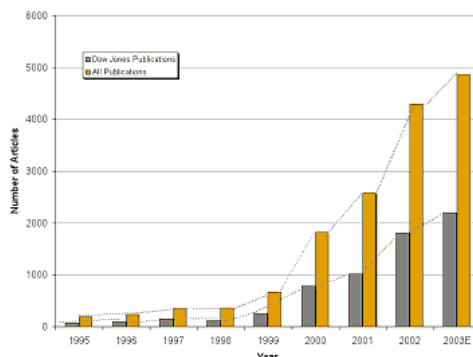




CBEN

Center for Biological and Environmental Nanotechnology

Nanotechnology



The Big Science of the Very Small

Kristen M. Kulinowski, Ph.D.

Department of Chemistry

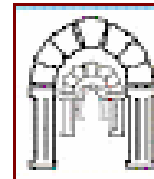
CBEN Executive Director for Education and Public Policy



CBEN Information

- Inception
 - September 2001
- General Activities
 - Research
 - Educational program
 - Industry-related programs
- Financial Scope
 - \$11.8 million from NSF over five years
 - \$5.3 million from Rice over five years
 - Competitive renewal for a second five years
- Span of Activities
 - 10 Departments
 - >20 Directly Funded PIs

- Shared Equipment
 - Purchases of new equipment
 - Maintenance of old equipment
 - Technical staff
- Outreach Partners



Center for
Education



Houston
ISD



Jones Graduate
School of
Management



School of
Continuing Studies



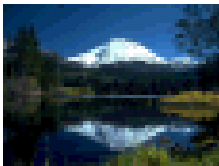
Baker Institute for
Public Policy



What is Nanotechnology?

Nanotechnology is the study and use of materials with nanometer-scale dimensions.

Mountain



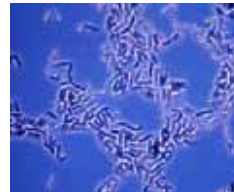
Child



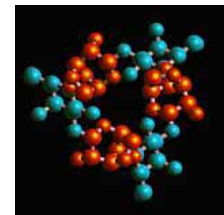
Ant



Bacterium



Sugar Molecule
(45 atoms)



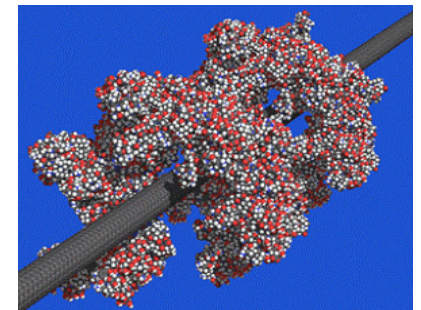
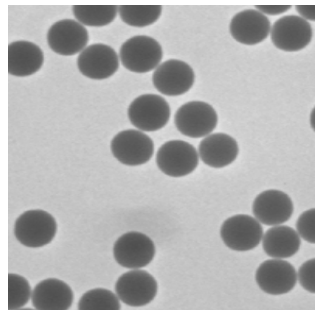
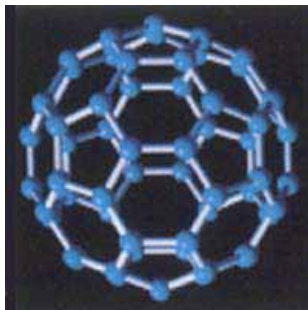
1 kilometer
(1000 m)

1 meter
(1 m)

1 millimeter
(0.001 m)

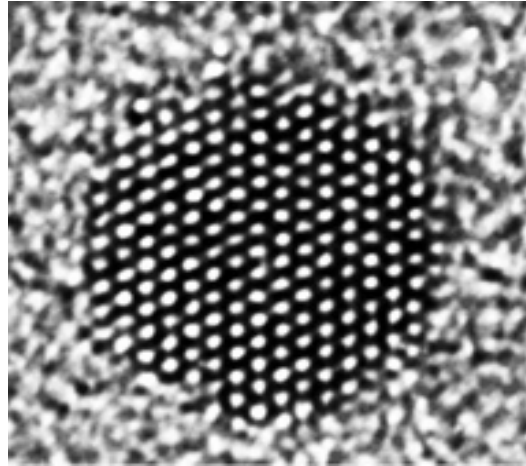
1 micrometer
(0.000001 m)

1 nanometer
(0.000000001 m)

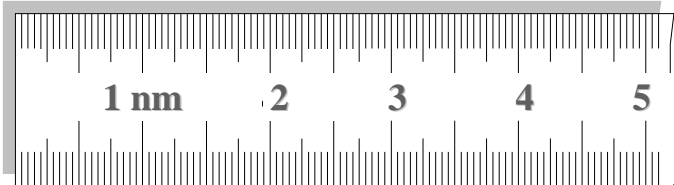
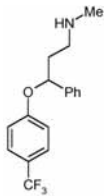




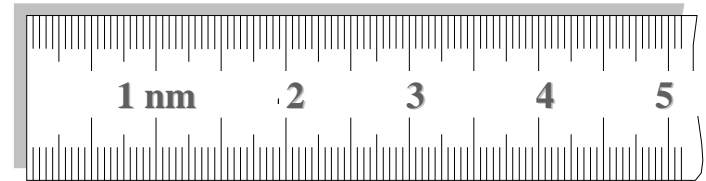
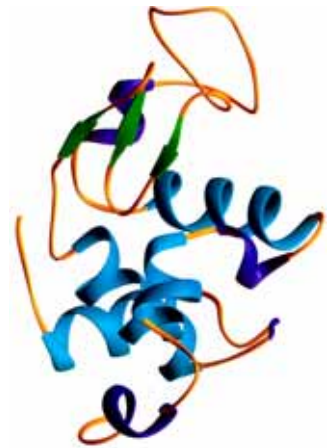
Nanoscience and Nanotechnology



A nanocrystal



Molecules



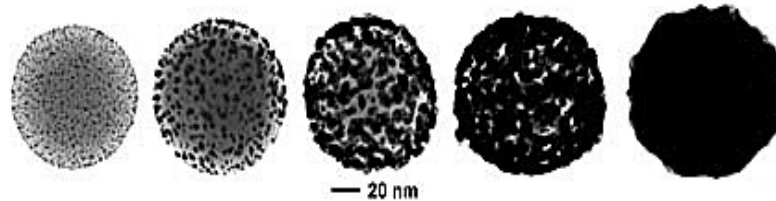
Lysozyme





What is Nanotechnology?

Nanotechnology is the creation of functional materials, devices, and systems through control of matter on the nanometer length scale, exploiting novel phenomena and properties (physical, chemical, biological) present only at that length scale.



"If I were asked for an area of science and engineering that will most likely produce the breakthroughs of tomorrow, I would point to nanoscale science and engineering."

Neal Lane
Former NSF Director
Assistant to President Clinton for Science and
Technology



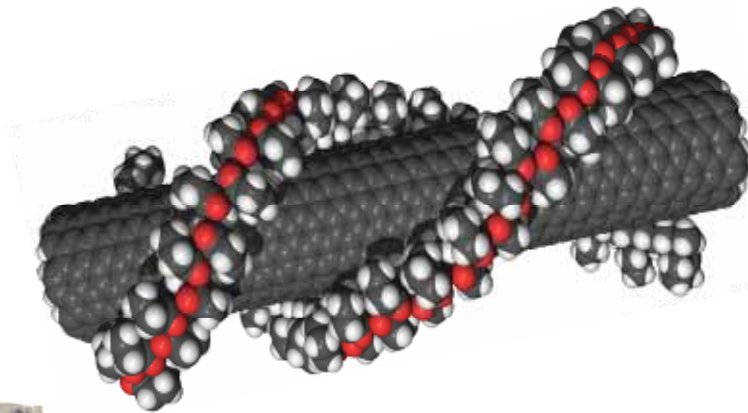
Nanomaterial Advantages

- **Near-Infrared optical signatures**
- **Transparent composites**
- **Accessibility to biological environments**
- **Tunable nanoscopic pores**

Physical
size

Surface
Availability

Optical
Properties



Nanotechnology is the application of unique nanomaterials.

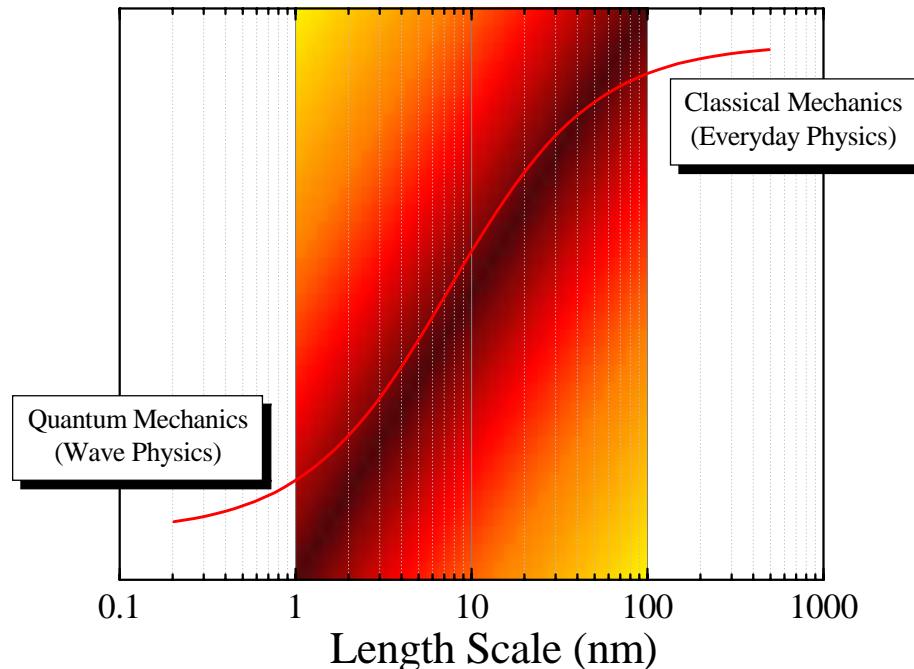


RICE



Why is Nano Different?

- At the micron (1,000 nm) and larger scale, classical physics determines properties.
- At the Angstrom (0.1 nm) scale, quantum mechanics determines properties.
- At the nanometer scale, fundamental properties depend on exactly how big the particle is.



The nanoworld



Size Matters



Bulk Gold = Yellow

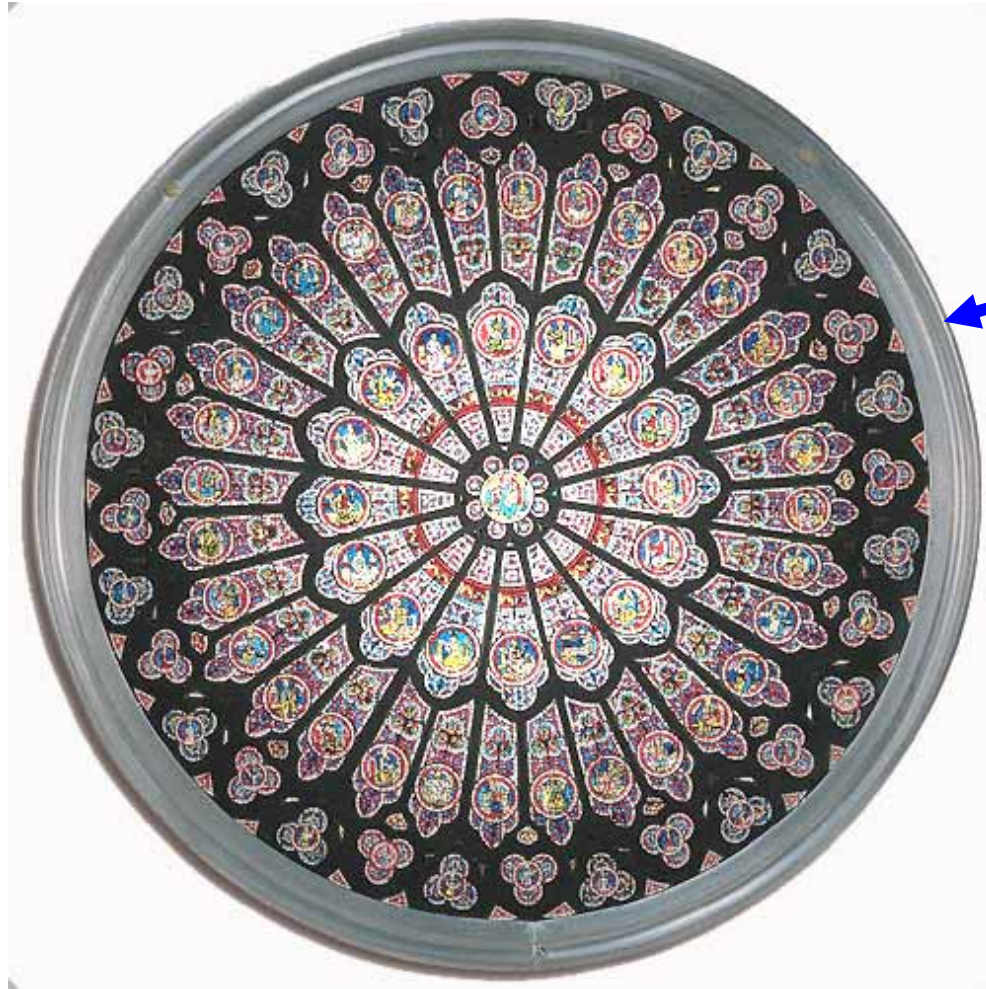


Nanogold = Red





Early Nanotechnologists



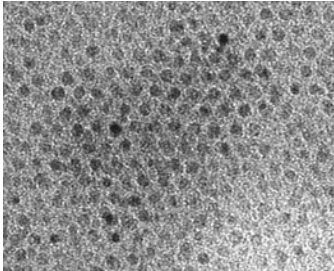
nano
inside

Rose Window of Notre Dame in Paris



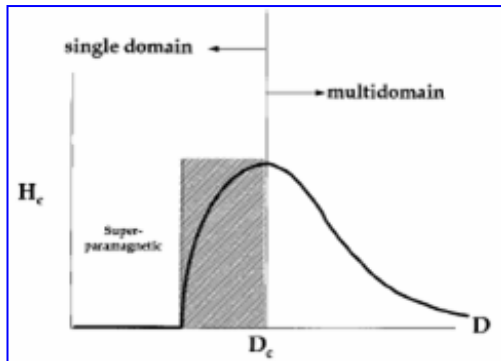
Nanomaterials are a Broad Class

Fe_3O_4 , $d=4.5$ nm



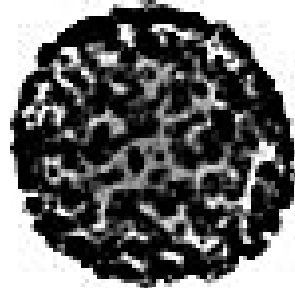
10 nm

Size-dependent Magnetism



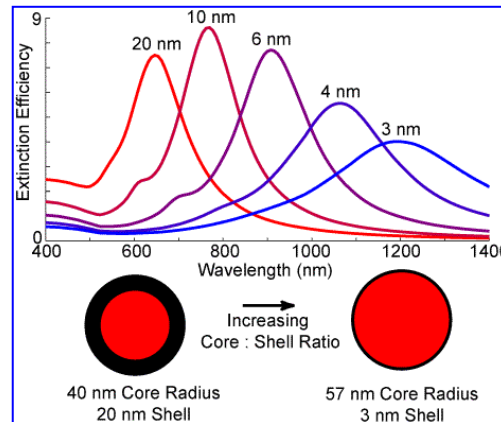
Colvin

Nanogold on Silica



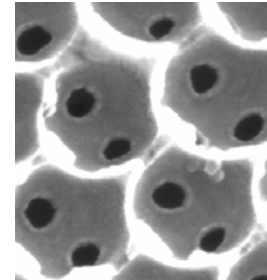
20 nm

Size-dependent Absorption



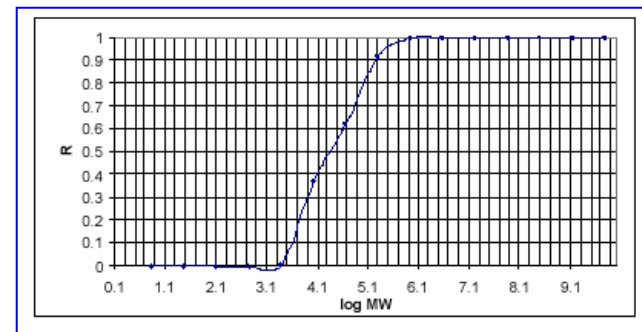
West

Mesoporous Polymer



100 nm

Size-dependent Filtration

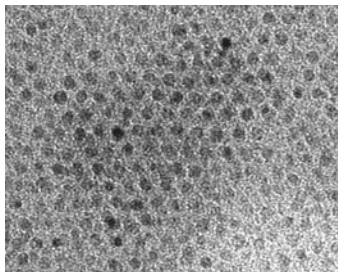


Wiesner, Colvin, Barron



Properties Key In Technologies

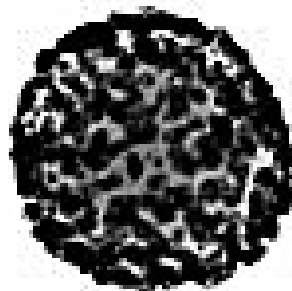
Fe_3O_4 , $d=4.5$ nm



— 10 nm

Magnetic Separations

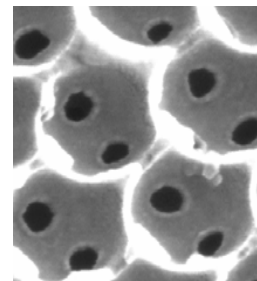
Nanogold on Silica



— 20 nm

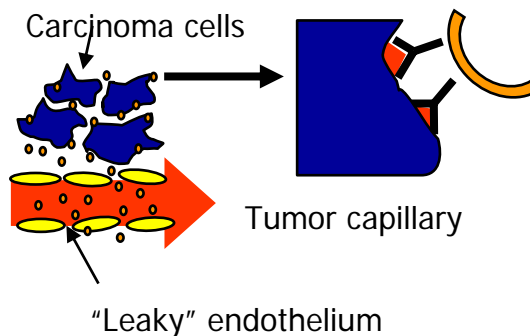
Photothermal Therapy

Mesoporous Polymer



— 100 nm

Membrane Systems



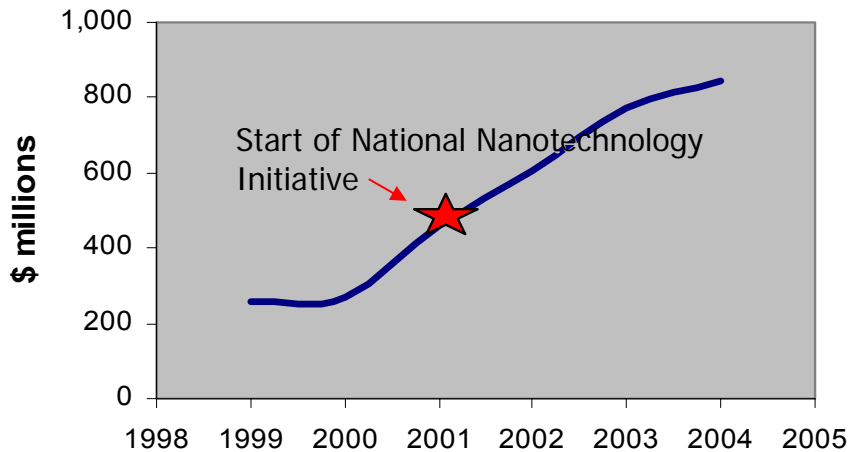
RICE



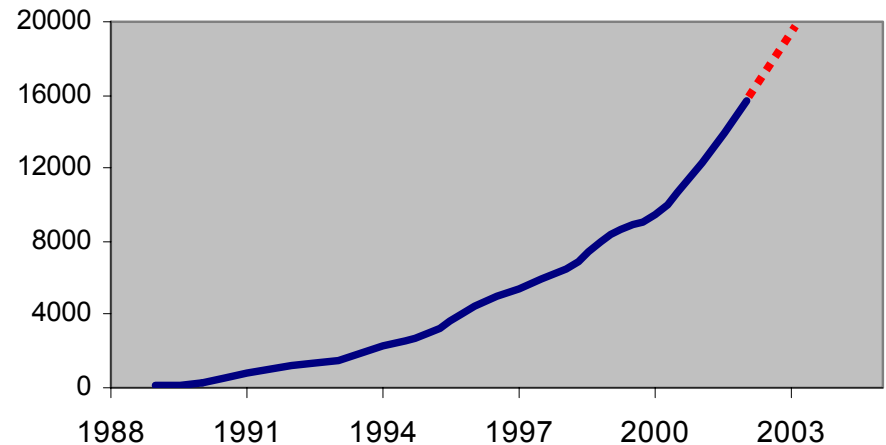
Nanotechnology is Here

The biggest frontier in materials development: Nanomaterials

Federal R&D Investment in Nanotechnology



"Nano" Papers per Year



- Industrial investment catching up but hard to quantify
- New nano law demonstrates commitment to future federal funding



Highlights of the US Nano Law

Most significant outcome: “Seal of approval” for nanotech R&D, education, tech transfer, commercial application activities

- Authorizes \$3.7 billion US over 4 years
 - NSF, DOE, NASA, NIST and EPA
- Requires oversight of planning, management and coordination of all US federal nanotech R&D
 - Requires development of plan for commercialization
- ★ ■ Establishes research program to identify societal, ethical, environmental and other appropriate concerns
- Requires studies of feasibility of “molecular self-assembly” and need for strategies for ensuring responsible development of nanotech



Nanotech is Hip



GE ad

Stereotypical geek

- Then: Computer engineer
- Now: Nanotechnologist

Nanotech is the (unspecified)
technology of the near future



HP ad



Superhuman strength, senses

- Then: Superman (Alien)
- Now: Nano-enhanced Human



Nanotech is Hyped

"Nano" in firm's name fuels stock's hefty gain

Reuters, 12.03.03



**Nanotechnology -
The Science Behind
Better Supplements**

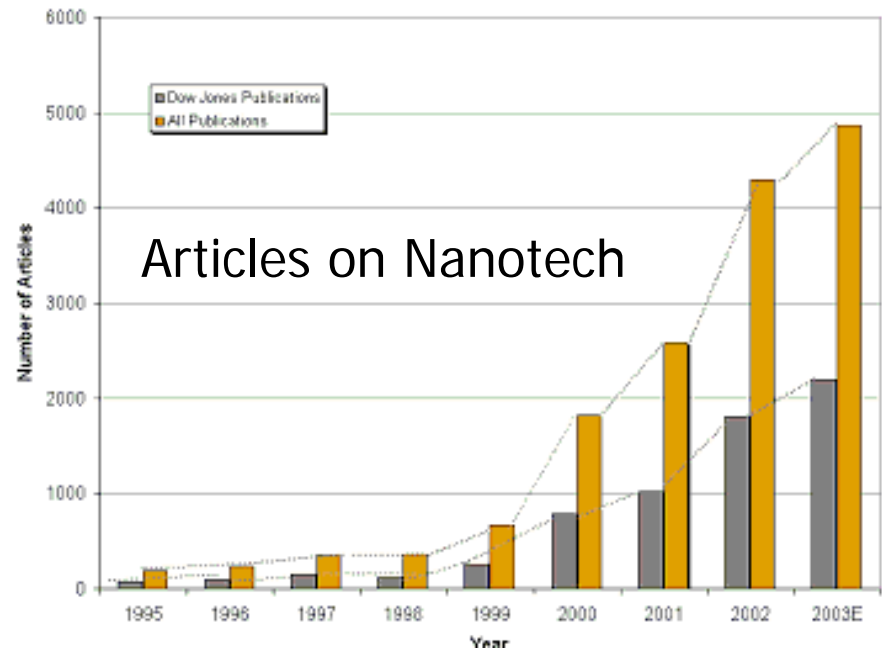


**A technological revolution
that will irreversibly alter
the way people live and work.**

"Nano frenzy hits Wall Street"

Forbes/Wolfe Nanotech Report,

Sept 2003



RICE



Nano is Now...

Product

"Nano Inside"

Value Added

All Natural Sunscreens



Active Ingredient:
Nanoscopic TiO_2 /
 ZnO

Transparency



Lined with Ceramic
Nanoparticles

Gas
Impermeability



Embedded with
"Nano Whiskers"

Stain- and Wrinkle-
Resistance



RICE



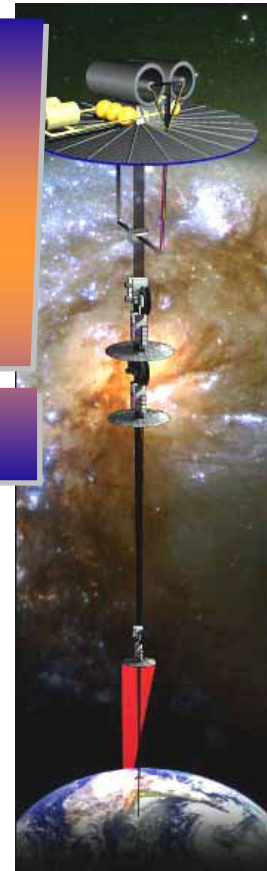
... and Nano is Yet to Come

Battlesuit that monitors health, eases injury, communicates & enhances performance



Able to leap tall buildings in a single bound?

Elevator that ferries satellites, spaceships, and pieces of space stations into space



WOW!



Hypospray: Nano Inside?



RICE



Tone of Media Coverage is Shifting

Hype → Fear

Los Angeles Times

- Nanotechnology: Will it be a boon – or kill us all? (11/26/02)

The New York Times

- From Nanotechnology's Sidelines, One More Warning (02/03/03)
- Research Shows Hazards in Tiny Particles (04/14/03)

SCIENTIFIC AMERICAN.COM

- Nanotech: It's Not Easy Being Green (08/14/03)
Researchers and activists go to loggerheads over the science of small

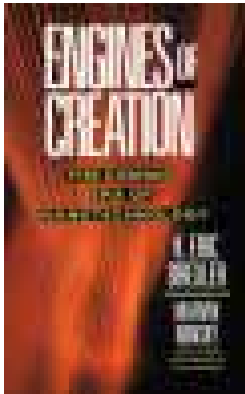
GuardianUnlimited

- Research on tiny particles could damage brain, scientists warn (1/09/04)



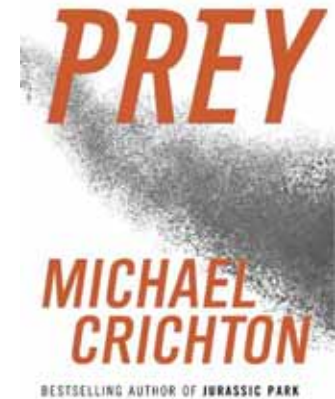
Is Nanotech Horrible?

Far-term: Nanorobots/"Gray goo"



Guardian Unlimited

Prince sparks row over nanotechnology (04/28/03)



Near-term: Nanoparticle Toxicity



Big questions for tiny particles

From clear sunscreen to self-cleaning cars, nanotechnology seeps into daily life and starts to raise tough ethical issues. (08/14/03)



The Wow-to-Yuck Trajectory

Early enthusiasm for a new compound/technology vanishes as health or environmental risks emerge.

WOW!

YUCK!

Air-conditioning/
Refrigeration

BANNED

Ozone Hole Depletion

Malaria-bearing
mosquito control

BANNED

"Silent Spring"

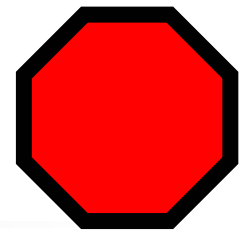
Fire-retardation/
Insulation

BANNED

Toxicity/SuperFund



Wow to Yuck to Bankrupt?



Public perception can turn against a new technology even in the absence of proven risk factors.

WOW!

- Increased shelf-life/nutrition
- End to world hunger
- Cure/prevent malaria, cancer, hemophilia, cystic fibrosis...



YUCK!

- Superweeds
- Allergic reactions
- Eugenics
- Discrimination

BACKLASH





Potential Roadblocks for Nanotech

CBEN's Contribution



**Public
Acceptance
of Nanomaterials**

- Engagement of media
- Public education
- Societal impact studies



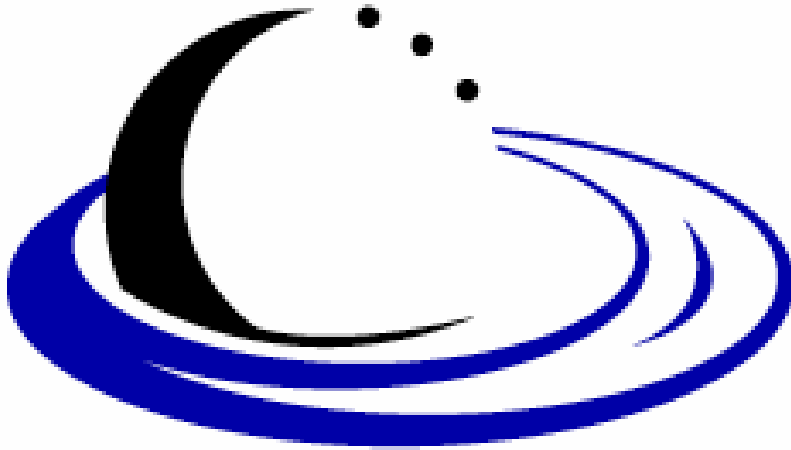
**Sustainable
Methods for
Making
Nanomaterials**

- Nanomanufacturing project
- Health and environmental impact studies





The Mission of CBEN



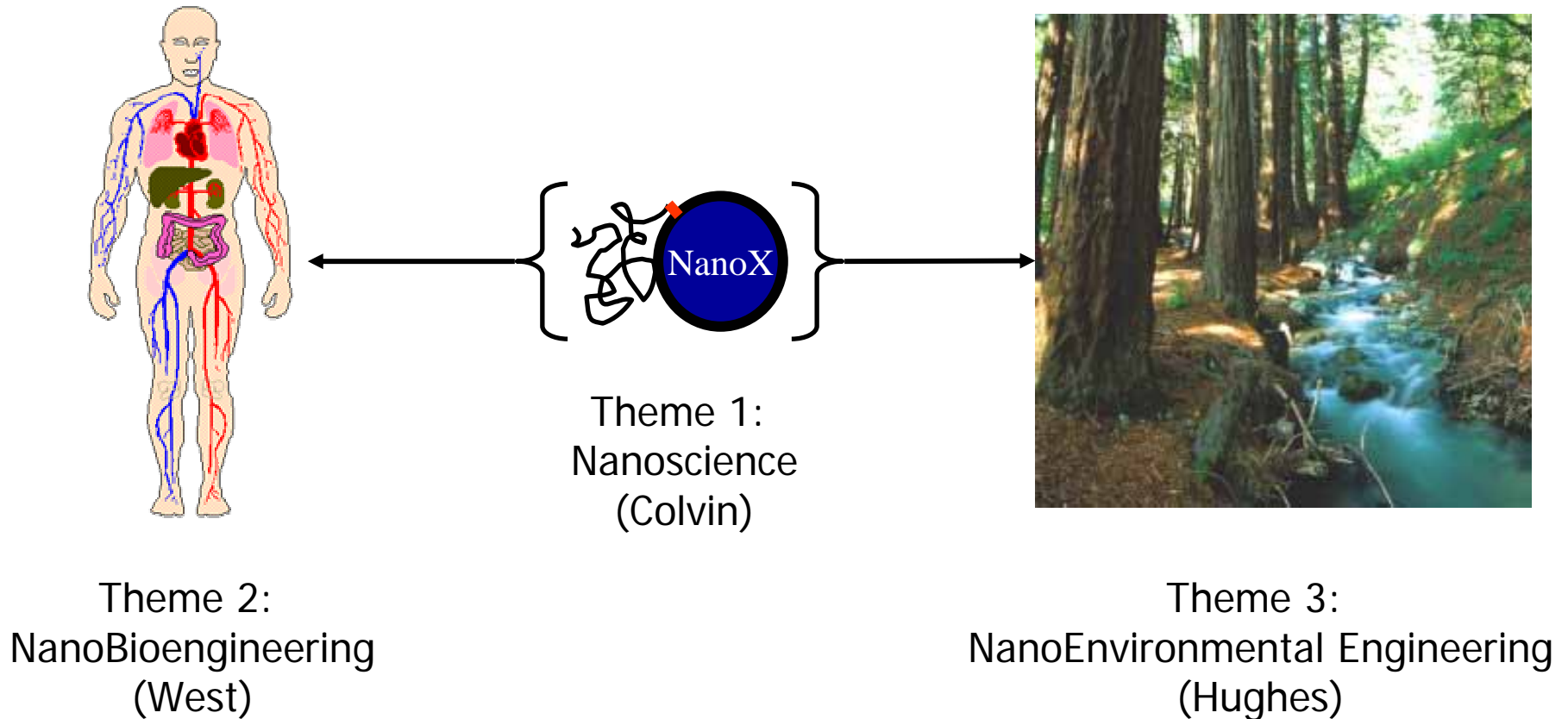
Center for
Biological and
Environmental
Nanotechnology

Our mission is to create sustainable nanotechnologies that improve human health and the environment.



CBEN's Organizing Principle

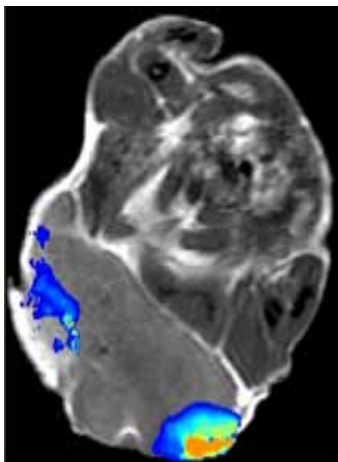
The Wet/Dry Interface



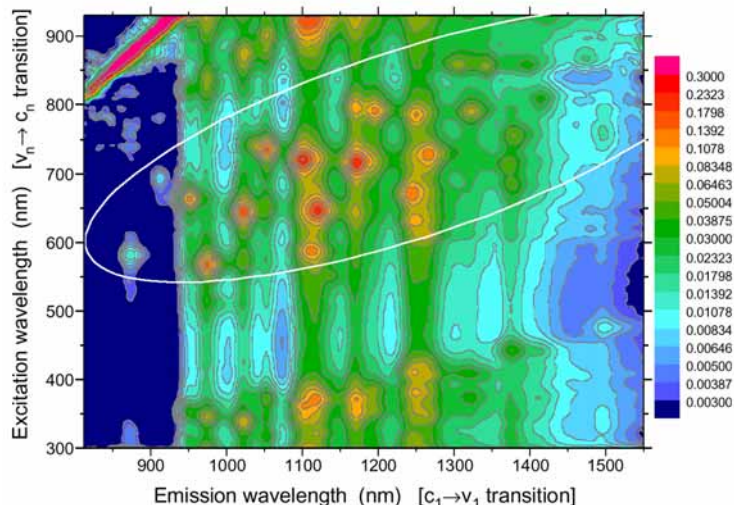
Applications *and* Implications



Research Highlights

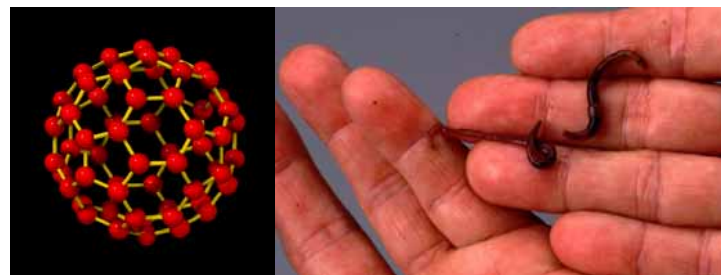


**Nanoshell-heated
cancer tissue (West)**



**Nanotube fluorescence
(Weisman)**

- Cancer photothermal therapy
- Carbon nanotubes for bioimaging
- Fullerene bioaccumulation



**Earthworm bioaccumulation of
fullerenes** (right-hand image from
<http://www.sarep.ucdavis.edu/worms/image5.htm>)

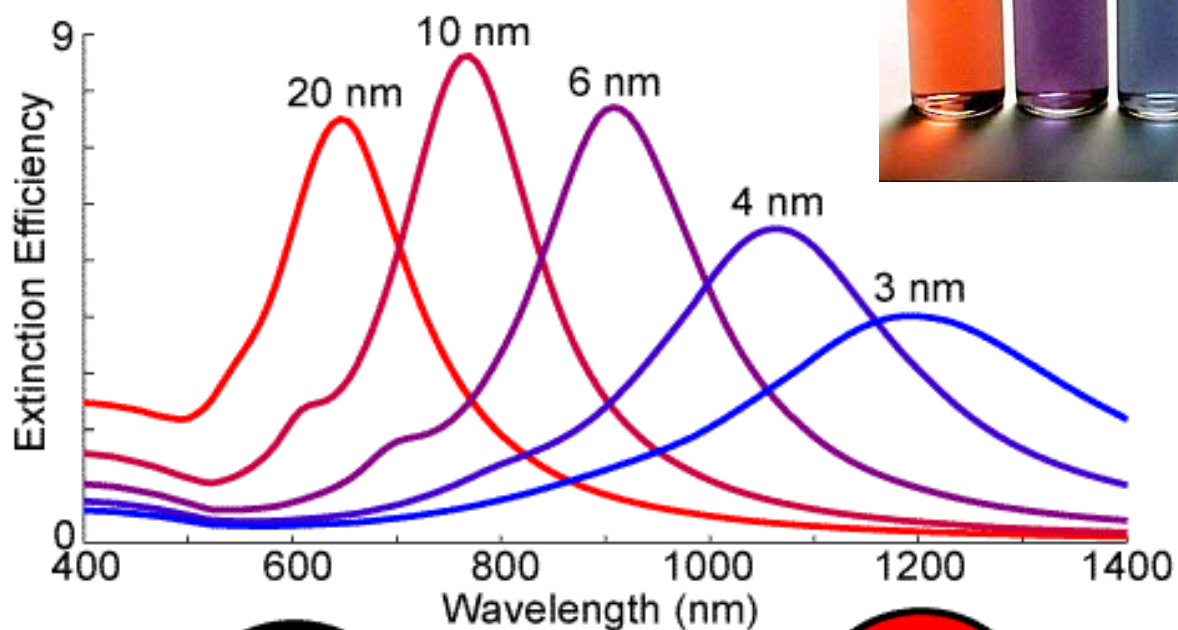




Metal Nanoshells

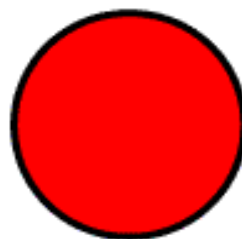


Jennifer West



40 nm Core Radius
20 nm Shell

→
Increasing
Core : Shell Ratio

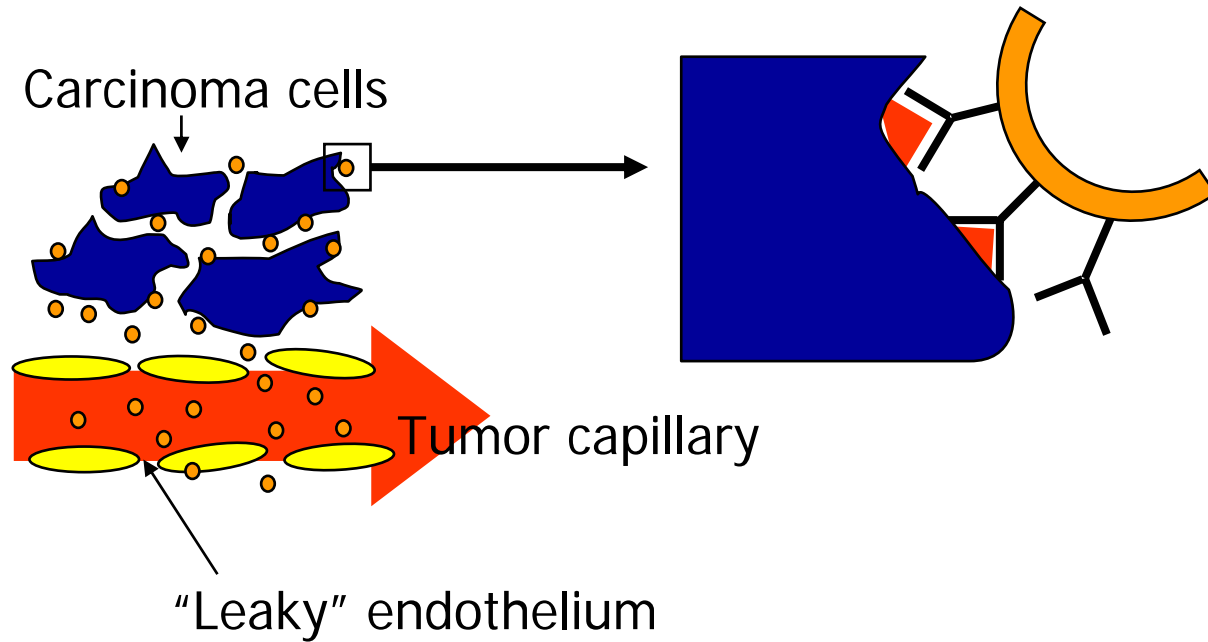


57 nm Core Radius
3 nm Shell





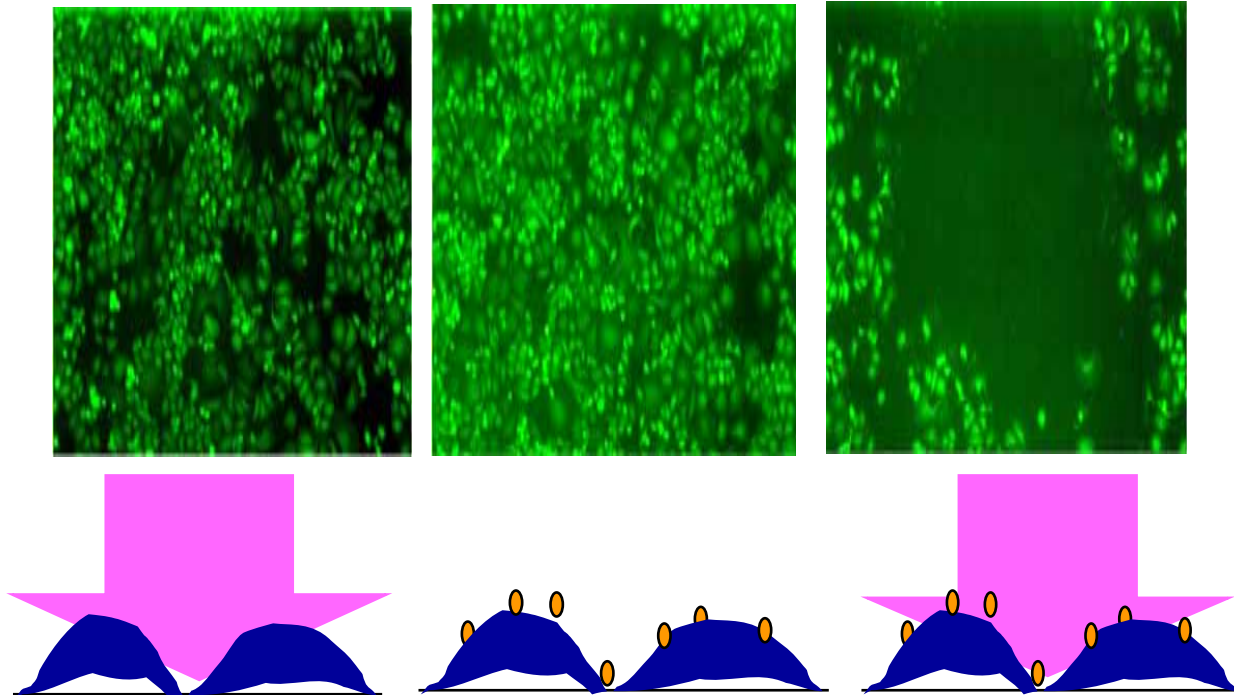
Nanoshell-Based Therapeutics



Jennifer West



Nanoshells for Photothermal Cancer Therapy

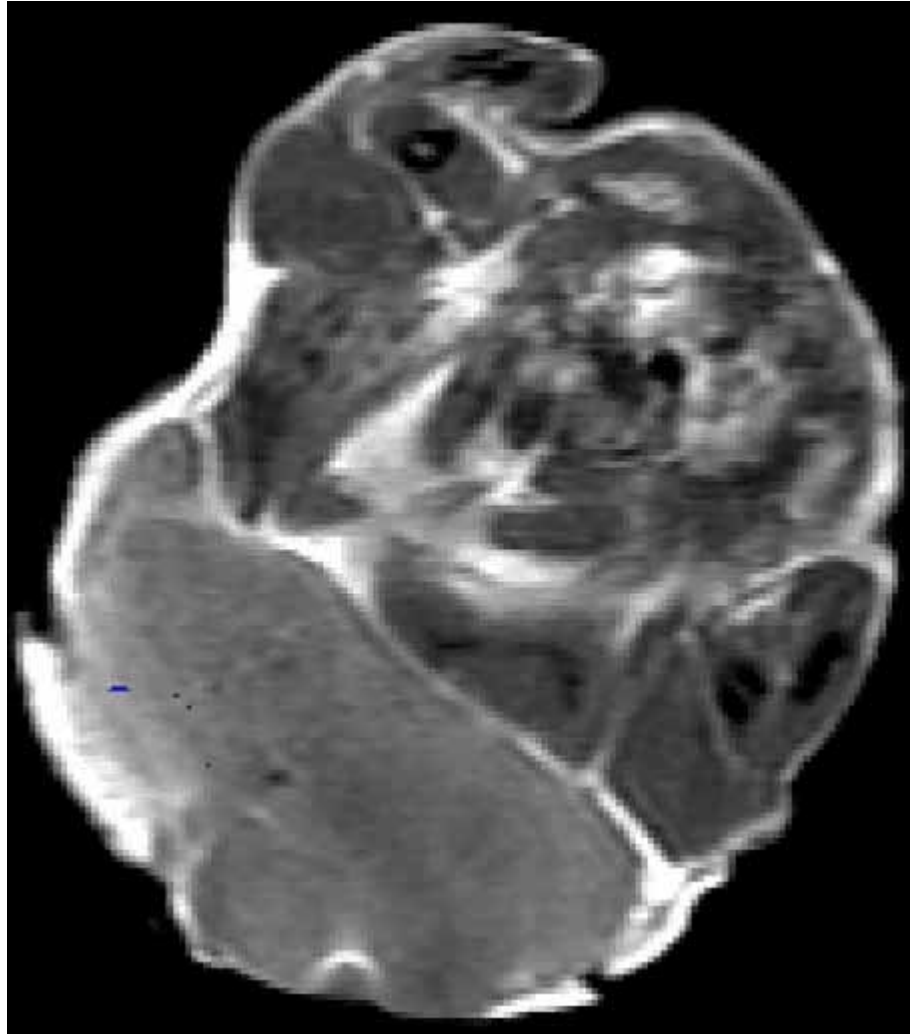


Nanoshell BNCs + near IR light =
Carcinoma cell death

Jennifer West



Nanoshells for Photothermal Cancer Therapy

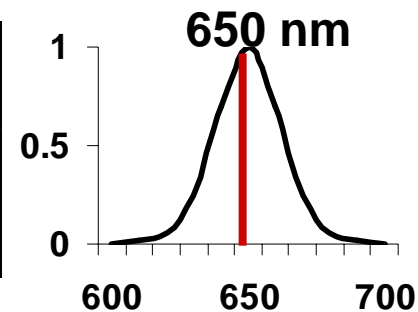
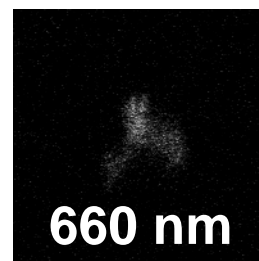
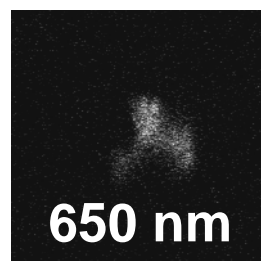
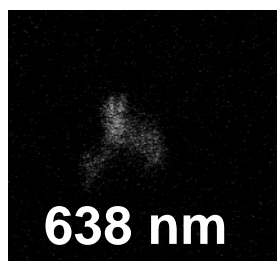
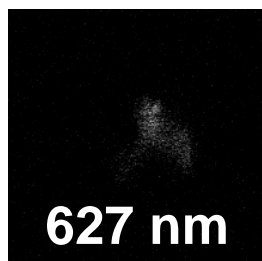
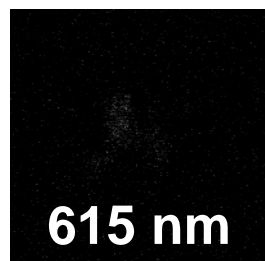
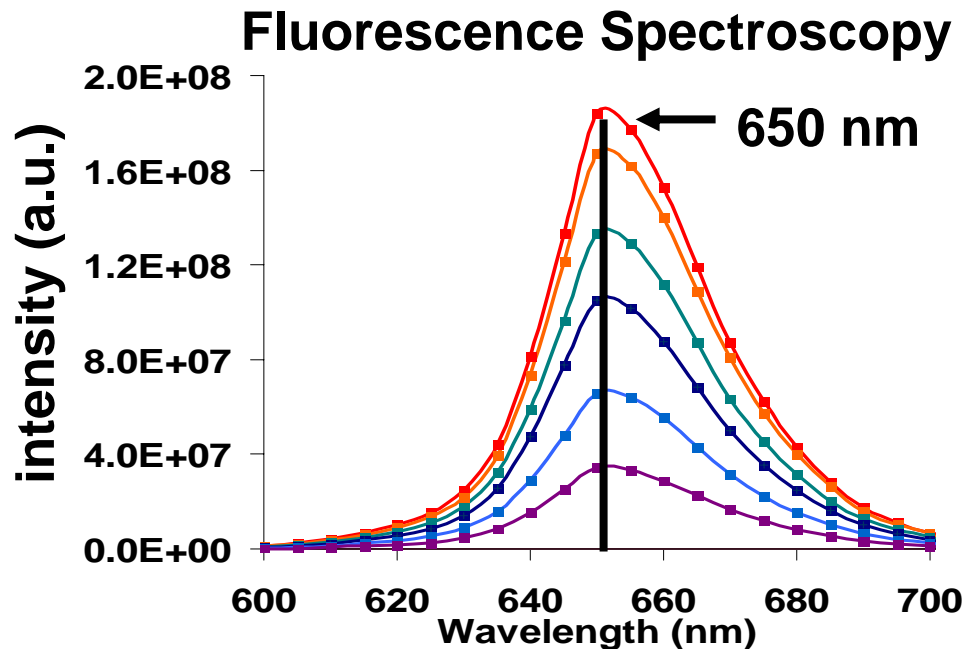
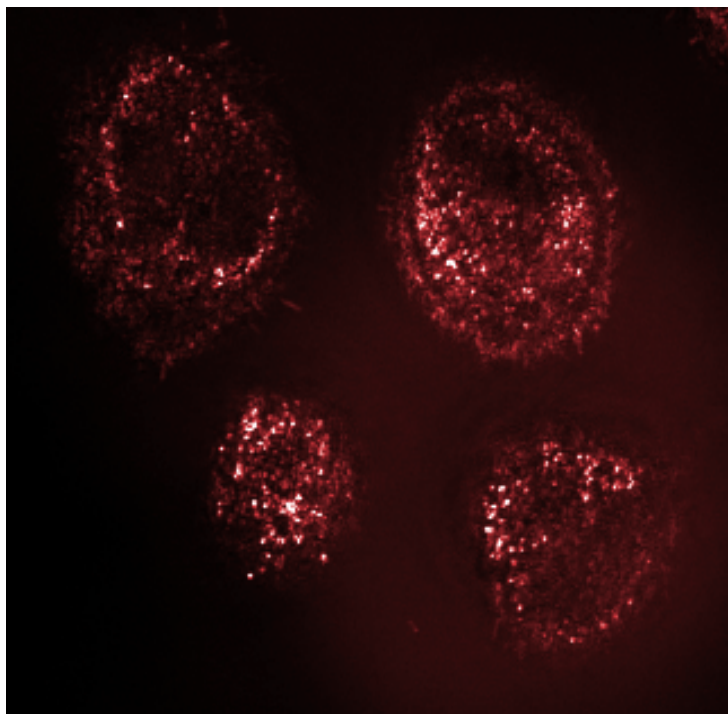


RICE

Jennifer West



Two-Photon Quantum Dot Imaging in Living Breast Carcinoma Cells



R. Drezek

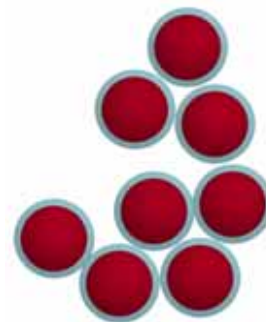
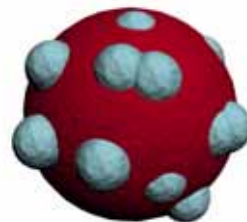


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Environmental Applications of Nanomaterials: Separations, Sorption and Catalysis

A. R. Barron, P. Laibinis, M. Wong

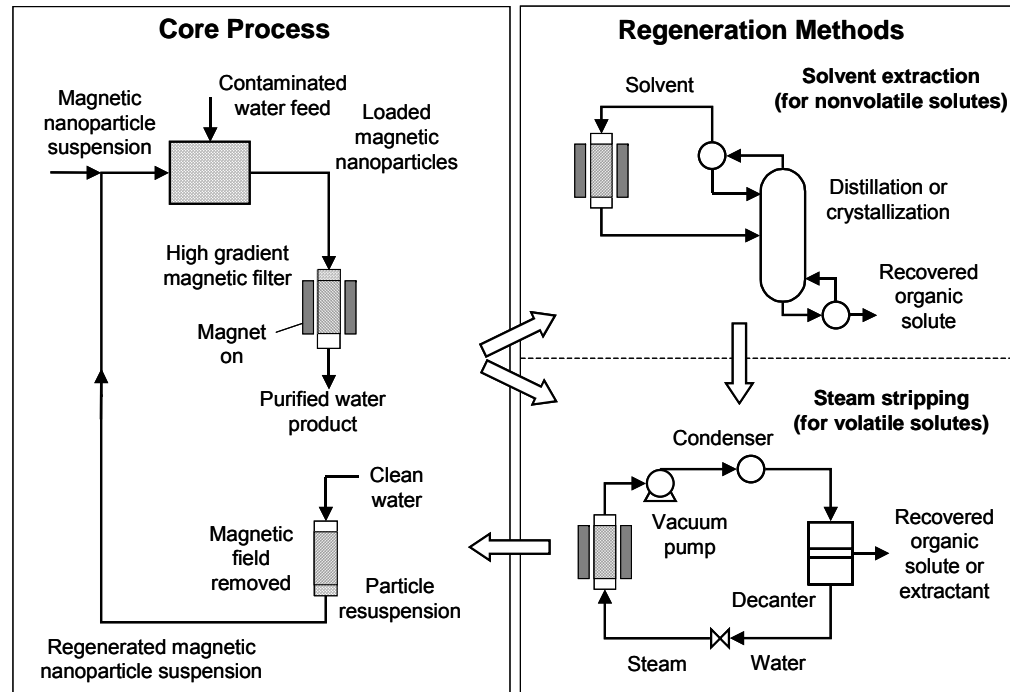
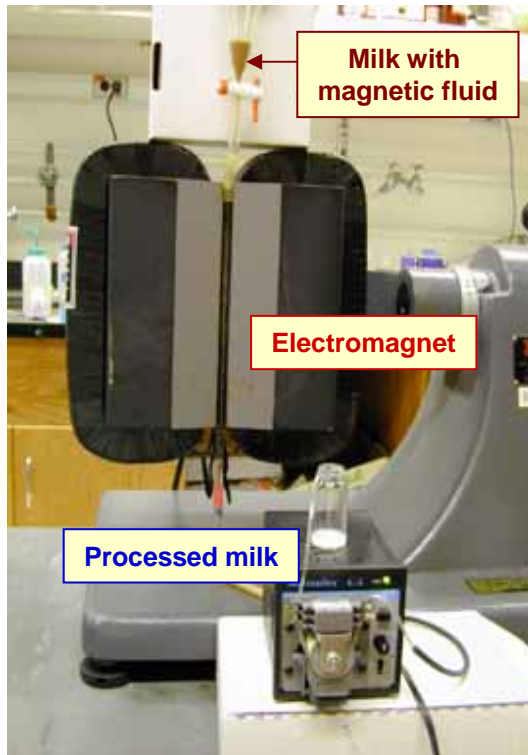


RICE

Dynamic Filtration: Magnetic Filtration

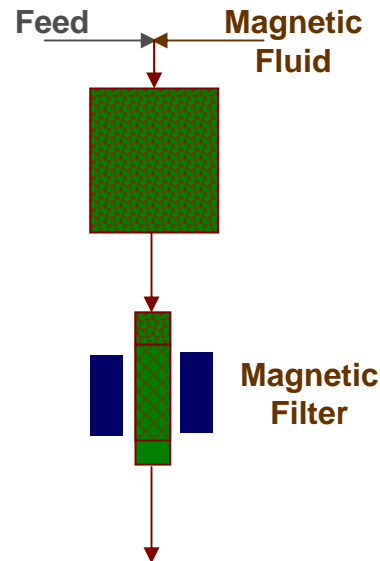
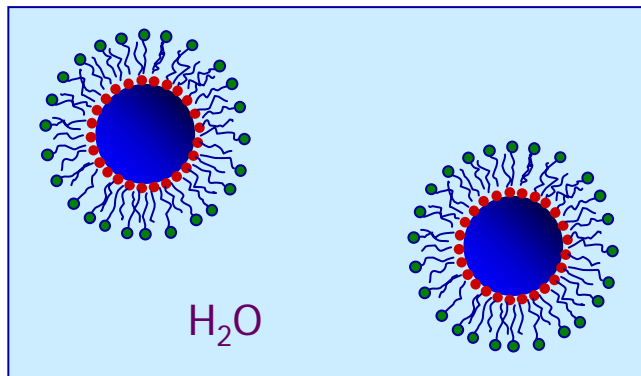
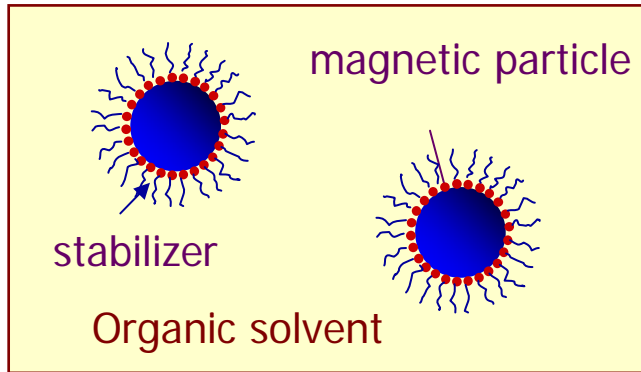
Colloidal suspensions of magnetic nanoparticles:

- Magnetic material: magnetite Fe_3O_4
- Particle size (Magnetic core): nm to microns
- Surface modification





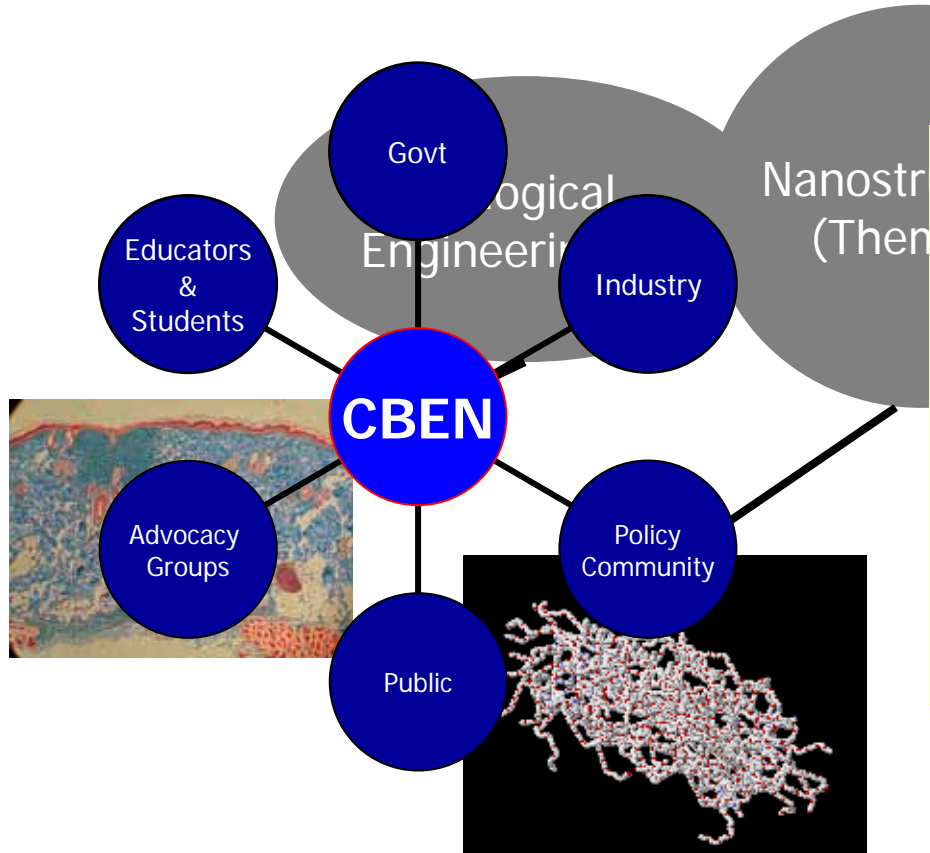
Filtration with Magnetic Fluids



- Small particles are not retained efficiently and are lost to the filtrate
- Magnetic filtration of particle suspensions are limited by particle size, but can be overcome



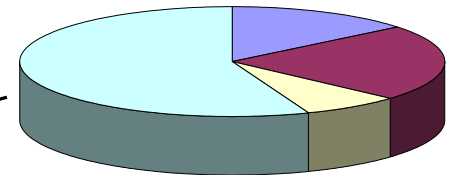
Research and Outreach



Outreach Goals

- Trained workforce
- Informed public
- Industry collaborations
- Government input

— Research —
— Education and Outreach —





Approach

Community



Faculty

Graduate/Post-Doc

Undergraduate

High School

Middle School

- Need to begin developing workforce now
 - Graduate and post-doc training
- Start training workforce of future
 - Target many educational levels
- Provide a continuum of programs



RICE



Education and Human Resources

■ High School

1. 9th-grade Teacher Training Sequence
 - Spring Content Course
 - Summer Internship
 - Model Science Lab II
2. Workshop for Advanced Placement Teachers
3. High School Student Summer Academy

■ Middle School

4. NanoKids™ Curriculum Development

■ Undergraduate

5. Curriculum Development
6. Nanotech Research Experience for Undergraduates

■ Graduate/Post-doc

7. Curriculum Development
8. Entrepreneurship Education
9. Student Leadership Council
10. Science Policy and Ethics course

■ Community

11. Public Courses on Nanotechnology
12. Science Café

■ New for 2004-2005

1. NUE course, CHEM/ANTH 235 "Nanotechnology: Content and Context"

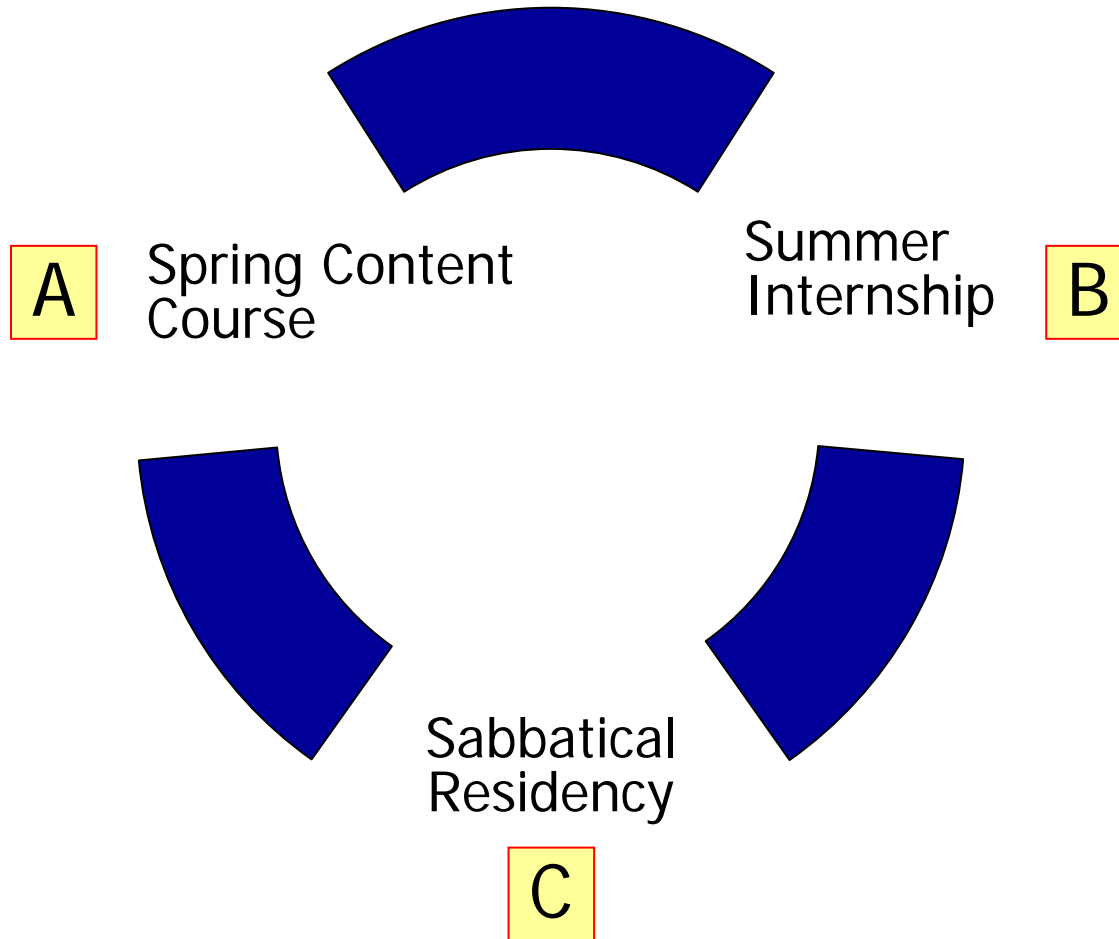
Highlights

- ➡ >1750 participants in reporting year
- ➡ New grant for UG nano course
- ➡ Meet/exceed nat'l diversity %





Three Phases of Teacher Training





NanoKids™ – Changing the Face of Science Education

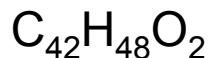
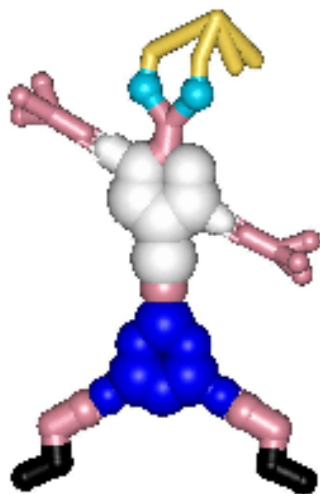
- Anthropomorphic molecules that have been synthesized in the laboratory
- Act as characters in animated videos that explore molecules, cells, etc.
- Support from CBEN and NSF SGER grant

Community

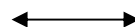


High School

Middle School



"Marsky"



RICE

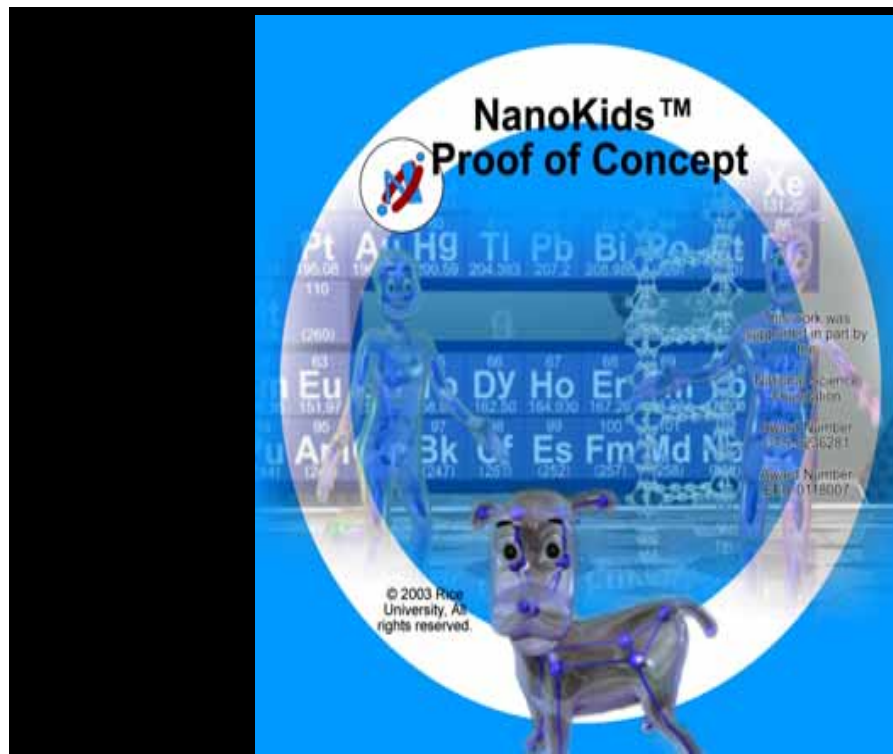
J. Tour



NanoKids™ DVD-1 Trailer

- Developed
 - Interactive Workbook
 - Interactive Teacher's guide
 - Interactive Parent's guide
 - Support website
- Approved for testing in 13 HISD middle schools Sept 2003
 - Linked to Texas Assessment of Knowledge and Skills (TAKS) objectives
- Formative evaluation underway

Scenes from 20-min proof-of-concept animation DVD



[Click here](#)



RICE

J. Tour



High School Student Summer Academy



Dr. Mary E.R. McHale

For More Information:

<http://www.ruf.rice.edu/~cbensa>



to the CBEN Summer
Academy for 9th
Graders

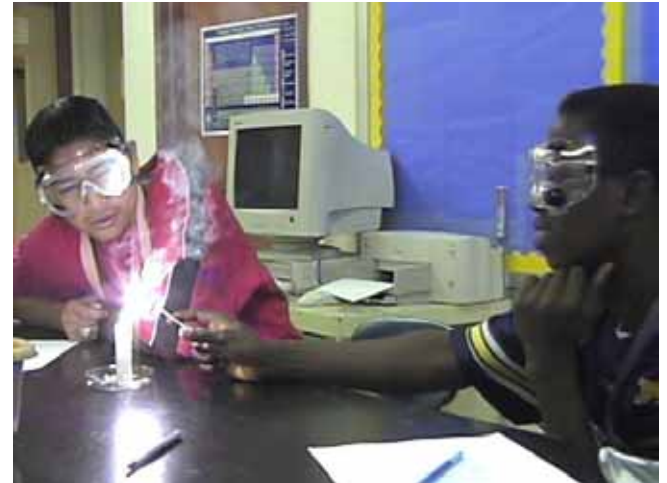
Summer 2004!

- Two-week workshop focusing on water quality
 - Sampling of local water sources
 - Testing for variety of environmental contaminants
- Open to promising 9th and 10th grade students



Nano relies on scientists and engineers

- Physics
- Chemistry
- Biology
- Environmental Science
- Electrical Engineering
- Chemical Engineering
- Bioengineering
- Materials Science
- Applied Mathematics...





Acknowledgments

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