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Applications of Nano-Bio Interfaces for Homeland Security

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Center for Integrated Nanotechnologies (CINT)
Sandia National Laboratories
Albuquerque, NM

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Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

CINT is one of five U.S. Dept. of Energy Nanoscale Science Research Centers

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CINT has two facilities with extensive capabilities

Characterization Wing

- TEM, SEM
- Low Temp Transport
- Scanning Probe Microscopy
- Ultra-fast Spectroscopy

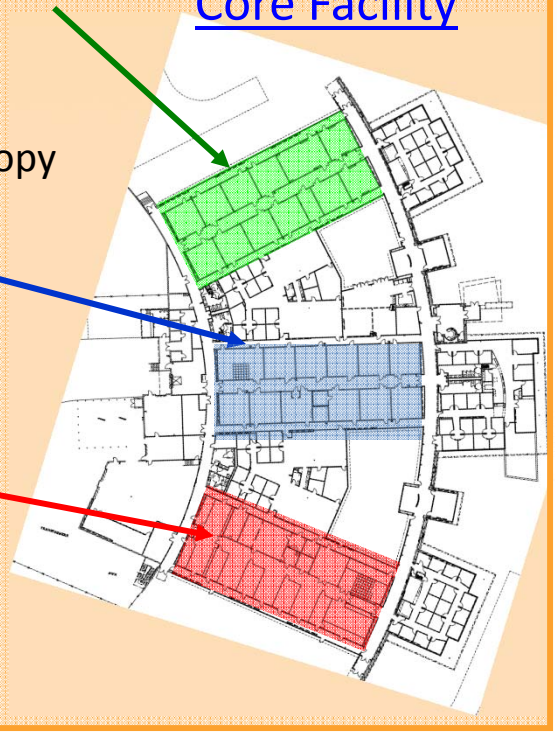
Synthesis Wing

- Molecular Beam Epitaxy
- Chem & Bio labs
- Molecular films

Integration Lab

- E-beam lithography
- Photolithography
- Deposition & Etch
- SEM / FIB

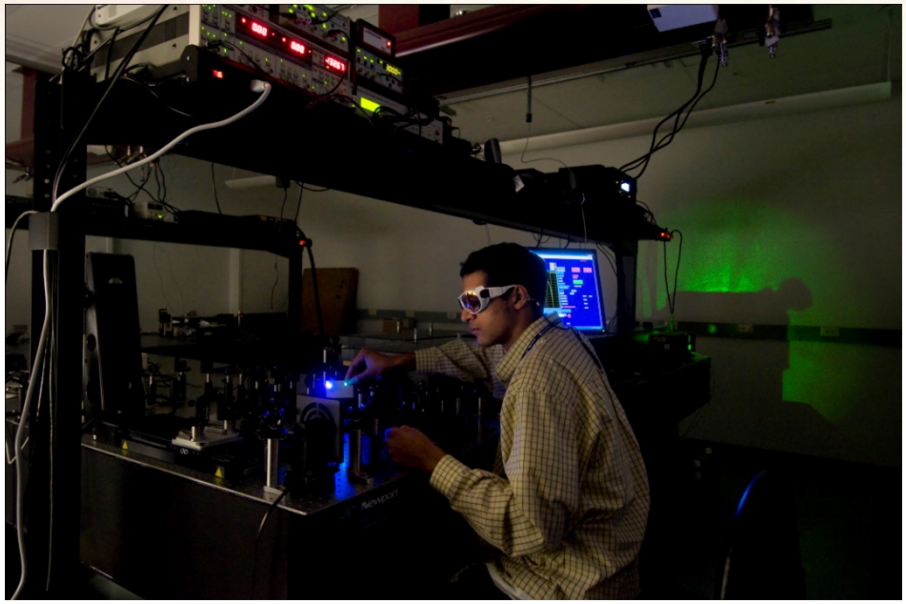
Core Facility

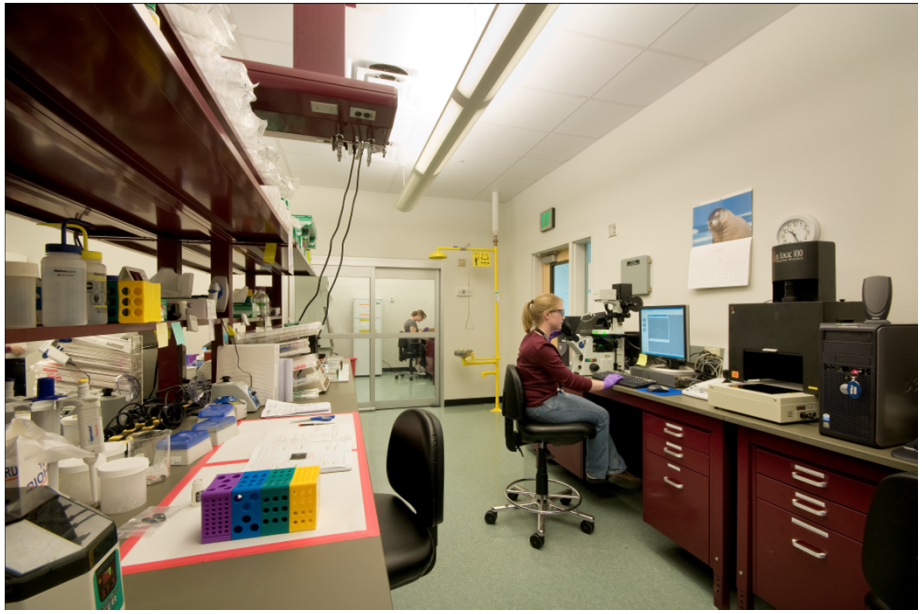


Gateway to Los Alamos Facility

- Biomaterials & Chem synthesis
- XRD, SEM
- UV-vis, ellipsometry
- Nano-indentation
- Nanoscale optical probes
- Microscopies
- Physical Synthesis
- Pulsed Laser Deposition
- Ultra-fast Spectroscopy
- Computer Cluster
- Visualization Lab

CINT has two facilities with extensive capabilities





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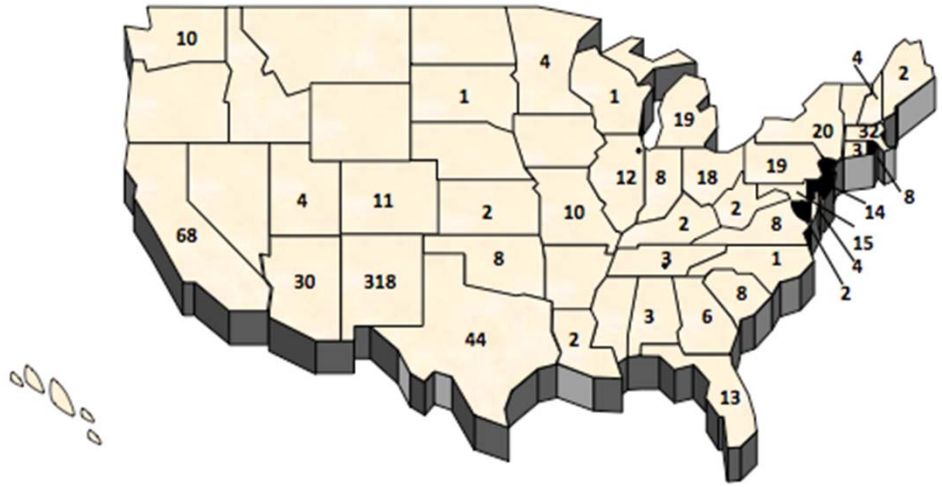
CINT receives approximately 200 User Proposals each year

Cycle	Submitted	Accepted	Rapid Access
2006	175	130 (74%)	
2007	101	79 (78%)	11 (2007 total)
Spring 2008	172	160 (93%)	
Fall 2008	119	107 (90%)	31 (2008 total)
Spring 2009	109	95 (87%)	
Fall 2009	67	56 (83%)	29 (2009 total)
Spring 2010	115	review in progress	



BES User Category	2007	2008	2009
Badged	122	189	240
Off-Site	67	83	114
Total	**189**	**272**	**354**

354 users, 610 researchers involved in 258 current projects, representing 39 States and 14 Foreign Countries

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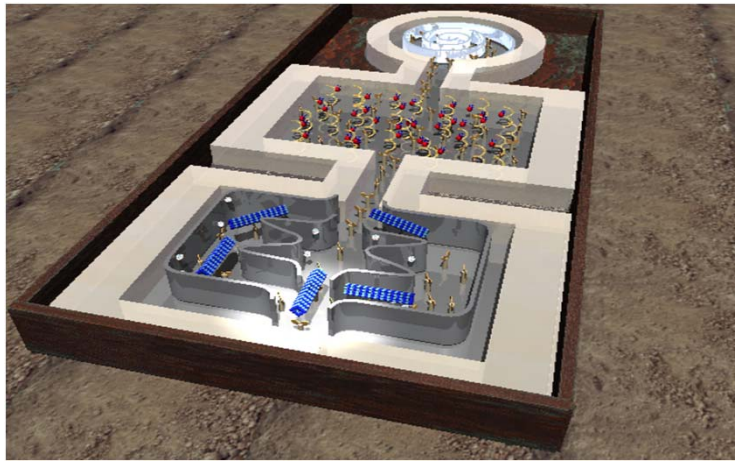
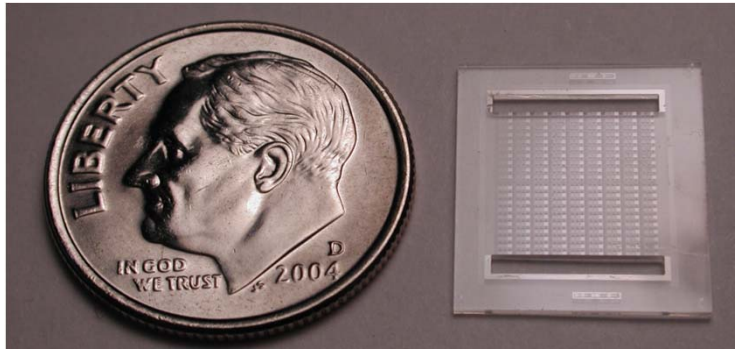
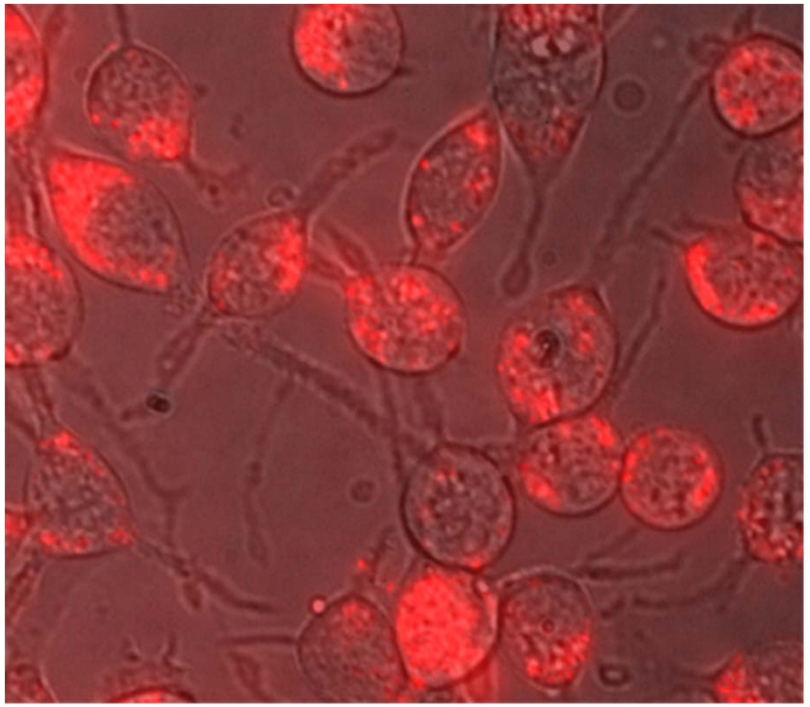
Homeland Security & Nano-Bio Interfaces

Goal: Exploit active biomolecules to develop autonomous, nanoscale sensors for remote detection of CB agents





Goal: Understand how the chemical and physical properties of nanoparticles regulates their uptake and toxicity in mammalian cells



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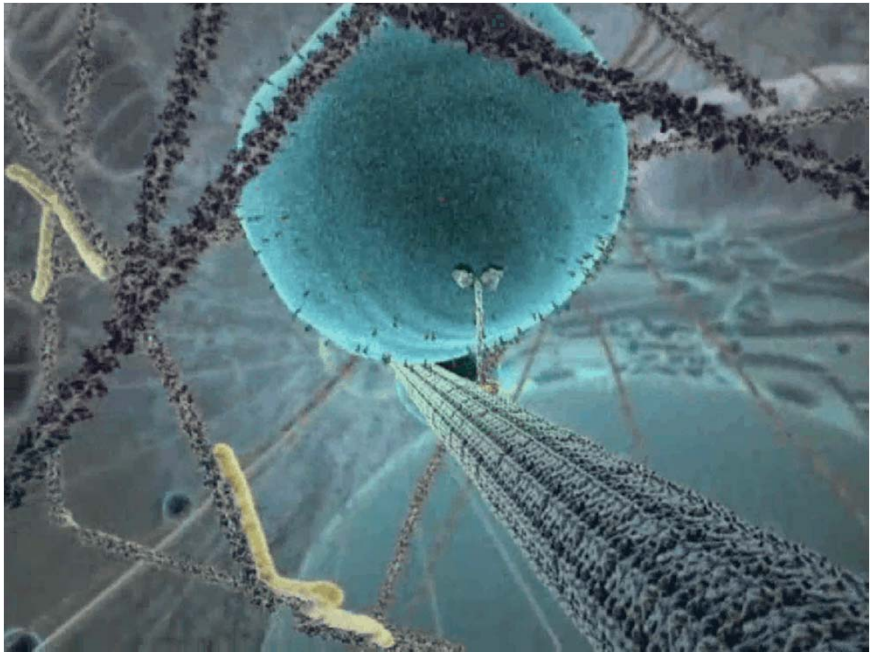
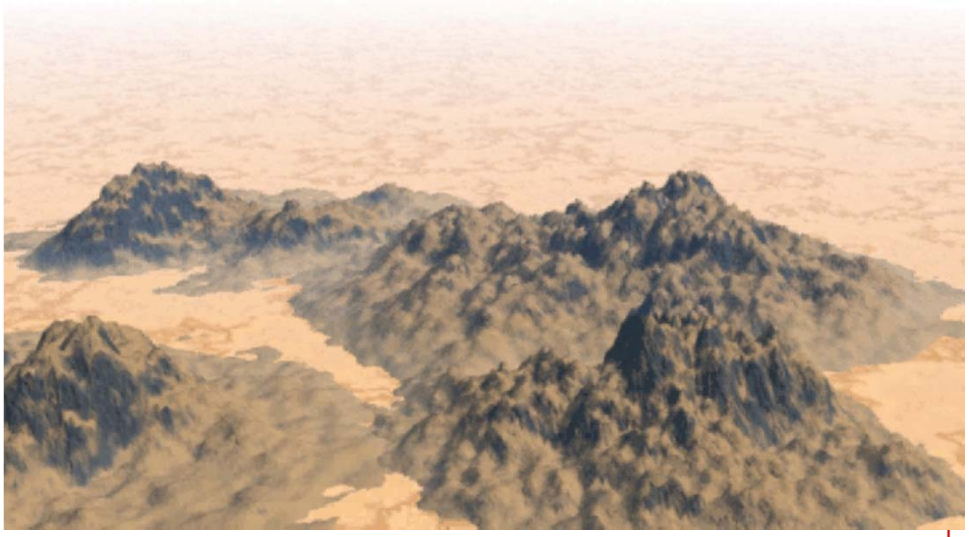
Biomotor-Driven CB Nanosensors

Problem: Most CB sensors require electrical energy to perform on-chip processing, which significantly increases the size and weight of the sensor

Goal: Exploit active biomolecules to develop autonomous, nanoscale sensors for remote detection of CB agents





Can we engineering biomotor-powered nanosensors for CB agents?

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Biomotor-Driven CB Nanosensors

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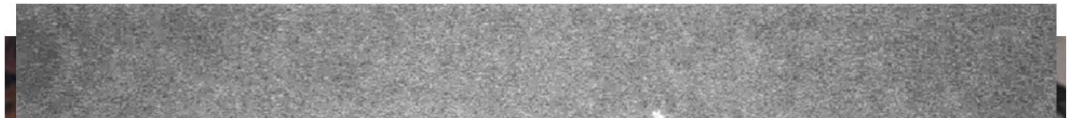
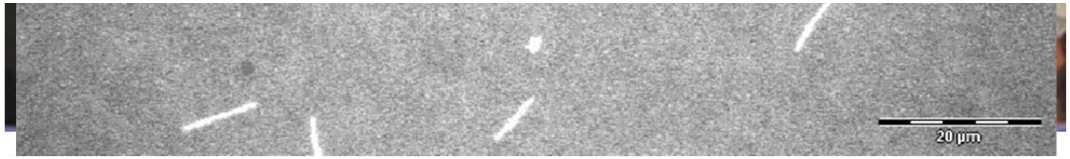


Challenges to integrating motor proteins in nanoengineered systems

- Stability: intracellular operation vs. synthetic systems
- "User" control: biochemical networks vs. simple switches
- Interface: biological molecules vs. inorganics
- Others: ???



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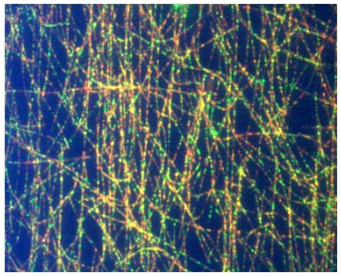
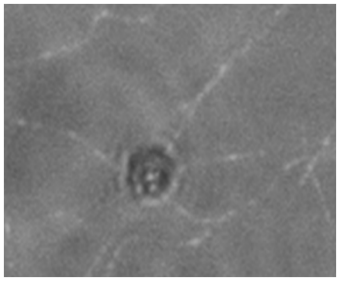
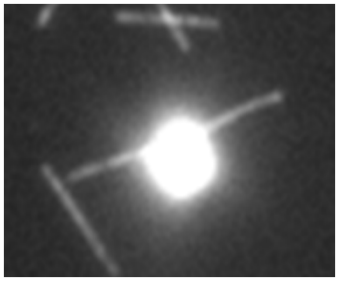
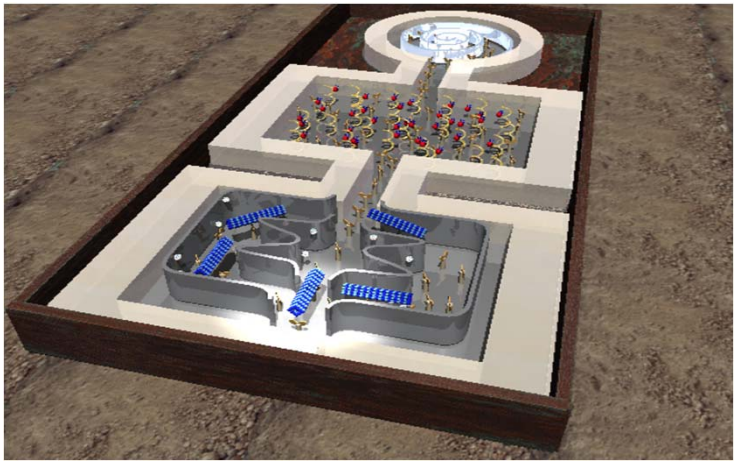
Biomotor-Driven CB Nanosensors

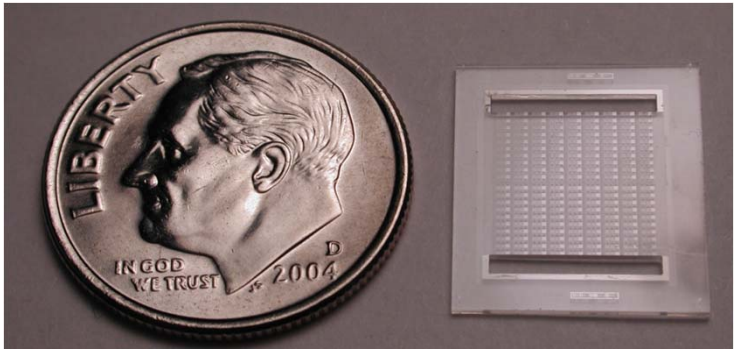
Outcome:

- Biological active transport systems engineered to capture a wide range of bioagents

Limits of detection for various analytes

Proteins	Bacterial spore	Viruses
		
1.5 ng / device	100 spores / device	10^7 viruses / device





- Genetically engineered motor constructs developed (e.g., molecular “ignition” switch added.
- Prototype sensors – proof-of-principle devices demonstrate successful application of technology for remote sensing

DARPA DSO

Funding from Defense Advanced Research Projects, Defense Sciences Office

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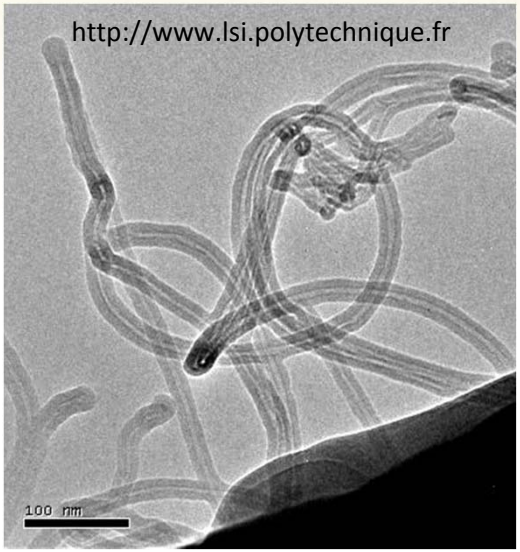
Engineered Nanoparticles & Homeland Security

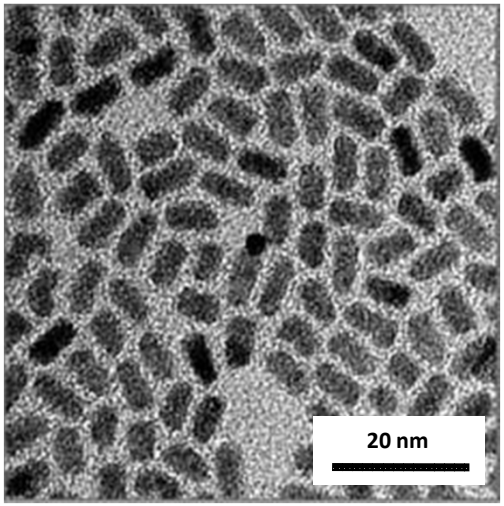
Do engineered nanoparticles represent a "special" hazard?



Maybe – in some cases

Toxicology & environmental impact are unknown!

- Often exhibit novel properties not found in the bulk (e.g., catalysis in Au-NPs)
- Size enables rapid aerosolization and dispersion
- Difficult to detect release/contamination
- Similar in size to biomolecular components (e.g., proteins)
- Synthesis and modification methods produce huge range of materials very quickly



Goal: Understand how the chemical and physical properties of nanoparticles regulates their uptake and toxicity in mammalian cells

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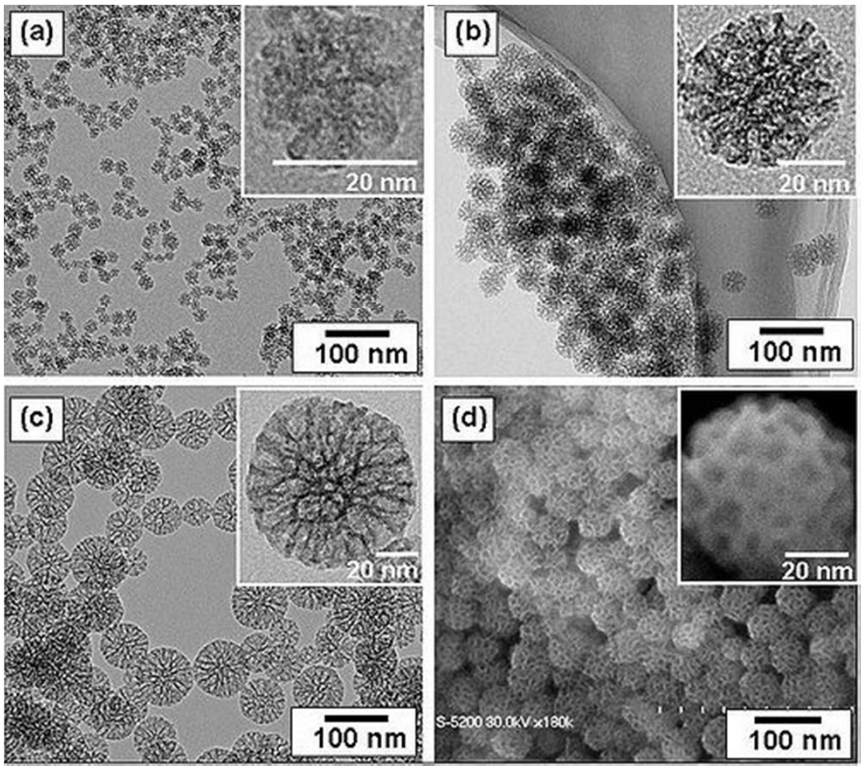
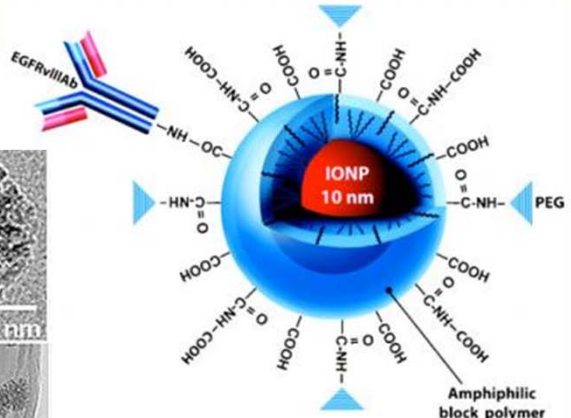
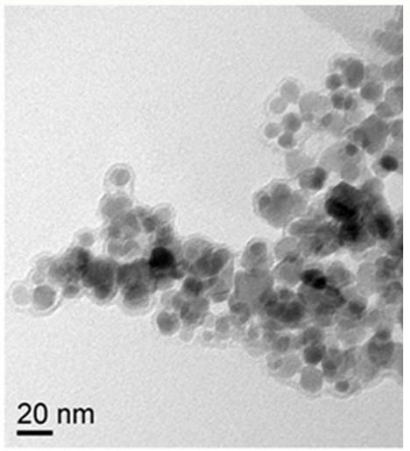
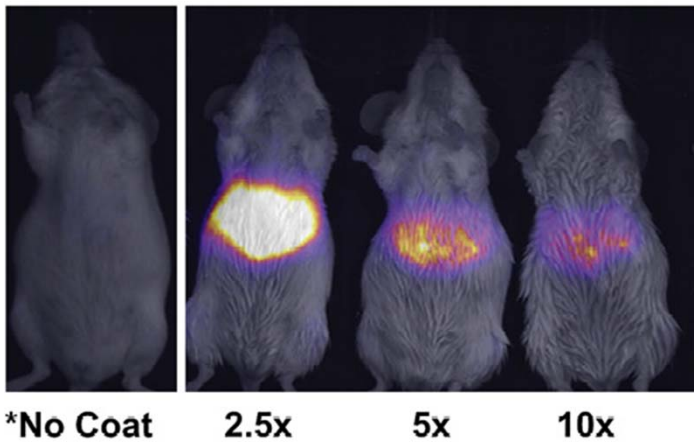
Engineered Nanoparticles & Homeland Security

Nanoparticles are being engineered with increasing sophistication, including targeting and chemical/biomolecules release.









A.B.D. Nandiyanto; S.-G Kim; F. Iskandar; and K. Okuyama (2009). "Synthesis of Silica Nanoparticles with Nanometer-Size Controllable Mesopores and Outer Diameters". *Microporous and Mesoporous Materials* **120** (3): 447–453

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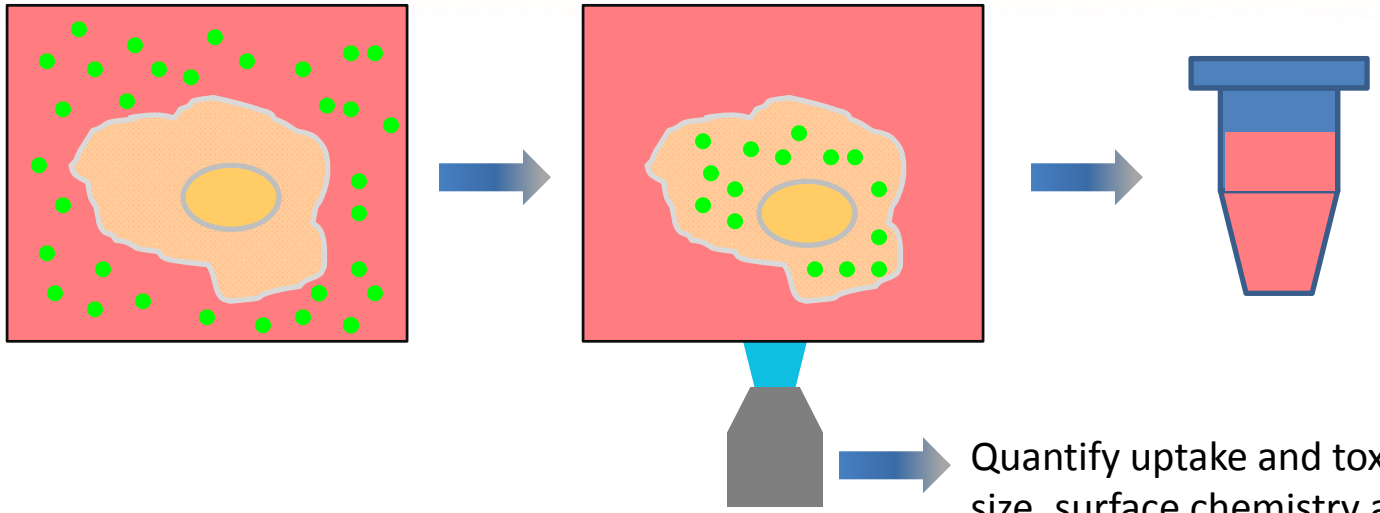
Engineered Nanoparticles & Homeland Security

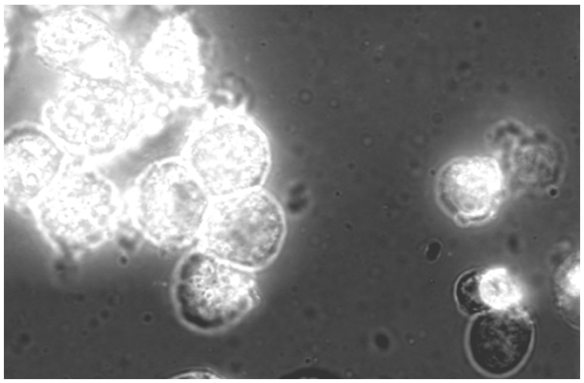
Hypothesis: Uptake and response in mammalian (human) cells are dependent on Qdot size, surface chemistry, and concentration.



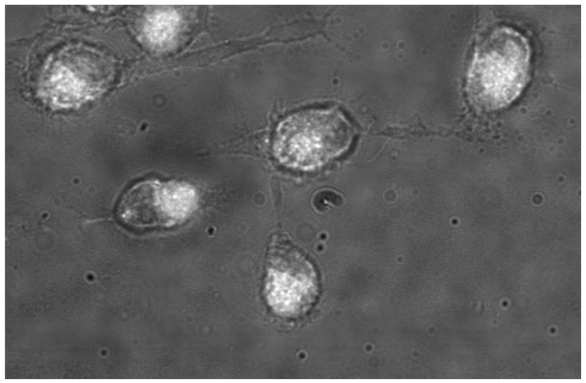
Assay for cytokines by ELISA

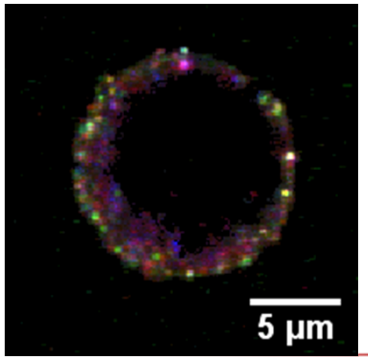
Quantify uptake and toxicity with respect to size, surface chemistry and concentration

Qdot 655-COOH



Qdot 655-PEG





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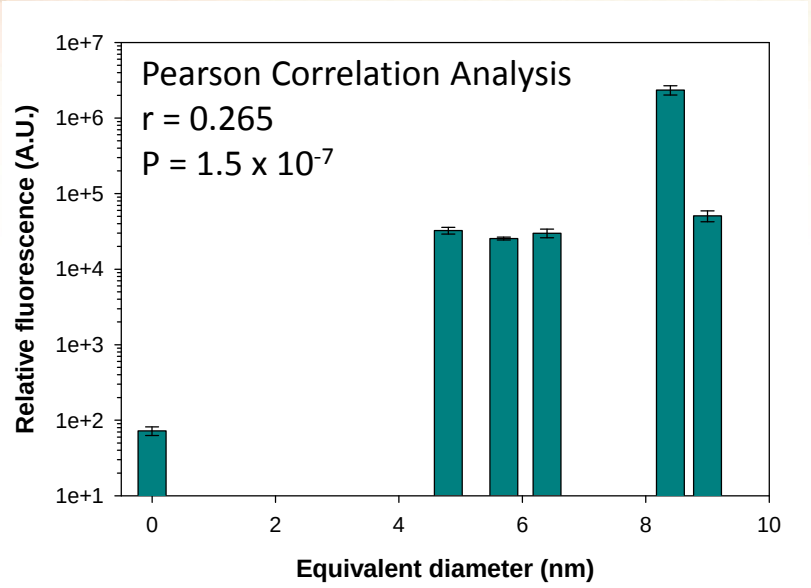
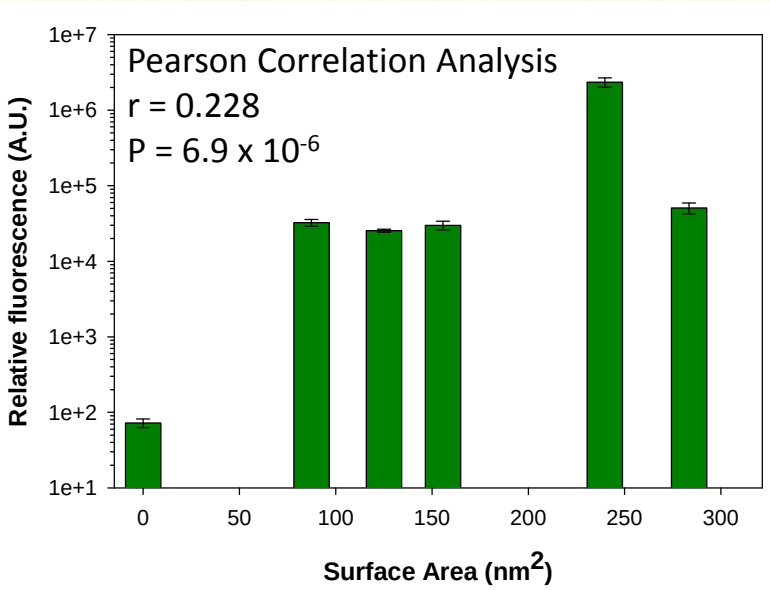
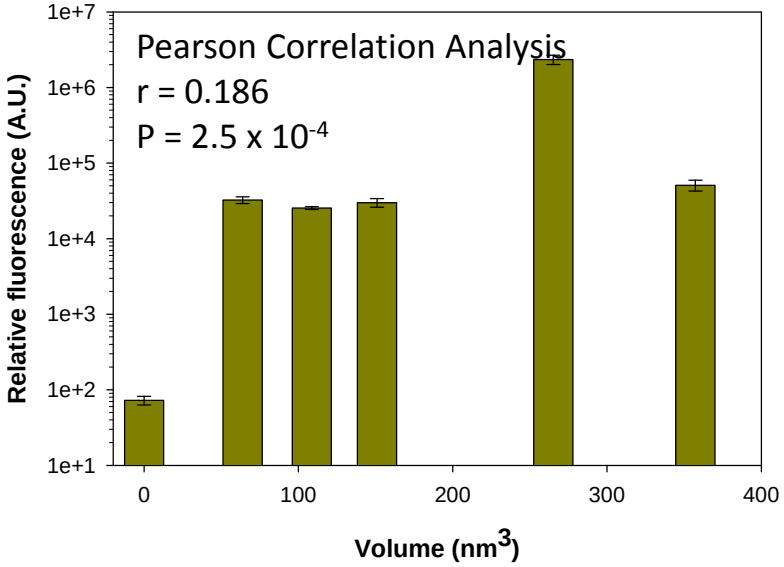
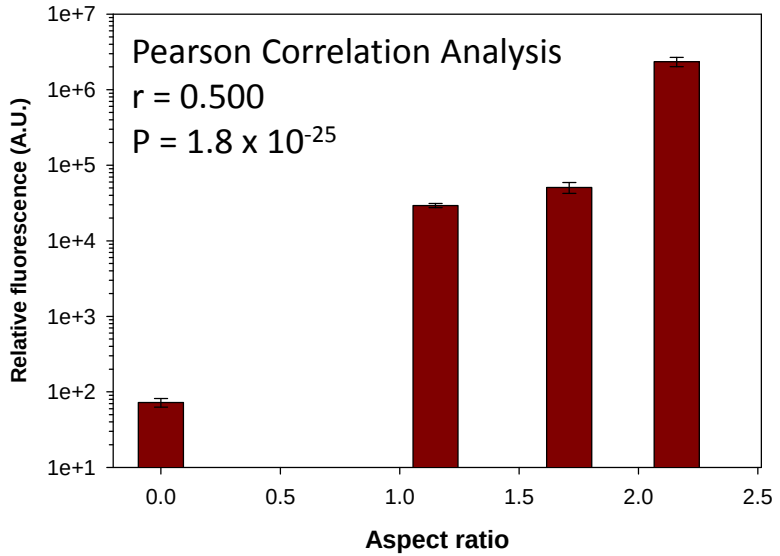
Engineered Nanoparticles & Homeland Security









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Adrienne Greene
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