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WHAT DO WE MEAN BY NANOSCIENCE OR NANOTECHNOLOGY EDUCATION?

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Talk intended to raises issues and encourage dialog about the nature of Nanoscience and Nanotechnology Education
(expand on ideas from other talks and raise of new topics)

Shares educational experiences from education activities conducted jointly with the University of Washington and Washington State University

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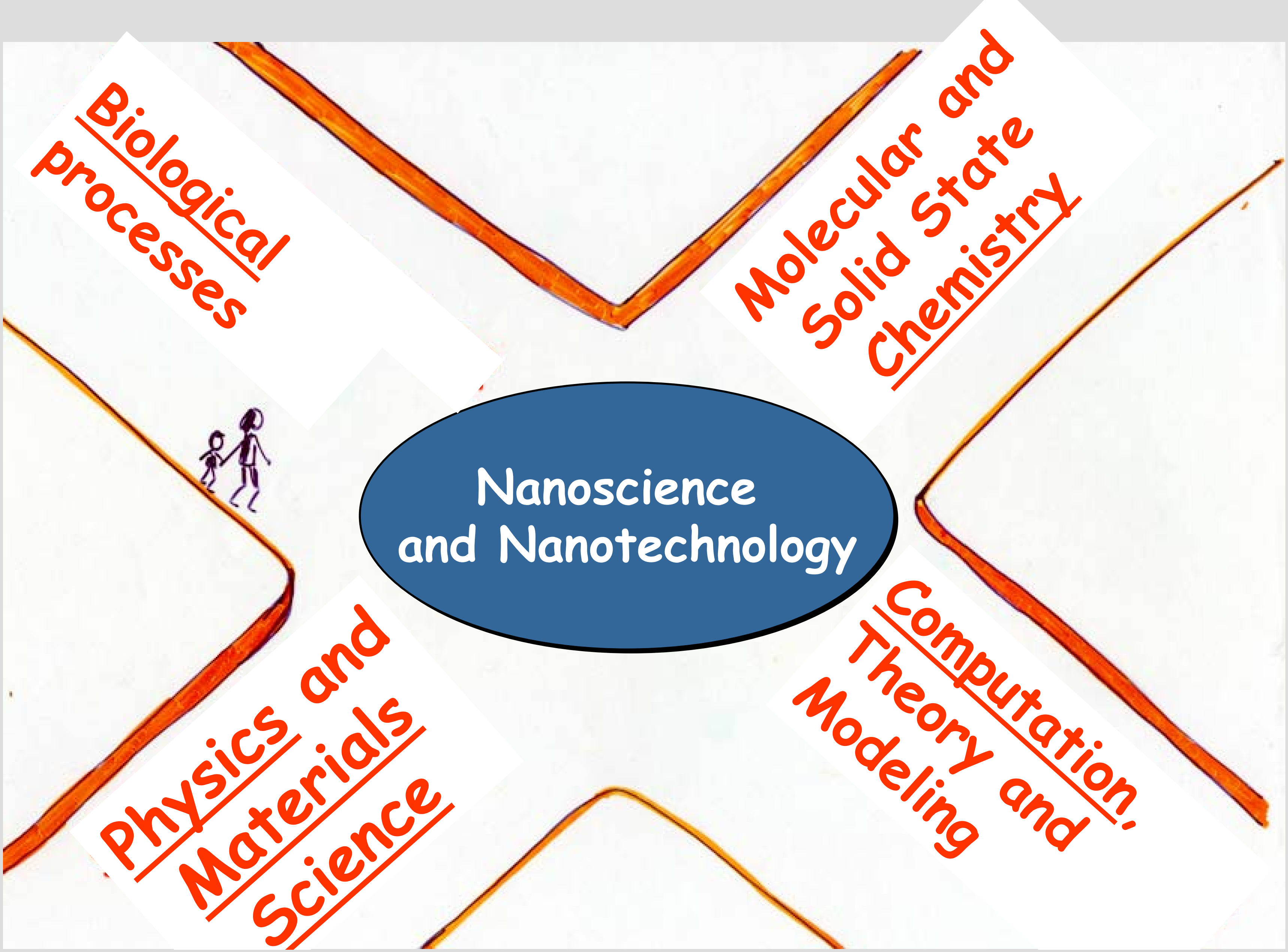
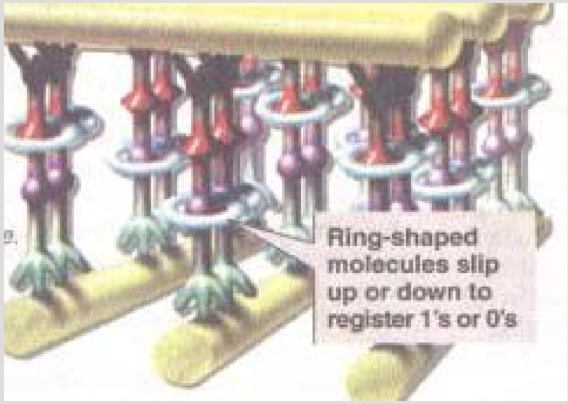
Topics

- **Nature of nanoscience and nanotechnology has implications for the types of education needed**
- More than one type of education is needed needed:
  - Experts – research, engineering, manufacturing, policy, safety and regulation
  - General Public
  - Workforce
- General issues that impact education, research and manufacturing
  - Tools for research and manufacturing - Need deeper understanding of characterization tools, more advanced use of analysis methods and appropriate metrology for manufacturing and commerce
  - Need terminology appropriate for education, regulation and manufacturing
  - Need to facilitate formation of creative multi-disciplinary teams

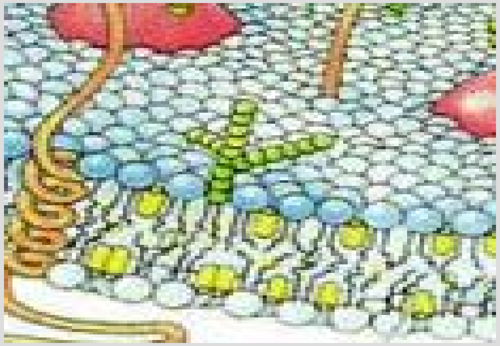


Adapted from Design of Organometallic Molecular and Ionic Materials
D. Braga, et al. **Coord. Chem. Rev.** 2001, 216, 225-248

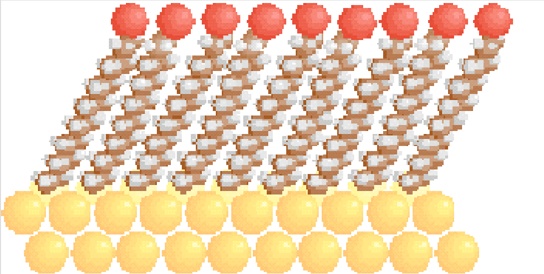
Many overlapping ideas, concepts and approaches link chemistry, physics, biology and information storage at the nanoscale



Molecular nanocircuit



Cell membrane

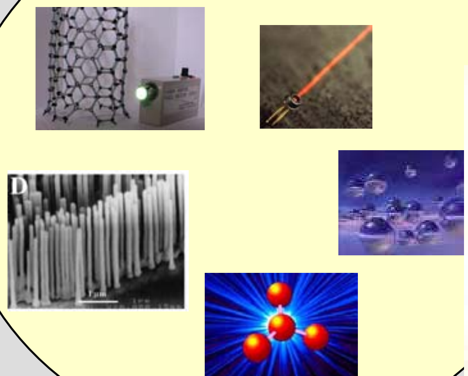


Self assembled monolayer

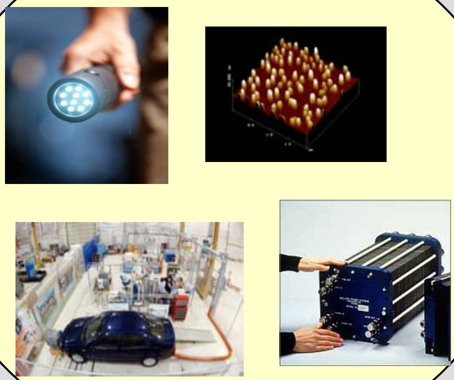
Nanotechnology will impact many areas!!

Consumer Products

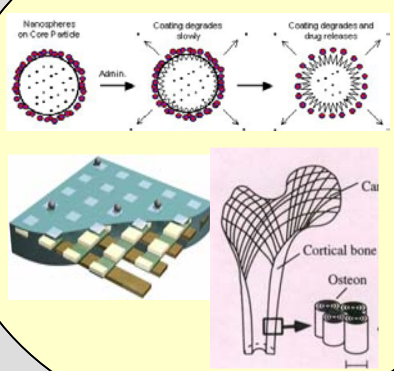
Information Technology

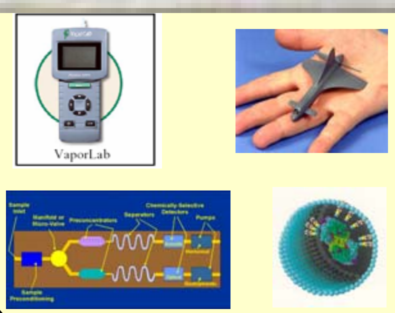


Energy Use and Production

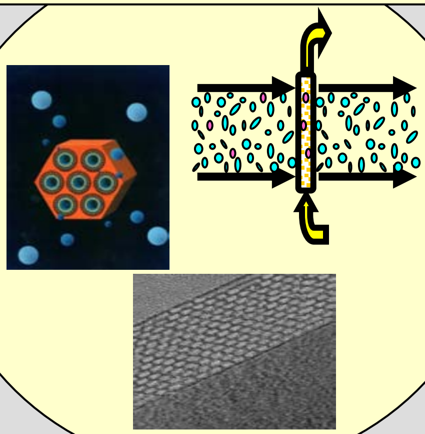


Medicine and Biotechnolo





Environmental Quality



Collection of Characteristics

Implications for Education?

Characteristics

- *Chemistry, physics, biology and information storage at the are linked at the nanoscale. Nanoscience and nanotechnology are not one cohesive discipline.*
- *Nanotechnology will impact many technologies on short and long term time frames*
- *Eventually nanotechnology will alter the way we make things and have the broad impact of the industrial or information revolutions*
- *New ways of making chemical and products may impact distribution, consumption, energy use, environmental contamination. Potentially large impacts on the way we live.*
- *Rate of change and information growth is very rapid*
- *The large impacts and rapid rate of change will likely cause disruption of some type and fear*

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- General Issues that Impact Education, Research and Manufacturing
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What do we need education to do relative to nanoscience and nanotechnology?

- **For science, technology and business leadership - Develop <u>experts</u> with ability to work in <u>multidisciplinary</u> teams to take advantage of the opportunities.** *Require learning the **<u>language</u>** of several disciplines and an ability to work in teams.*

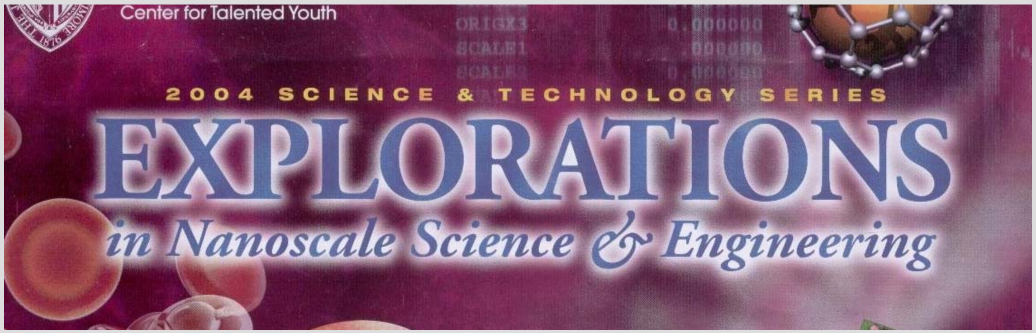
- **Impact on Society - <u>Equip everyone</u> with the language and knowledge to deal with the societal, environmental, economic and environmental choices and risks.** *This includes development of experts in specific topics and providing a general knowledge level for most people.*

- **Business and Economy - <u>Educate a work force</u> to deal with the new demands and skills needed.** *Fundamental changes in technology alter how we live and the skills needed for success.*

Long Term Education Needs

- **K-12** - Nanoscience information integrated into course structures. Development of concepts and language.
- **College** – Specific courses in nanoscience concepts and integration of nanoscience concepts into other science and math courses.
- **Graduate** – Combine knowledge depth in at least one skill area **with** skills to participate in and lead multi-disciplinary teams.
- **Lifelong education** – With the rapid knowledge growth, education is a continual process
- **Workforce** skills need to be identified and taught (clean room skills, computer skills, ….)

Sharing the excitement of science
with middle school students
Center for Talented Youth Family Symposium Nov 6, 2004, PNNL



Multi-disciplinary, multi-institutional courses provide one method to introduce a wide variety of students to Nanoscience and Nanotechnology

Intensive Courses in Nanoscience and Nanotechnology

For more information, or to register go to
http://www.nano.washington.edu/education/jin.asp

Course development supported by a grant from the National Science Foundation

University of Washington 1861 · LUX SIT

NANO Science, Engineering and Technology

Washington State University

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Three Nanoscience Courses Developed with NSF Funding

Given in Richland and/or Seattle

- Introduction/Overview
- Fabrication & Characterization
- Theory

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Lecture Topics – NanoFabrication and Characterization Course

Fabrication of nano-materials

MBE	CVD	NanoparticlesIon
Implantation	Clusters	Nanotubes
SAMS and SAMMS	Ballistic deposition	Sol-Gel Organic
Layer/nano-films	Supramolecular Chemistry	
Magnetic Nanoparticles	Sensor Materials	

Characterization of nanomaterial systems

XPS	TEM	SEM
SPM	AES	XRD
Ion Channeling/RBS	NMR	AFM/SERS
Defects detection/theory	XAS,	Magnetic properties

Small Projects – NanoFabrication and Characterization Course

Synthesis Activity (three per course)

MBE – a)Chromia or doped b) TiO2 MBE Film c) Oxide nano cluster

Sol-Gel - Nanostructured Ceria films

Sputter Deposit – Nanofilm of Co on Si for contacts

Characterization Activity (five analysis teams)

electron microscopy	electron spectroscopy
X-ray (XRD XRR)	SPM

Ion Beam (RBS, Channeling, NRA)

- The “dirty” secret of nano-structured materials is that they have surface contamination that is often not characterized or examined.

- Many surface analysis tools can be useful for analysis of nano-structured materials, but there are challenges in applying them to such materials, including importance of time and environment.

- Intelligent and informed use of multi-techniques is important for getting useful information about nanoparticles.

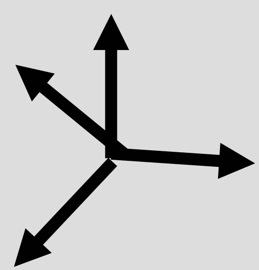
- Need information not just about single nano-objects but about LARGE distributions (truck loads) of nano objects.

- There is lots of room new types of analysis and need for careful analysis that uses all the information available!!

Experimental Axes Multi Dimensional Analysis

- Time
- Energy/composition
- Resolution/Dimension
- Environment

Nanoparticle properties vary with time and depend on the environment



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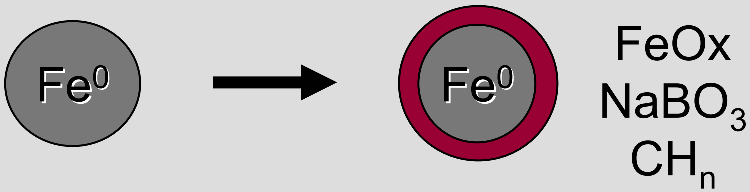
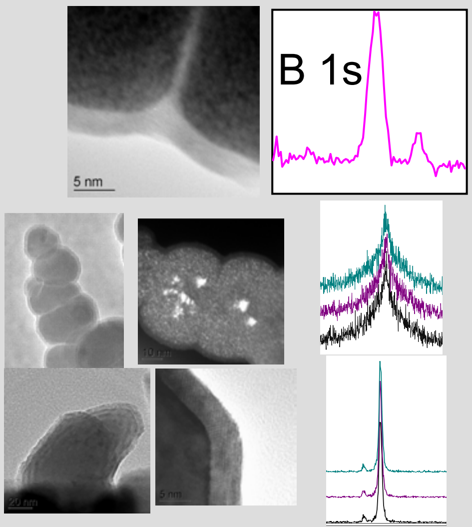
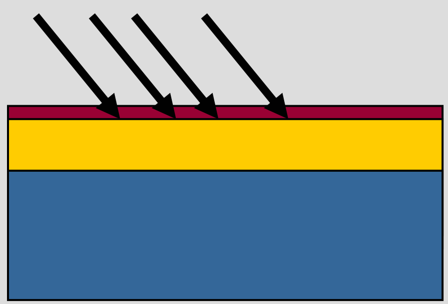
We need to teach people how to use more tools and to use them better

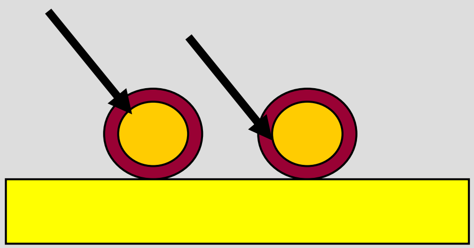
Nanoparticles are difficult to accurately characterize





Knowing particle shape information allows more information to be extracted from XPS



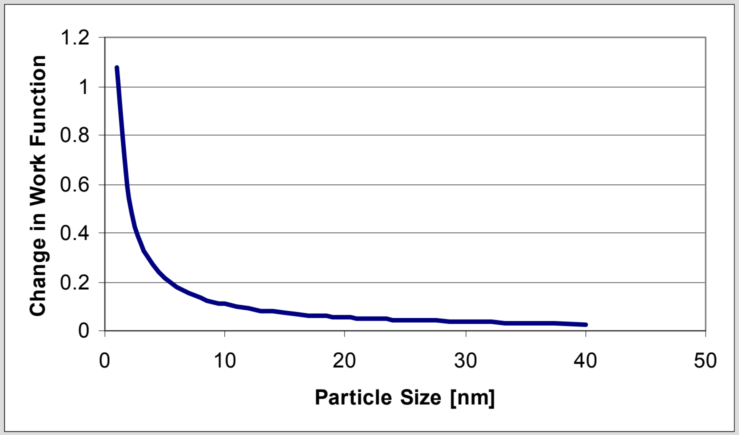


Several Different Nano-size Effects

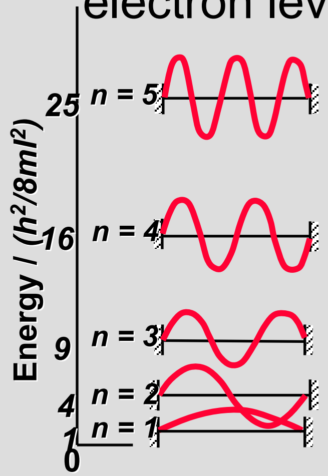
There are many causes of NANO-Size effects. Usually these are not indicated.

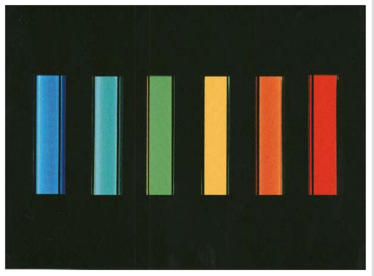
Clear Terminology Can Help Researchers, Readers and Students

Classical Size Dependence of Work Function for Small Metal Particles - Cu

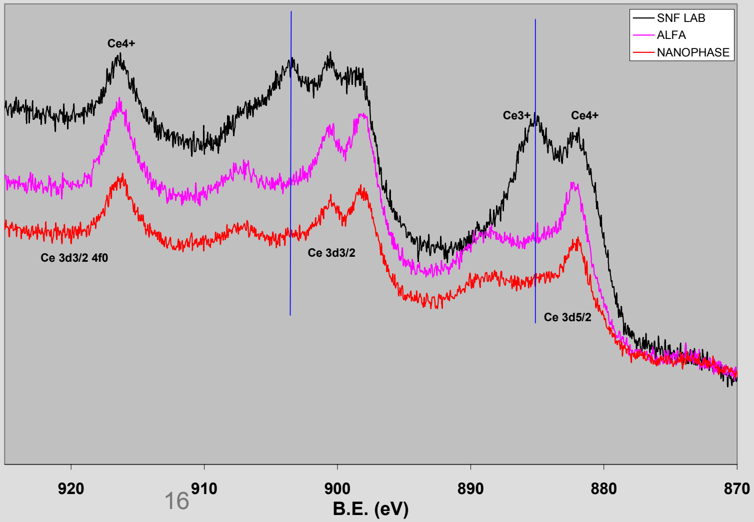


Particle in a Box – Size induced electron levels – Cd Se





Size Induced Instabilities - Oxygen vacancies form for small in small ceria nano-particles producing a Ce^{+3} oxidation state



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Terminology is used to distinguish concepts

Example from ASTM E42 on surface analysis

Old terminology – one concept

Electron Attenuation Length

New terminology – different but related concepts are distinguished

Electron mean free path

Electron inelastic mean free path

Electron effective attenuation length

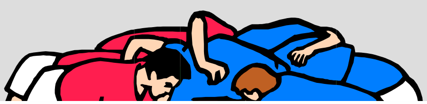
Emission depth distribution function

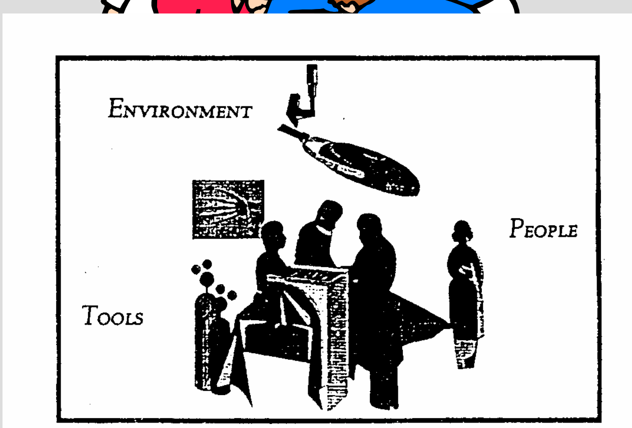
Critical terminology must be developed for nanoscience and nanotechnology and then incorporated into the education process

The wide base of nanoscience and nanotechnology concepts and opportunities, requires an education process that facilitates team formation [Culture]

Although there will be exceptions most progress will not be made in one discipline or by a single person

The traditional linear hand off from one discipline or person to another does not encourage multiple discipline synergism.





There are a number of different types of teams where everyone needs to work together for the benefit of all

A surgical team assembled with a specific skill set for a specific problem is good example. *For a team of experts to succeed they need a common language and some knowledge of the expertise of others.*

Challenges to those doing nanotechnology

In my view:

Education must involve a **new culture** of teamwork and communication as well as **depth** of knowledge.

Understanding and managing how nanoscience and nanotechnology will **impact society, managing these effects** and teaching concepts to general public may be critical to near term success.

For education and commerce, we need appropriate **terminology** to explain and distinguish the important **concepts.** The **reasons** nanoparticles have different or interesting properties are not always being adequately examined. What is meant by a "nano" effect is too often undefined.

There are fundamental challenges to getting important information about nanoparticles or nano-sized components in larger systems. We need to **expand the types and sophistication of analyses** that are used for most systems. This will involve team efforts and "expert" use of many techniques. This topic is commonly called metrology.

Theory is critical for understanding things we cannot see directly. We need to make more links between what we can measure and theory. New theory is being developed to handle nano-systems and it needs to be deployed and taught as rapidly as possible.