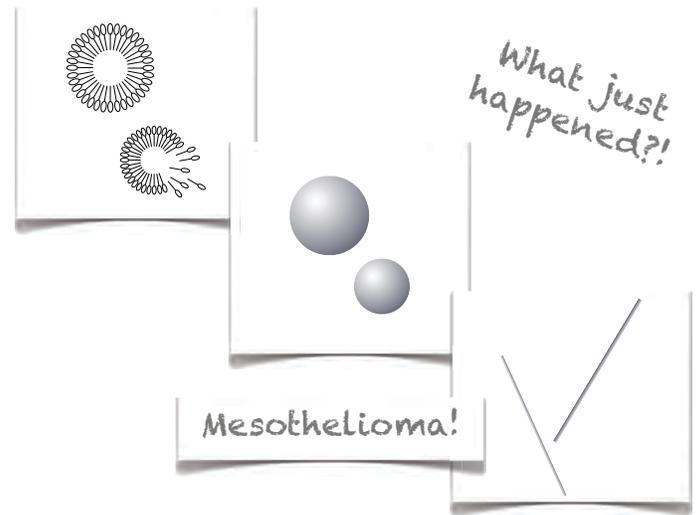
Green Earth Technologies, www.getg.com

The undersigned public-interest organizations respectfully urge the EPA to deny approval of this and similar projects that seek to release nanoscale chemicals or chemicals measuring less than 300 nanometers into the environment. In this case the company claims their product is composed of particles measuring 1-4nm. **Manufactured nanoparticles have been shown to be toxic to humans, mammals, and aquatic life.**

NGO Consortium, www.foe.org/sites/default/files/EPAOpposeGETNanoDispersants.pdf

"A decision to use nanoparticle-based dispersants in the gulf is less an engineering or environmental decision, but more a public health and individual patient care issue. **As does asbestos, nanoparticles have been shown to cause an aggressive cancer called mesothelioma**"

AOL Online, www.aolnews.com/nation/article/scientists-to-epa-say-no-to-nanotech-dispersant-for-gulf-oil-spill-cleanup/19495279

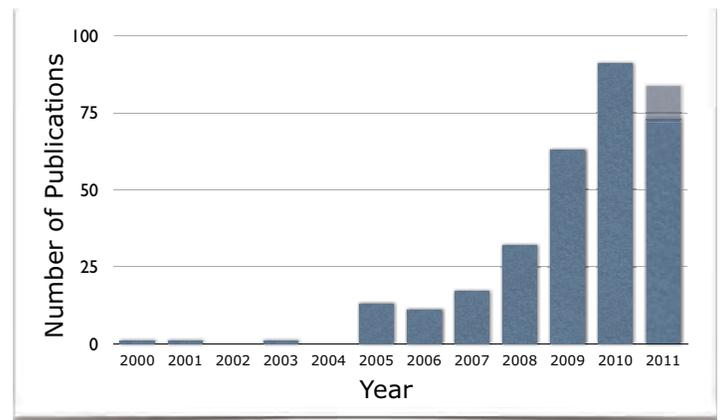


Friends of the Earth calls for an **immediate moratorium** on the commercial release of products that contain manufactured nanosilver until nanotechnology-specific regulation is introduced to protect the public, workers and the environment from their risks, and until the public is involved in decision making

Friends of the Earth Australia. 2009. Nano and Biocidal Silver – Extreme Germ Killers Present A Growing Threat to Public Health. Melbourne: FoE Australia.

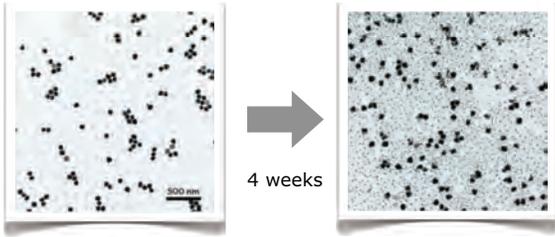
Publications

Related to nano silver impacts



ICON Virtual Journal, http://icon.rice.edu/virtualjournal.cfm

Ubiquitous Ag Nanoparticles...



Glover RD, Miller JM, Hutchison JE. 2011. Generation of Metal Nanoparticles from Silver and Copper Objects: Nanoparticle Dynamics on Surfaces and Potential Sources of Nanoparticles in the Environment. ACS Nano 10.1021/nn2031319.

Regulatory Decision Making

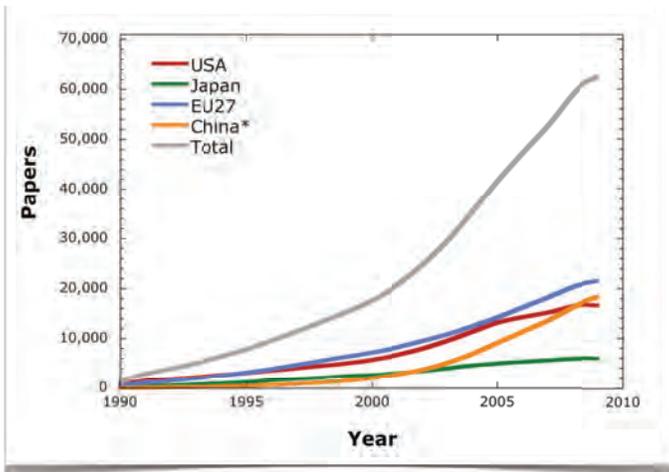
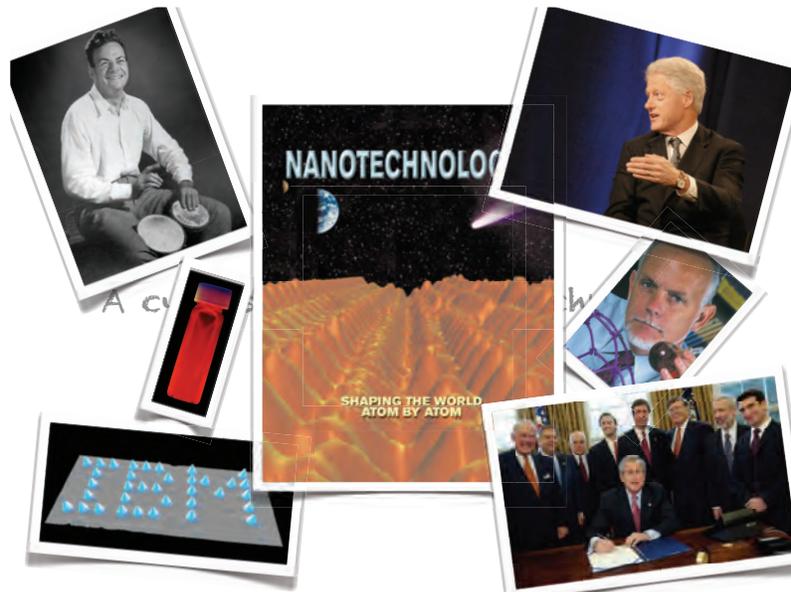
Laursen said that although the Commission would consider the public consultation and the advice of key scientific bodies such as the EU's scientific committee on emerging and newly identified health risks (SCENIHR), ultimately the definition [for regulatory purposes of an engineered nanomaterial] would be "a policy decision"

Euractiv.com, April 01 2011. <http://www.euractiv.com/en/innovation/commissions-nano-policy-lost-definition-news-503665>

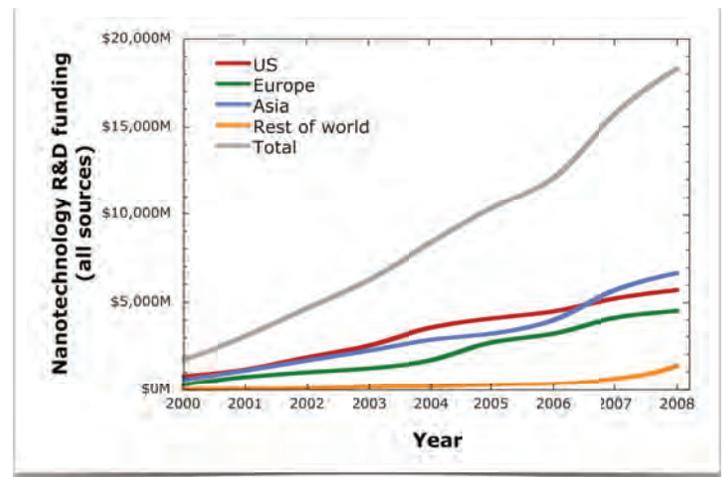
We have A Wicked Problem!

A Wicked Problem: a problem "which [has] a multitude of stakeholders showing interest, but an inability for stakeholders to agree on either the nature of the 'problem' (to the degree that it exists at all), or on the most desirable solution to be applied"

Klijin, E-H. (2008). *It's the Management, Stupid', On the Importance of Management in Complex Policy Issues*, Uitgeverij LEMMA: The Hague



Source: PCAST (2010) Report to the President and Congress on the Third Assessment of the National nanotechnology Initiative. Washington DC:President's Council of Advisors on Science and Technology.



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450 pages of stuff!

Long-Term Impacts and Future Opportunities for Nanotechnology, 2000-2020. Draft report available at: <http://www.wtec.org/nano2/>

Nano2: The next ten years of nanotech

- Nano-bio interfaces
- Biology inspired technologies
- Understanding interactions in complex nanosystems
- Molecular understanding of biological processes
- Interactions of nanostructures with external fields
- Powerful, compact batteries
- Interactive electronic books
- Cognitive technologies
- Next generation electronics
- Artificial organs
- Better disease treatment
- Novel computing systems
- Exploiting quantum effects
- Self-assembling materials
- Designing materials from atoms up
- Smart prosthetics

Long-Term Impacts and Future Opportunities for Nanotechnology, 2000-2020. Draft report available at: <http://www.wtec.org/nano2/>

Welcome to the Nanotechnology

BRAND



The Lady Gaga
Brand



The Nanotech
Brand

Nano presents a Wicked Problem!

A Wicked Problem: a problem "which [has] a multitude of stakeholders showing interest, but an inability for stakeholders to agree on either the nature of the 'problem' (to the degree that it exists at all), or on the most desirable solution to be applied"

Hodge, G. A., D. M. Bowman and A. D. Maynard (2010). Introduction: The Regulatory Challenges for Nanotechnologies. International Handbook on Regulating Nanotechnologies. G. A. Hodge, D. M. Bowman and A. D. Maynard. Cheltenham, Edward Elgar.

The **Important** Question...

How do we begin to address the potential **emergent risks** of substances that are **complex**, that are **dynamic**, and that exhibit **physicochemical form-related biological behavior**?

Defining **Nanotechnology**...

"the understanding and control of matter at **dimensions** between approximately 1 and 100 nanometers, where **unique phenomena** enable **novel** applications."

<http://www.nano.gov/html/facts/whatIsNano.html>

...a **stumbling block for safety?**

Deconstructing **Nanotechnology**

What is **OLD**?



Generation

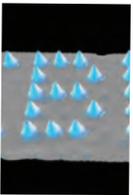


Utilization



Manufacture

What is **NEW**?



Control



Strangeness



Sophistication

Reconstructing ~~Nanotechnology~~ Nanoscale Science and Engineering

Reconstructing ~~Nanotechnology~~ Nanoscale Science and Engineering

What is **OLD**?



Generation

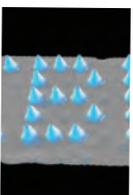


Utilization



Manufacture

What is **NEW**?



Dexterity



Exploitation



Complexity

Reconstructing ~~Nanotechnology~~ Nanoscale Science and Engineering

Playing around with **small stuff** to make the **big stuff** work better

Nanoscale control: Adding value to products

I wish my sunscreen wasn't so unsightly



I wish my socks didn't smell so much!



I wish my tennis racquet was lighter and stronger



I wish I could keep leftovers for longer, before they go off



I wish spilt red wine would run off my pants without staining

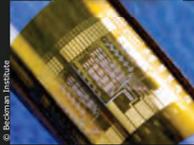


I wish I could get more songs on my iPod

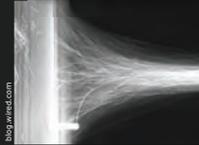


Over 1300 listed manufacturer-identified nanotech consumer products:
www.nanotechproject.org/consumerproducts

Electronics



Artificial muscles



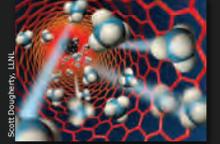
Spun textiles



Medicine



Desalination



Strong materials



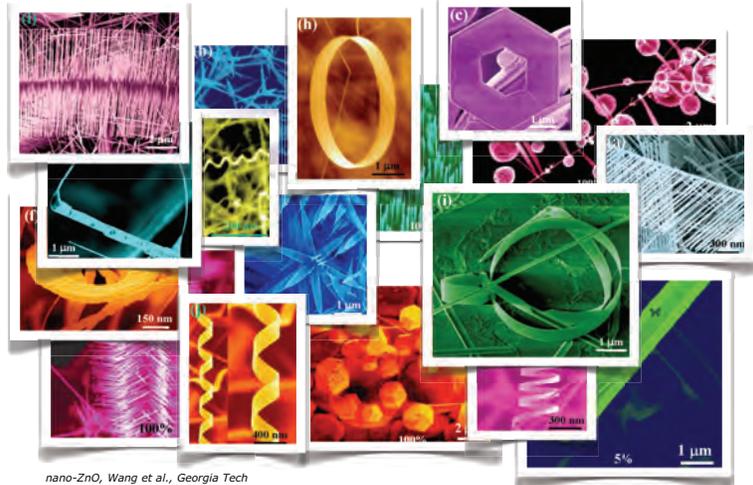
Flexible loudspeakers



Space elevator



Same Chemistry



nano-ZnO, Wang et al., Georgia Tech

Potentially Different Risks

Problem Formulation

Making sense of the nanoscale

Nanotechnology *n.* the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications.

Encompassing nanoscale science, engineering, and technology, nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale.

US National Nanotechnology Initiative

Regulators: Don't define nanomaterials



Maynard AD. 2011. Nature 475: 31

Making sense of the nanoscale

Nanoscale-associated behavior

Assumption that **size** leads to "novel" behavior

Attempts to define and **regulate** by size

Pressure to **fit** science to ideas

Making sense of the nanoscale

Nanomaterial *n.* (regulation) a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm – 100 nm.

European Commission, October 2011

Making sense of the nanoscale

Nanoscale-associated behavior

Nanoscale science and engineering-associated behavior

Assumption that **size** leads to "novel" behavior

Attempts to define and **regulate** by size

Pressure to **fit** science to ideas

Assumption that **design** leads to "novel" behavior

Possibility of defining and regulating by **behavior**

Opportunity to **develop** ideas from science

Making sense of the nanoscale

Nanoscale science and engineering-associated behavior

In the regulatory context, "nanomaterial" is replaced by "**sophisticated**" or "**advanced**" material or product



Assumption that **design** leads to "novel" behavior

Possibility of defining and regulating by **behavior**

Opportunity to **develop** ideas from science

Sophisticated Materials

"Undoubtedly, materials intentionally designed and engineered to behave in specific ways because of their fine structure are at the forefront of the new challenges being faced in toxicology. These materials increasingly demonstrate biological behavior that results from a synergistic interaction between chemical composition and physical form. But whether these new challenges can be confined to a narrow size scale implied by "nanotoxicology" is debatable.

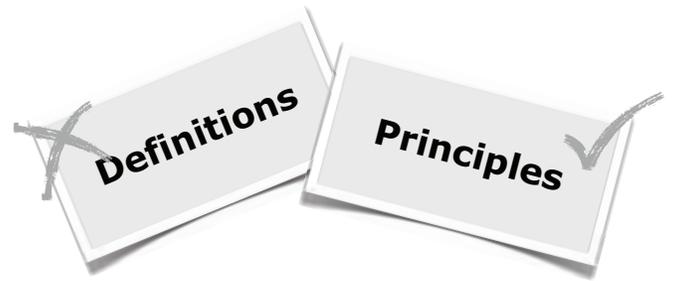
Rather, we would argue that a broader perspective is needed on the challenges presented by novel and functional materials, that captures the idea of "**sophisticated materials**."

These are substances that arise at the intersection of scientific disciplines and technology platforms, and demonstrate novel and even time and context-dependent functionality based on their engineered and increasingly complex physicochemical structure."

The Problem

Developing approaches to understanding and addressing the **novel health and environmental outcomes** arising from novel mechanisms of action and harm associated with **sophisticated materials**, including those that have been **designed** and engineered at the nanometer scale

Overcoming the **Definitions** Hurdle



Maynard AD, Warheit D, Philbert MA. 2011. The New Toxicology of Sophisticated Materials: Nanotoxicology and Beyond. Tox Sci 120(Suppl 1): S109-S129.

Criteria: **Emergent Risk**

The likelihood of a new material causing harm in a manner that is **not apparent, assessable or manageable** based on the current state of knowledge

Criteria: **Plausibility**

The **science-based likelihood** (qualitative) of a new material, product or process presenting a risk to humans or the environment

Criteria: **Impact**

The **likelihood** of a new material, product or process having a **substantial impact** on human health or the environment

Together, **they suggest that:**

Special consideration should be given to the research into the potential impact and oversight of materials, products and processes that have **plausible potential** to cause **substantial harm** in a manner that is **not apparent, assessable or manageable** based on the current state of knowledge.

Materials which Raise Concerns

- Materials demonstrating **abrupt scale-specific changes in biological behavior** - specifically, materials that undergo rapid size-dependent changes in physical and chemical properties which in turn affect biological behavior
- Materials capable of **penetrating to normally inaccessible places**
- **Active materials** - materials that undergo a change in their biological behavior in response to their local environment, a received signal or a predetermined series of events.
- **Self-assembling materials** - materials designed to assemble into new structures in the body or the environment once released.
- Materials exhibiting a **scalable hazard** that is not captured by conventional risk assessments.

	Emergent Risk	Plausible Risk	Impact
Gray Goo 	✓	✗	✗
Therapeutics 	✓	✓	✓
C60 	?	✓	✓
Nano Silver 	✗	✗?	?
Nano CeO2 	✓	✗?	✗

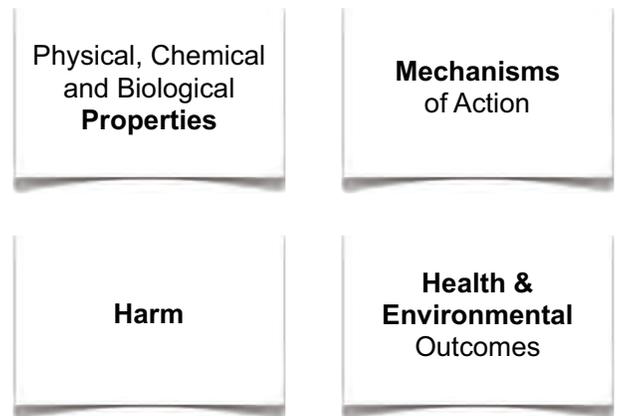
Novelty

novel *adj.* of a new kind of nature; strange; previously unknown

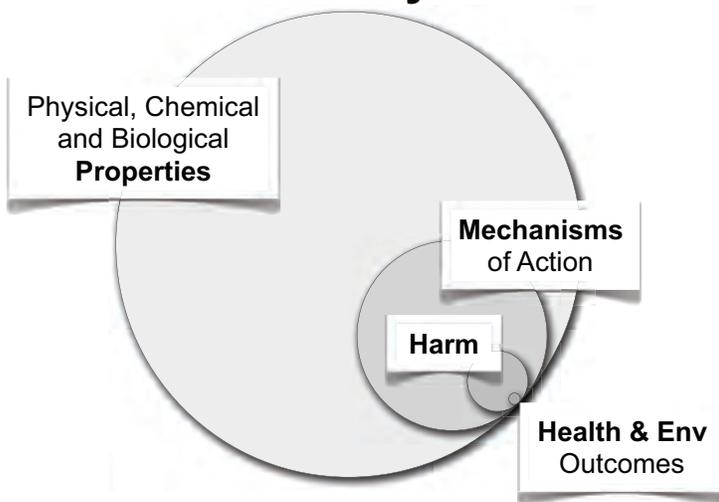
familiar *adj.* a well known; no longer novel. **b** common, usual; often encountered or experienced.

Oxford English Dictionary

Domains of Novelty



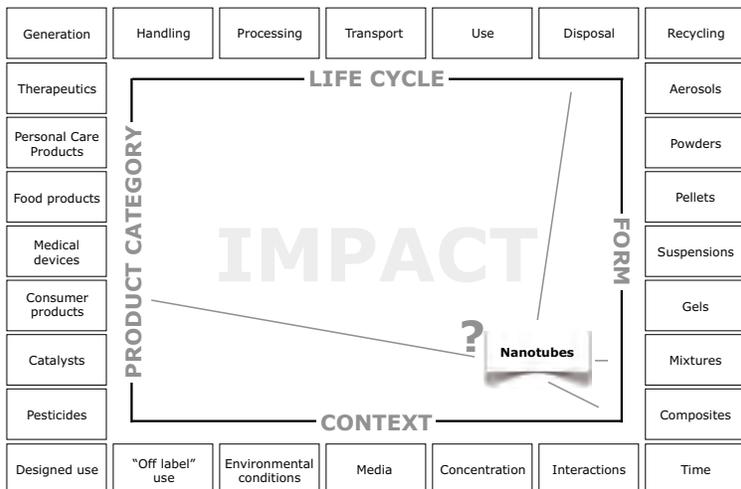
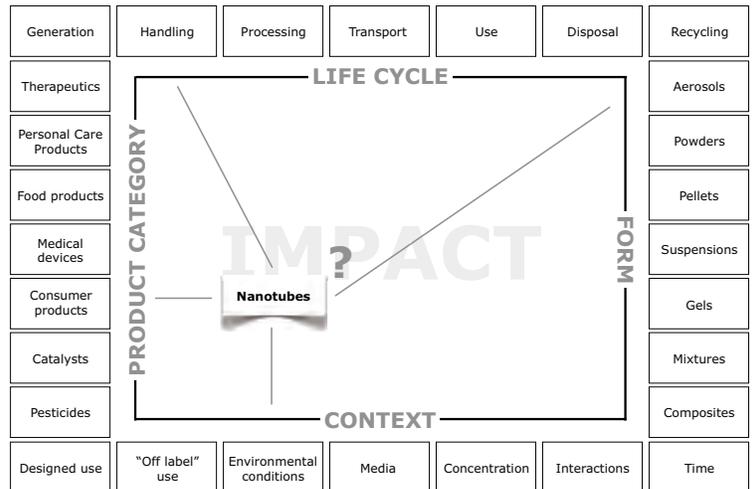
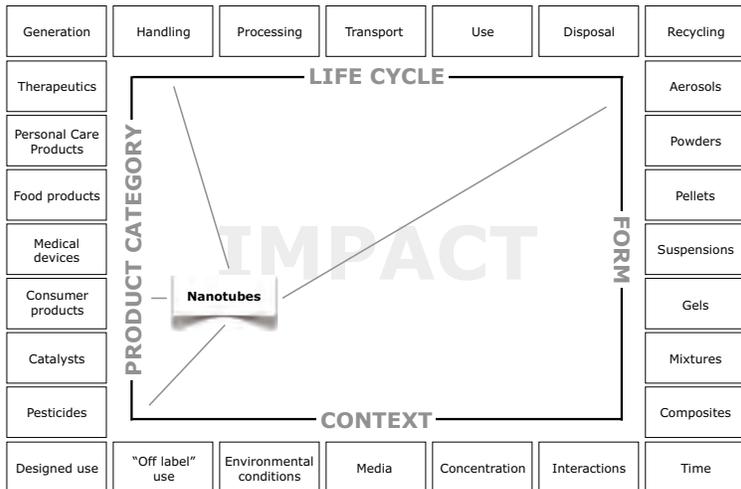
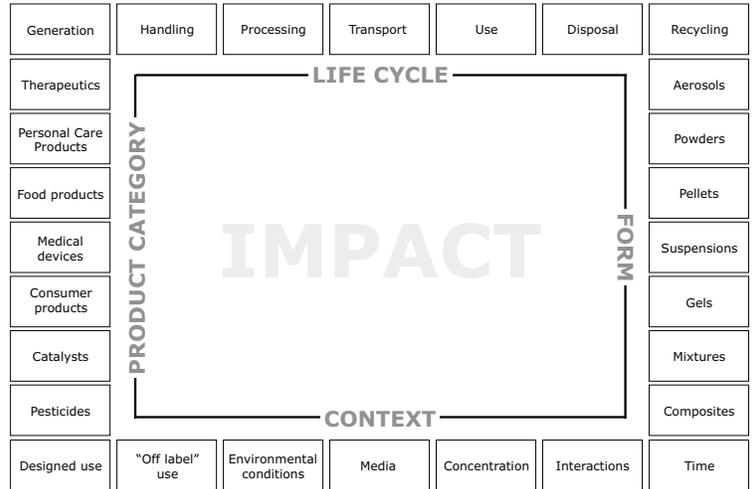
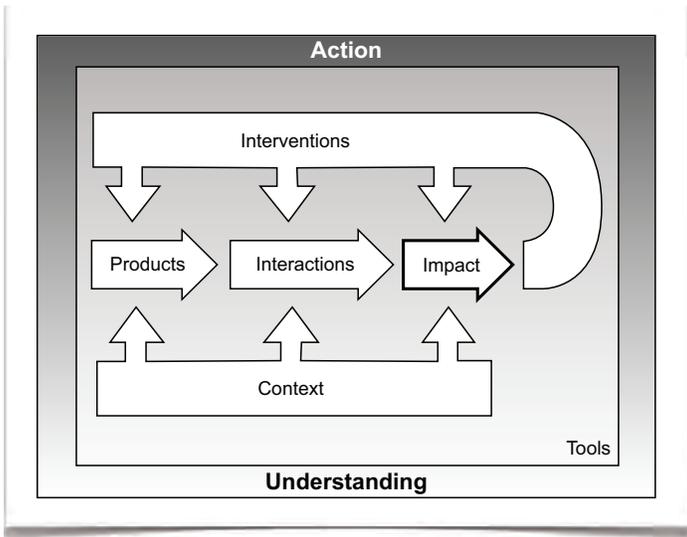
Domains of Novelty



Novelty and Outcome

Risk of adverse outcome:
F_n(Hazard, Exposure, Time)

Persistence & Accumulation
Transformation
Activation



So where does this leave us?

Some thoughts

Should focus on **Sophisticated Materials**, rather than Nanomaterials

Need to reframe potential health and environmental impacts in terms of **design**, instead of size

Should formulate problems that are grounded in science, based on evidence, and **responsive to new information**

Need to develop an **integrated perspective** on potential impacts within diverse, complex and dynamic systems

Mustn't get confused between brands and products!



Topless Humans Organized for Natural Genetics (THONG)

www.chicagothong.org

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