NANOTECHNOLOGY:
A PROACTIVE APPROACH FOR BENIGN DEVELOPMENT

Exposure Science in Policy Development

Modena 2; We-0-B4-03
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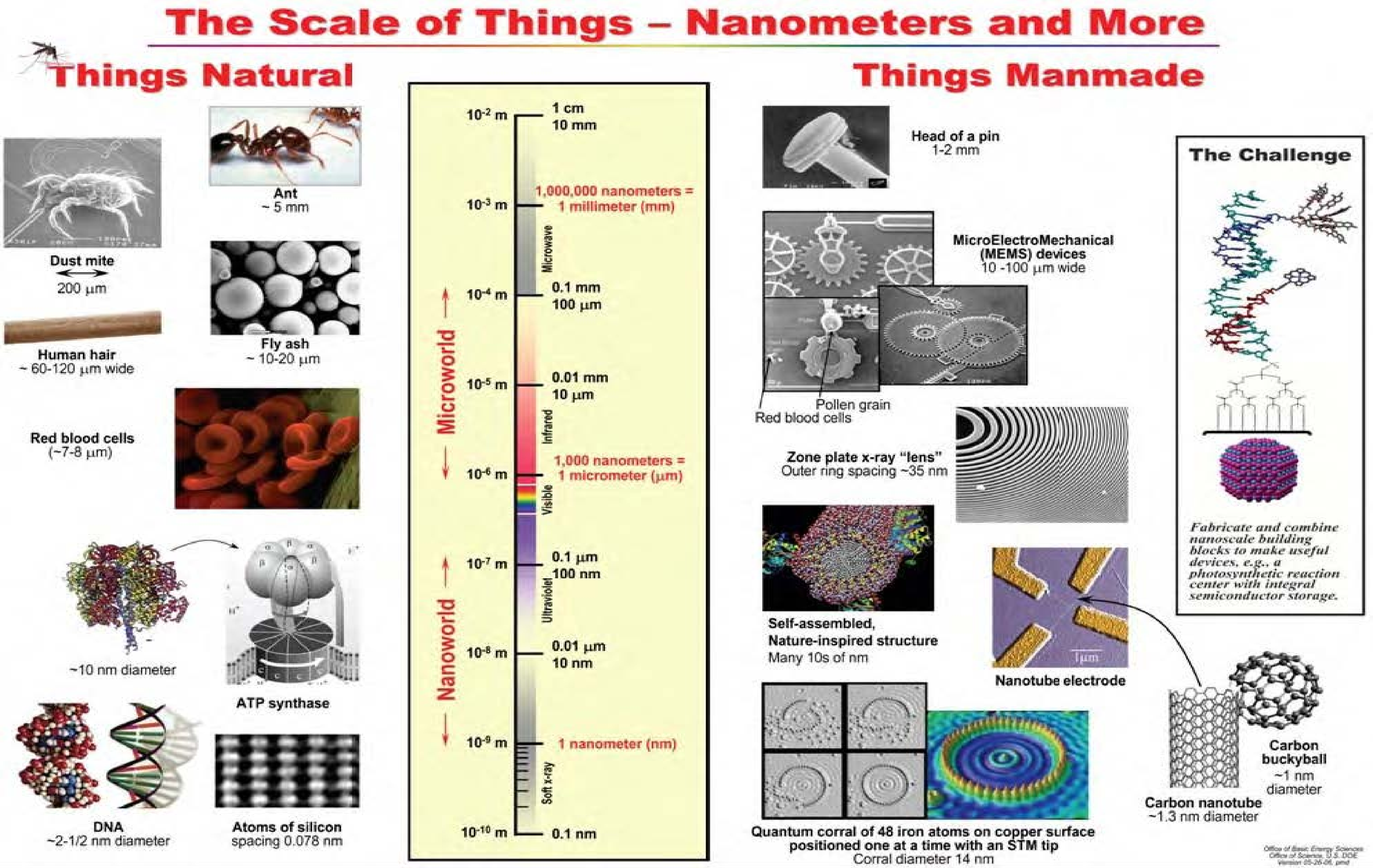
US EPA/ORD/NERL

NANOMATERIALS

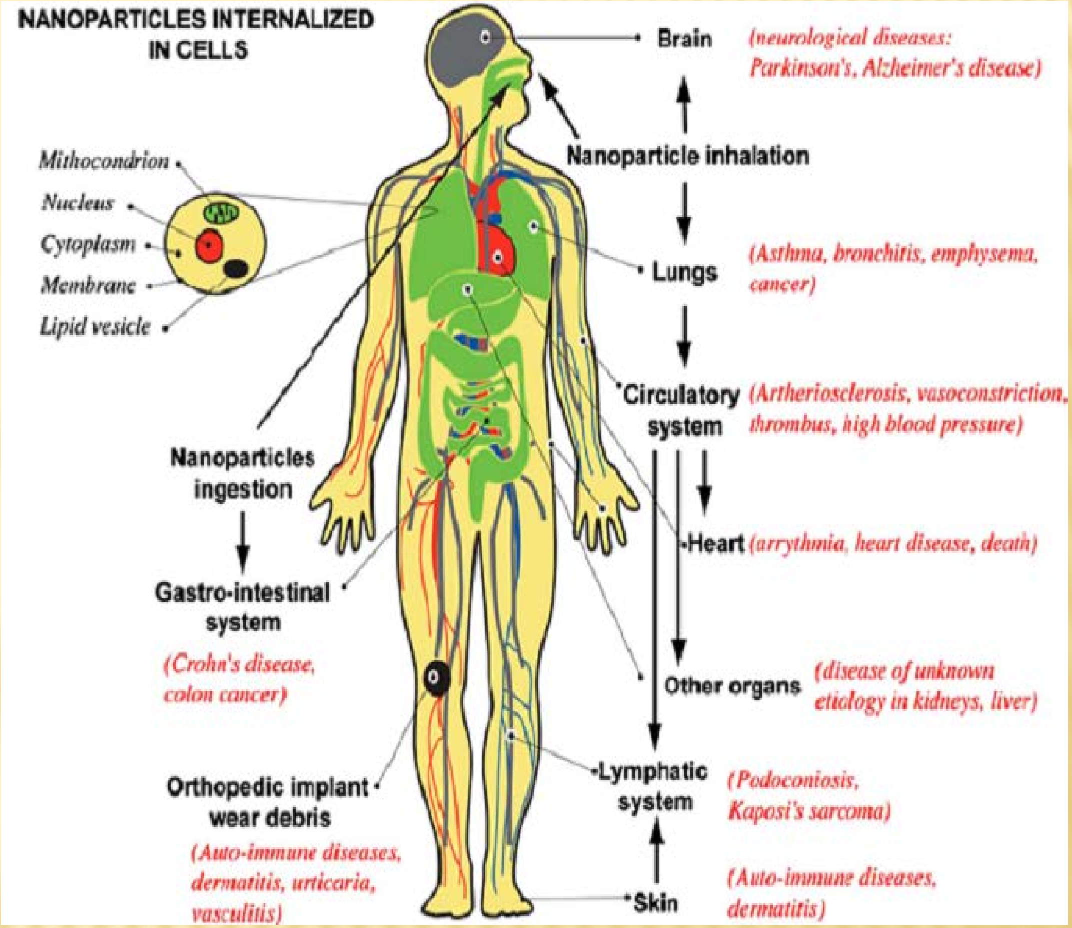


Consumer goods:

Categories	Subcategories	Examples
Personal care and cosmetics (30)	Skin care (14) Oral hygiene (6) Hair care (3) Cleaning (2) Coating (2) Baby care (2) Over the counter health products (1)	(Body) cream, hand sanitizer, hair care products, beauty soap, face masks Tooth brush, teeth cleaner, toothpaste Hair brush, hair masks Elimination wipes and spray Make-up instrument, watch chain Pacifier, teeth developer Foam condom
Textile and shoes (34) Tires	Clothing (28) Other textiles (2) Flooring (1) Toys (4)	Fabrics and fibers, socks, shirts, caps, jackets, gloves, underwear Sheets, towels, shoe care, sleeves and braces Linoleum Plush toys
Electronics (29)	Personal care (13) Household appliances (8) Computer hardware (6) Mobile devices (2)	Hair dryers, wavers, irons, shavers Refrigerators, washing machines Notebooks, (laser) mouse, keyboards Mobile phones
Household products/home improvement (19)	Cleaning (9) Coating (4) Furnishing (3) Furnishing/coating (3)	Cleaning products for bathrooms, kitchens, toilets, detergents, fabric softener Sprays, paint supplements Pillows Showerheads, locks, water taps
Filtration, purification, neutralization, sanitation (14)	Filtration (8) Cleaning (6)	Air filters, ionic sticks Disinfectant and aerosol sprays

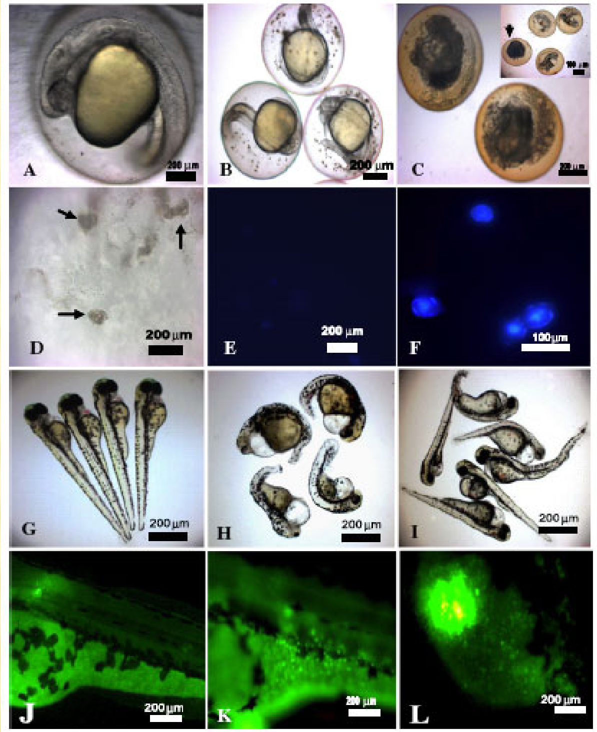
NANOTOXICITY

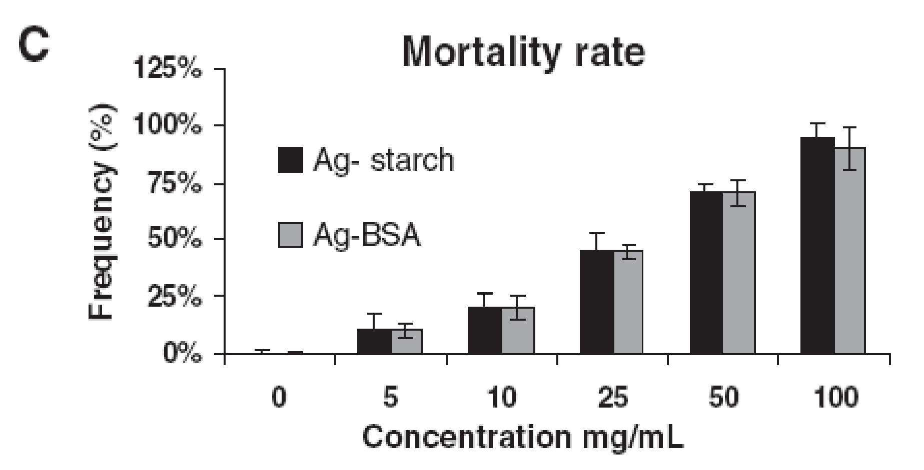
- Nanoparticles in consumer products
- Health and environmental toxic risks
  - Routes of exposure
  - Surface area
  - Size
  - Release of free radicals



Buzea, C.; Pacheco, I. I.; Robbie, K., *American Vacuum Society* **2007,** 2, (4), MR17-MR71

TOXICITY OF SILVER NANOPARTICLES



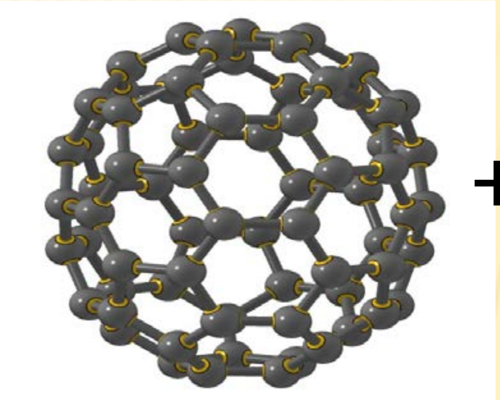


A concentration-dependent increase in mortality and hatching delay was observed in AgNPs treated embryos of Zebra fish.

Zebra fish

Nanotechnology **19** (2008) 255102

TOXICITY OF FULLERENES



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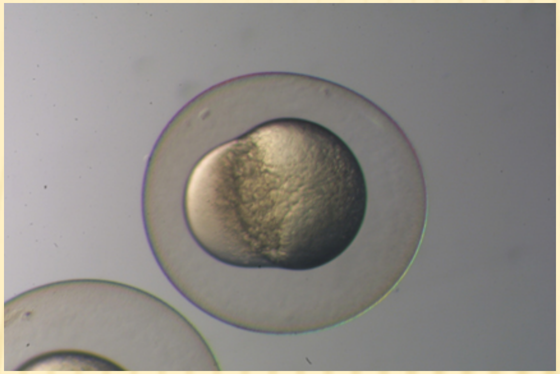

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C_{60} **Zebra fish Embryos** **Zebra fish**

Exposure to 200 µg/L C_{60} and C_{70} induced a significant increase in malformation, pericardial edema, and mortality.

(*Usenko et al. In vivo* evaluation of carbon fullerene toxicity using embryonic zebra fish *Carbon N Y*. 2007 August ; 45(9): 1891–1898).

Summary of Toxicity Effects

Exposure Route	Test Species or Cell Tissue Type	Dose	Particle Diameter (nm)	Specific Surface Area (m^2/g)	Crystalline Phase	Experiment Type	Reported Observation	Reference
Inhalation	human lung epithelial cells	3.6 - 2,000 ug/mL 1-48 hours	3-21	50-150	anatase, rutile	*in vivo*	cell death for conc. range of 0.1 to 2 mg/mL	44
	human	0.1 - 1.31 mg/m^3 Duration not provided	10-300	36-124	anatase	model prediction	EC50 of 0.43 ug/mL for inflammatory response	46
Dermal	human skin	0.1 g/cm^2 2 hours	21	50	anatase, rutile (80%, 20%)	*ex vivo*	No penetration through skin for test dose of 0.1 g/cm^2 Penetration depth of about 2 um	47
	human skin	50 mg/cm^2 2 hours		300		*ex vivo*	No penetration through skin for test dose of 50 mg/cm^2	48
Oral	rat	0.175 - 5 g/kg 48 hours	96-184	38.5	rutile	*in vivo*	NOEL for mouse death test dose range of 175 to 5,000 mg/kg	49
	rat	2 g/kg Lethal dose		≥ 500	amorphous	*in vivo*	NOEL for mouse death test dose of 2,000 mg/kg	50

Note: blank fields denote that information was not provided in the reviewed literature sources.

SUMMARY OF ECOTOXICITY EFFECTS

Environmental Compartment	Test Species	Reported Observation	Exposure Duration
Aquatic	Rainbow trout, *Oncorhynchus mykiss*	LC_{50} of 100 mg/L	8 weeks
		Low hazard, EC_{50} > 100 ug/mL	96 hours
	Invertebrates, *Daphnia magna*	LC_{50} of 5.5 ppm	1 hour
		Low hazard, EC_{50} > 100 ug/mL	48 hours
	Green algae, *Pseudokirchneriella subcapitata*	NOEC for test dose of 10 mg/L	72 hours
Terrestrial	Wood louse, *Porcellio scaber*	NOEL for test dose of 3 mg/gm	3 days

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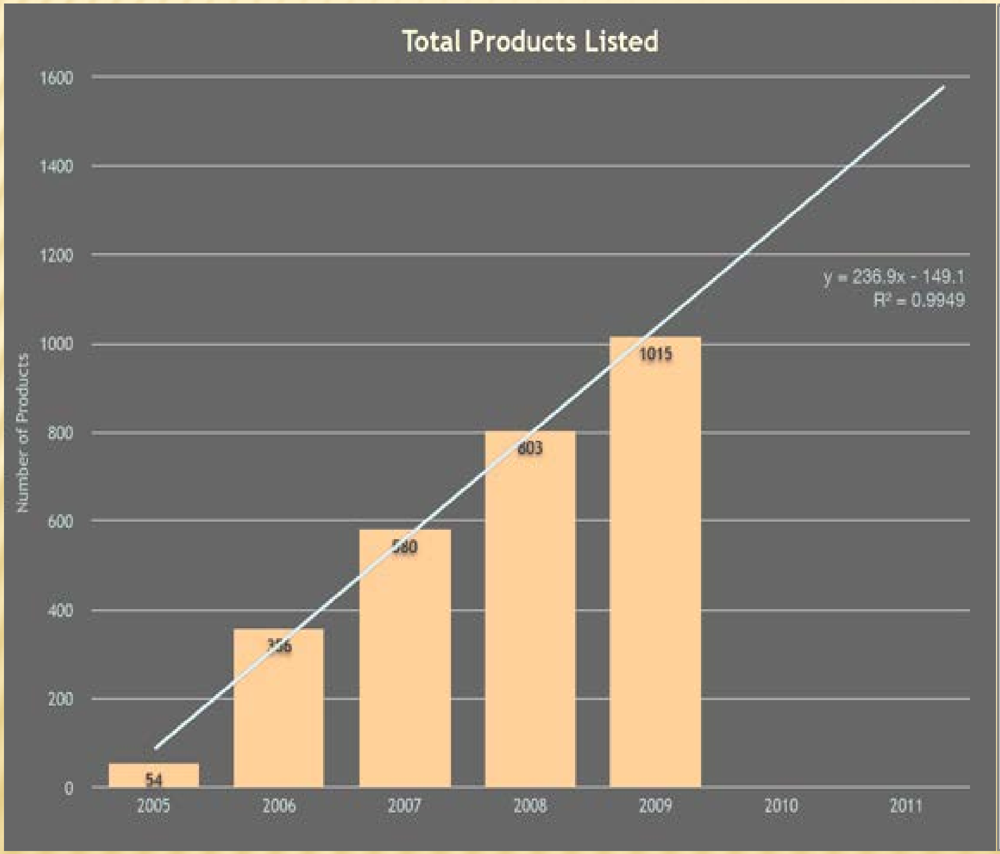
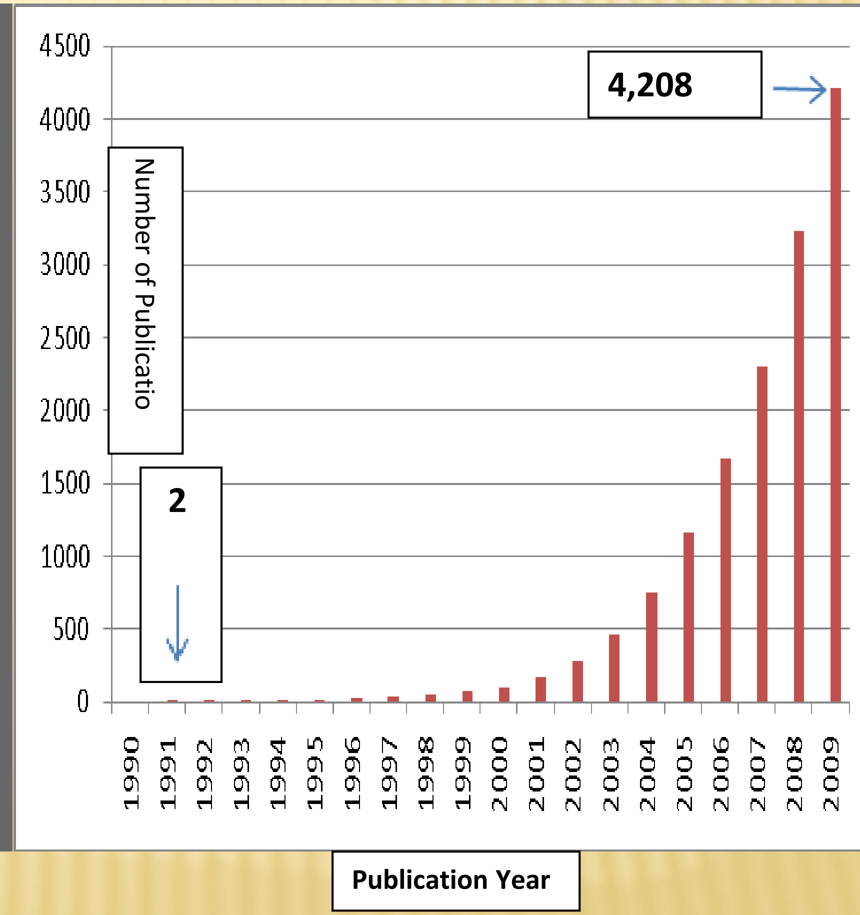
PROLIFIC GROWTH OF NANOTECHNOLOGY

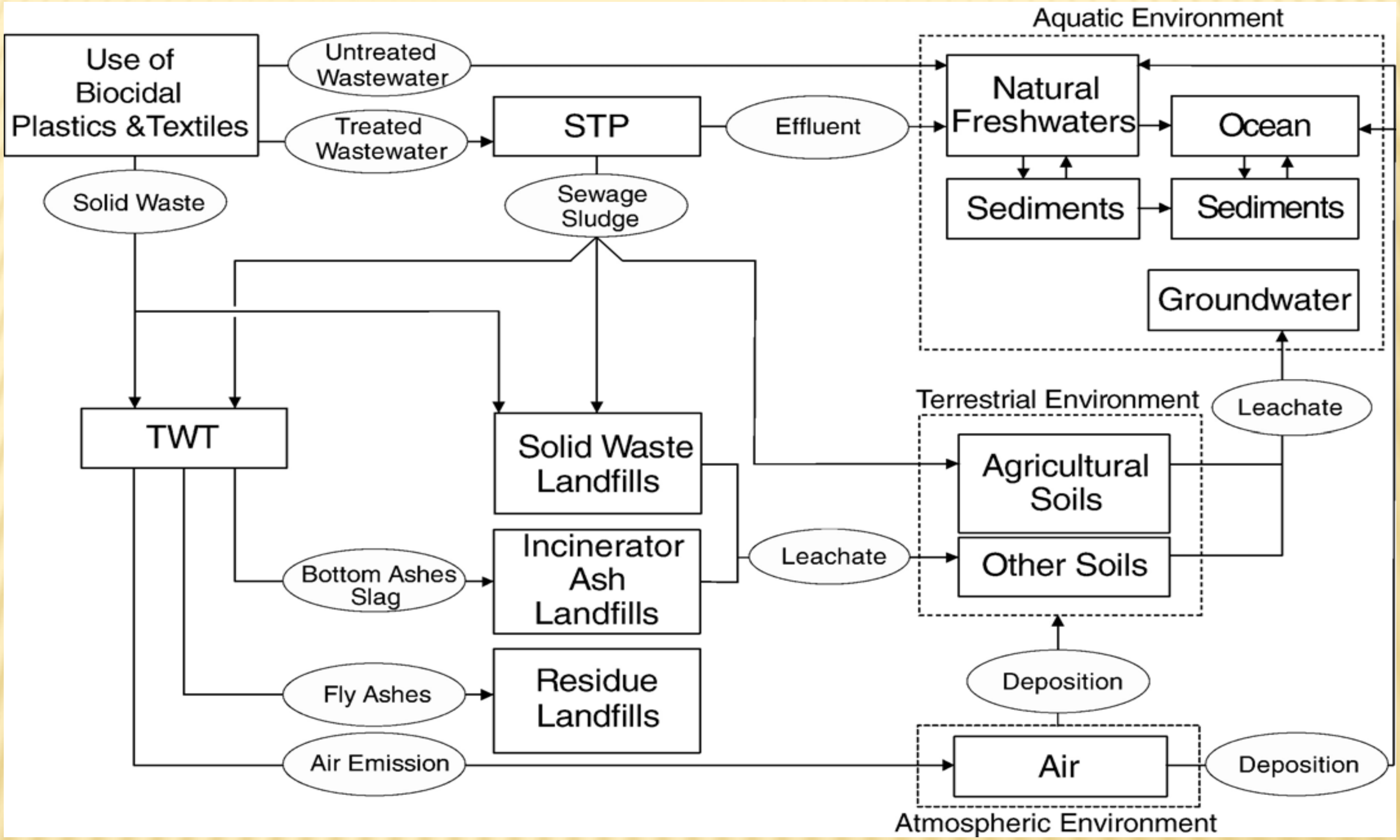
Nanomaterials are being incorporated into commercial products at a faster rate than the development of knowledge and regulations to mitigate potential environmental impacts.





Source: Project on Emerging Nanotechnologies

EXAMPLE OF POSSIBLE ENVIRONMENTAL EXPOSURE ROUTES:



Schematic of silver flows triggered by biocidal plastics and textiles. TWT represents thermal waste treatment and STP represents sewage treatment plant. (Adapted from Blaser *et al*., 2007).

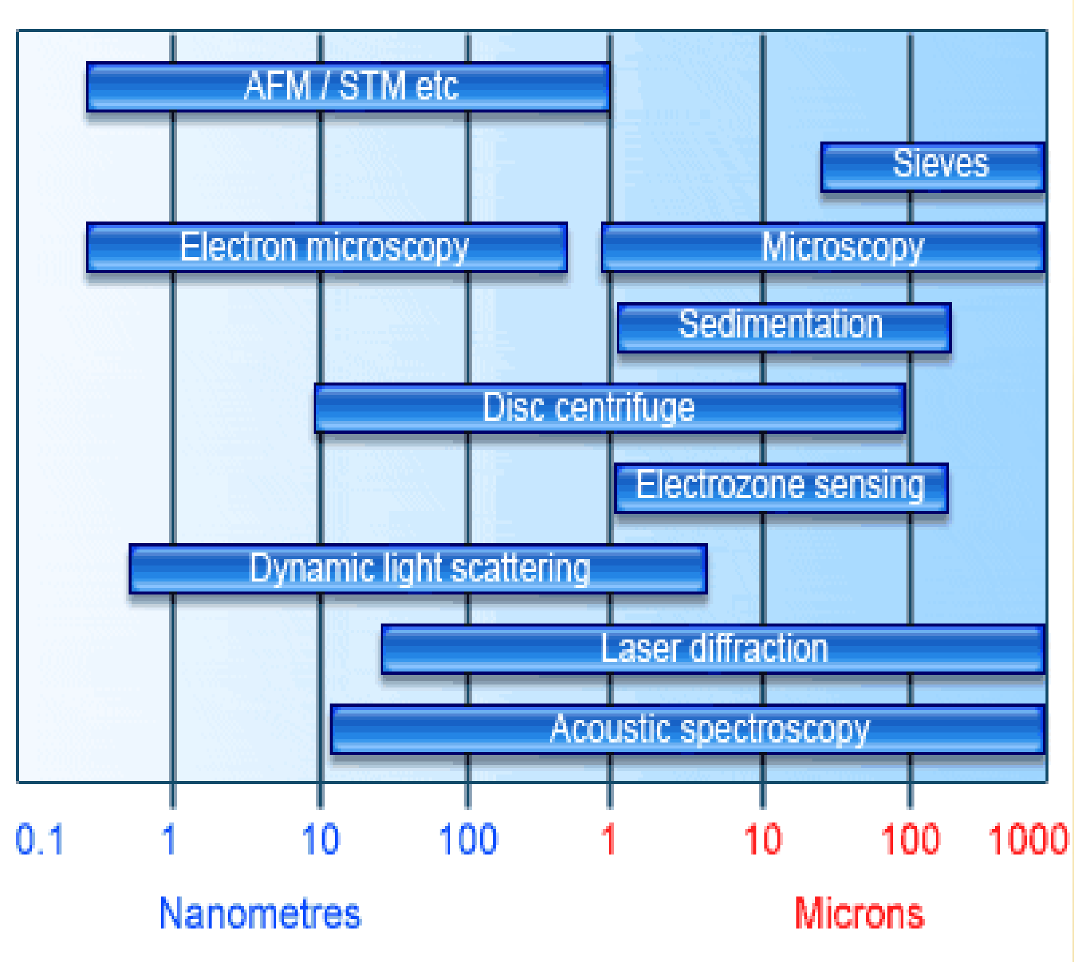
MANUFACTURING & TRACKING

- Past manufacturing on silver in North America, now shift to Far East (China, S. Korea, Taiwan & Vietnam)
- Difficult to track because of brand name & no labeling regulation
- Over 55 categories of nAg synthesis utilizing a variety of solvents as well as stabilizing agents
- Parameters of concern are particle size and charge, chemical/elemental composition and surface modifications
- Environmental media parameters to consider include pH, ionic strength, flow rate, composition, geophysical properties

SOIL, GROUNDWATER AND AIR TECHNIQUES

- Limited information
- Data gaps
- Absence of analytical method

DOSIMETRY & CHARACTERIZATION



Sadik et al, Journal of Environmental Monitoring(JEM), Critical Review, 11, 1782-1800, 2009

- Dynamic Light Scattering (DLS): is the only technique able to measure particles in a solution or dispersion in a fast, routine manner with little or no sample preparation.

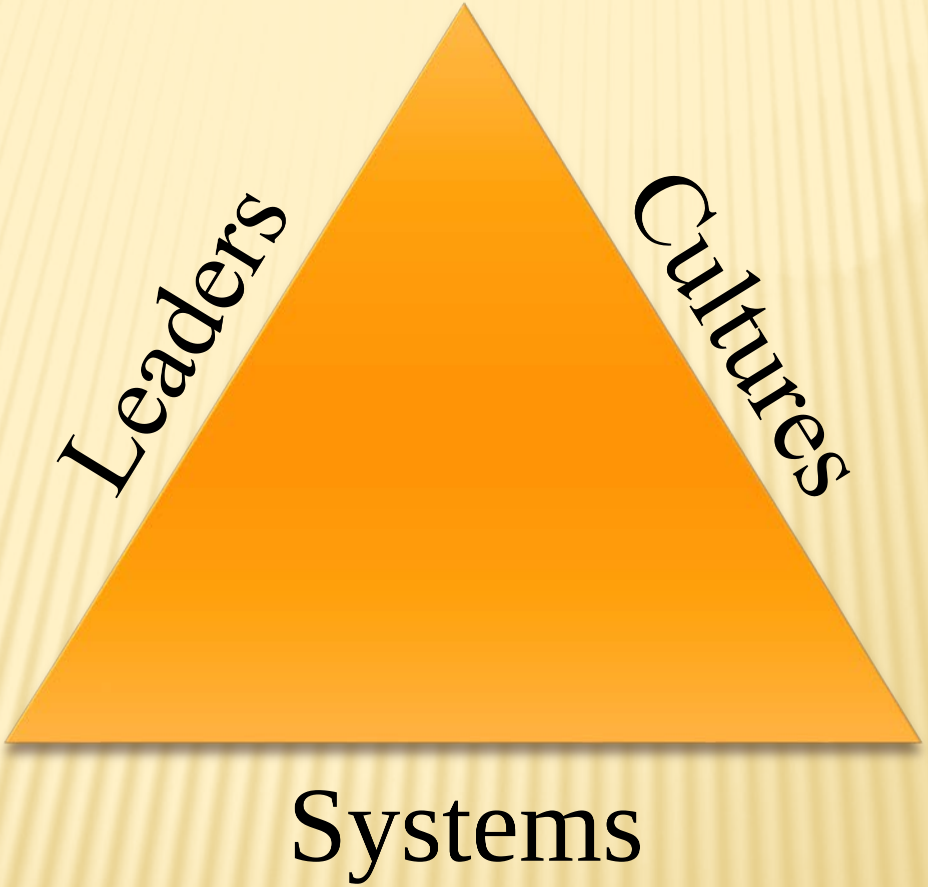
- AFM and STM: only suitable for ‘hard’ materials or conductors, i.e. those not affected by the preparation technique and is poor from a statistical point of view as only tens or hundreds of particles are measured.

- Electron microscopy: Provides information about the shape and surface structure of the particle than an ensemble technique like DLS.

OVERALL OBJECTIVE

Build and sustain
a total culture
of
safety, health, well-being,
and productivity

Essential factors to build and sustain safety, health, well-being, and productivity



A management view for possible application in our mission

FOUR STEPS FOR COMMUNITY ACTION

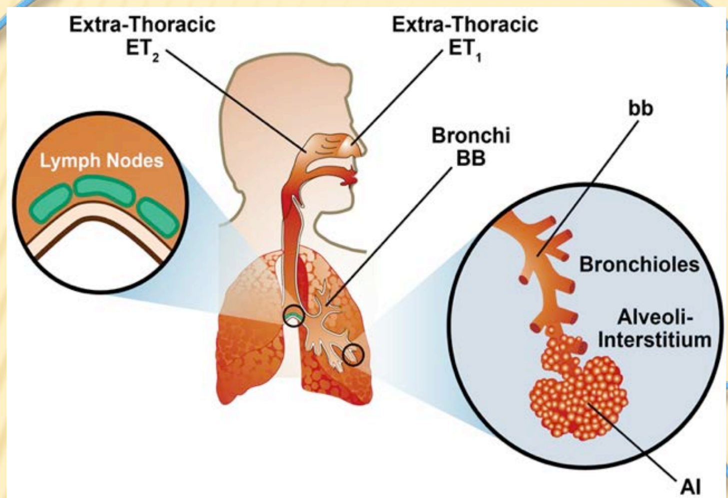
TO BUILD AND SUSTAIN A TOTAL CULTURE

OF SAFETY, HEALTH, WELL-BEING, AND PRODUCTIVITY

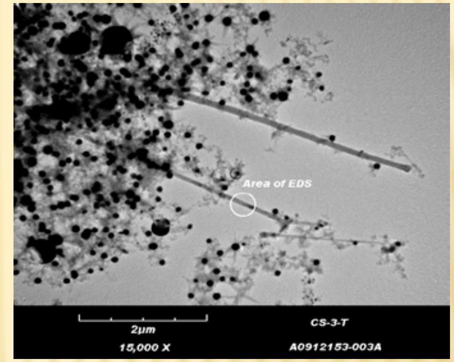
Leaders Systems Cultures

Adapted from our Nanoinformatics 2020 Roadmap

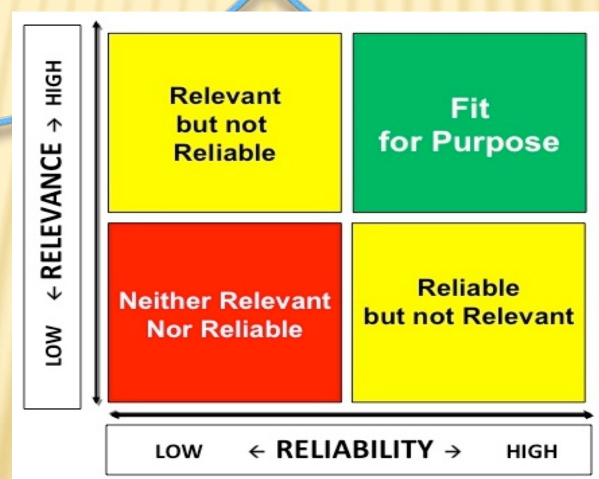
A CONTEXT FOR OUR WORK



Public Health



Emerging Technology



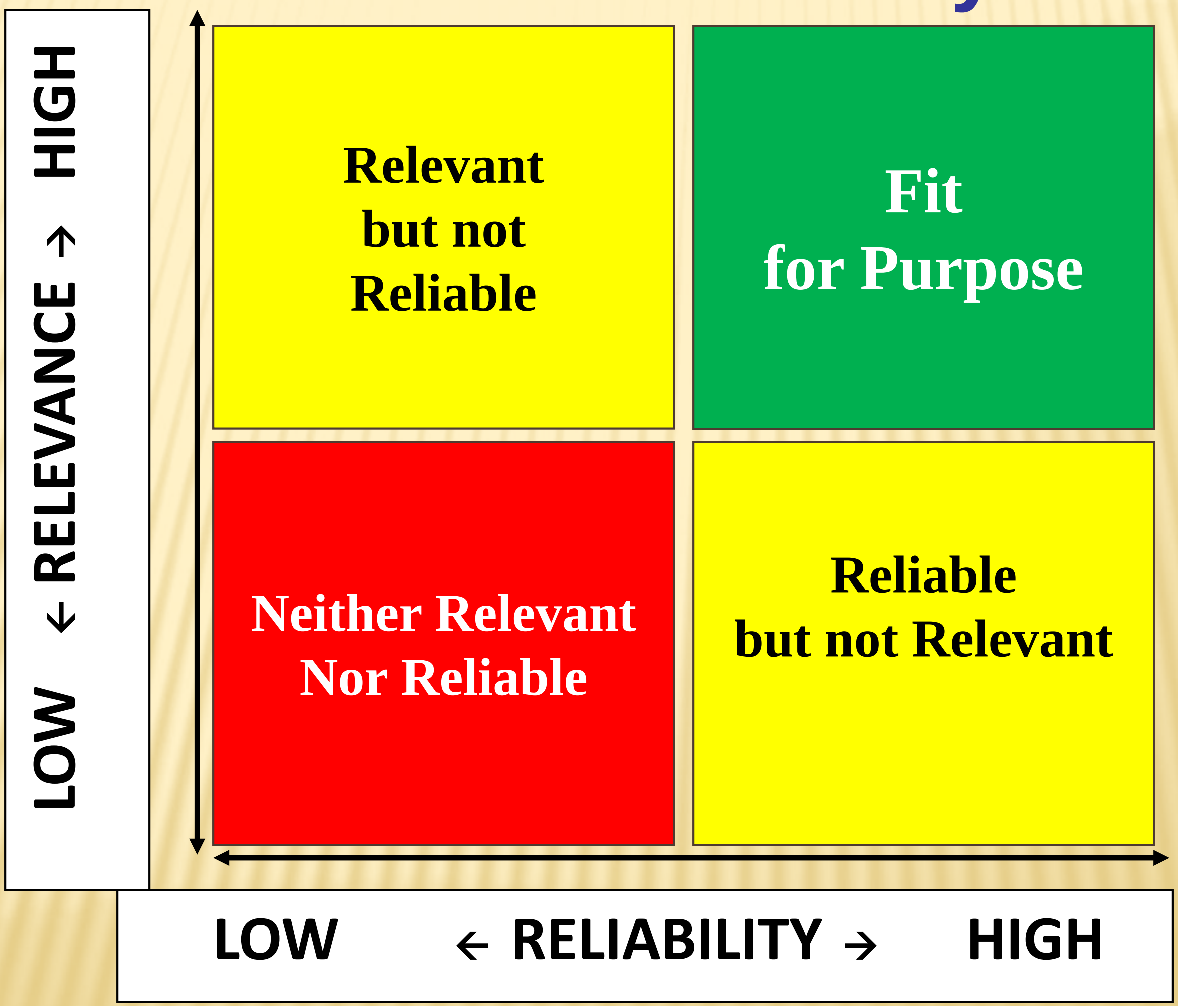
Risk Management

Adapted from L. J. Cash (2014)

INFORMATICS LIFECYCLE ROLES AND RESPONSIBILITIES

	Set Mission Objectives	Determine Relevance	Collect	Validate	Store	Share	Analyze and Model	Apply	Confirm Effectiveness
Customers	x	x						x	x
Creators		x	x	x					x
Curators		x		x	x	x			x
Analysts		x		x			x		x

Relevance-versus-Reliability Assignment



Hoover, Cash, Mathews, Feitshans, Iskander, and Harper (2014)

CLEAR COMMUNICATION ASSESSMENT CRITERIA

Concise

Logical.

Ethical

Ethical, legal, and societal issues

Accurate

Relevant

Hoover, Cash, Mathews, Feitshans, Iskander, and Harper (2014)

WE CAN PARTNER TO DEVELOP AND APPLY A *COMPREHENSIVE* DECISION-MAKING FRAMEWORK TO:

- Anticipate,
- Recognize,
- Evaluate,
- Control, and
- *Confirm*

Hoover et al., Synergist, 22(1): 10, 2011

***success** in proactive understanding and management of potential hazards, exposures, and resulting risks to safety, health, well-being, and productivity*

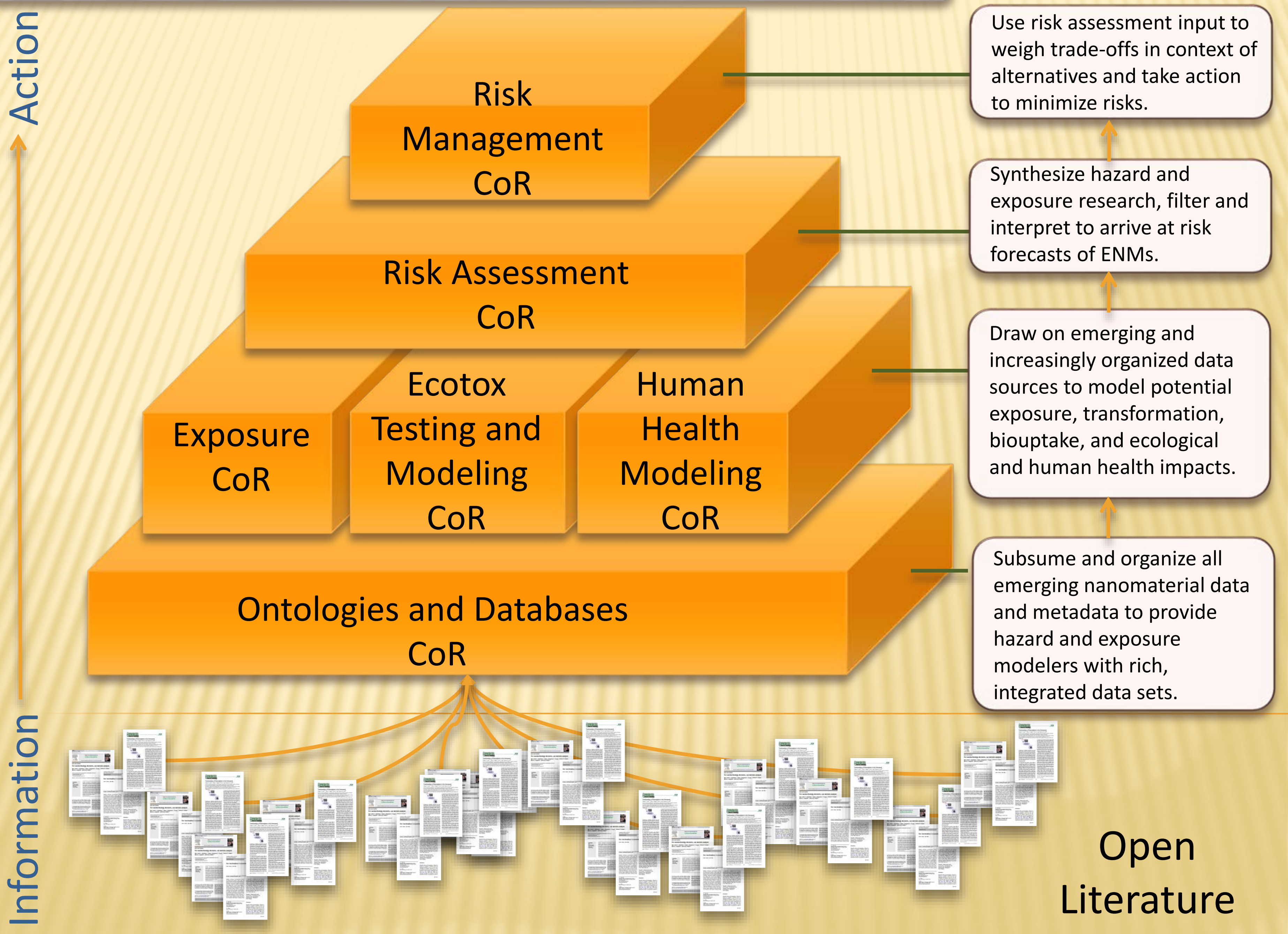
by applying a science- and practice-based approach to build and sustain ***leaders, cultures, and systems*** that are relevant and reliable and over which we have influence.

NANOINFORMATICS (A WORKING DEFINITION)

- The *science and practice* of determining ***which information is relevant*** to meeting objectives of the nanoscale science and engineering community,
- and then developing and implementing effective mechanisms
- to *collect, validate, store, share, analyze, model, and apply the information, and then to confirm achievement of the intended outcome* from use of that information.

http://www.internano.org/nanoinformatics/

Idealized Information-to-Action Continuum



Interrelationships of criteria for responsible development of nanotechnology

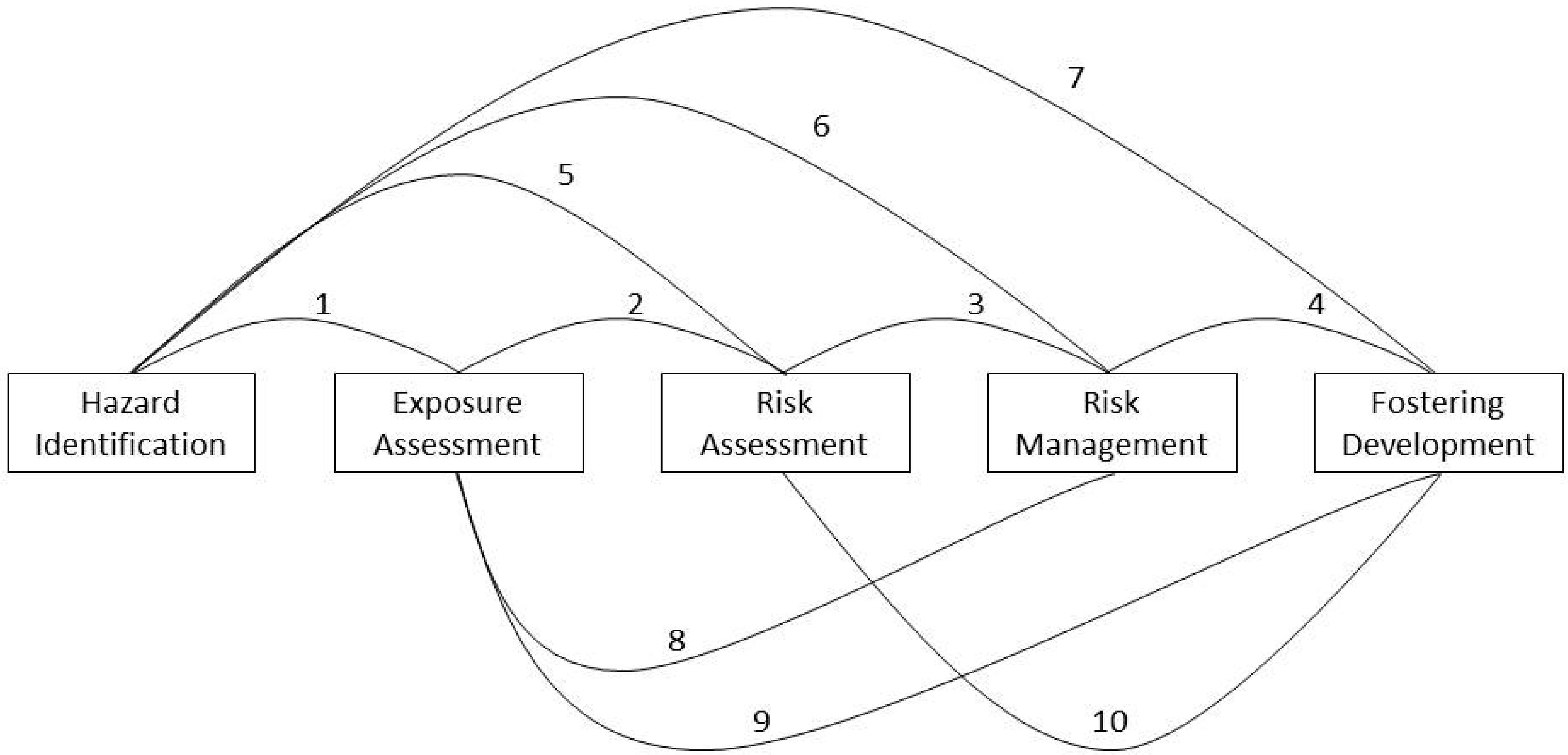


Figure 1. Interrelation of criteria for responsible development

Schulte et al. 2013, OSH Criteria for Responsible Development of Nanotechnology Journal of Nanoparticle Research

FUTURE DIRECTION TO DEVELOP SAFE AND SUSTAINABLE USE OF ENMS:

•To provide sustainable decisions, combine manufacturer and research data in order to understand reactionary relationships and characterize their impacts.

•Improve analytical methodology in order to apply efficient and effective evaluations for risk assessment.

•Balance → Protect resources →Provide education

•Green development

Simply put, we must save our future through reducing, reusing and recycling.
•Know the end of shelf life/reuse/recycle

THANKS FOR LISTENING TO THE SMALL TALK

- Any curiosities?? And or concerns?
- Nano-nano!

"Notice: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy."