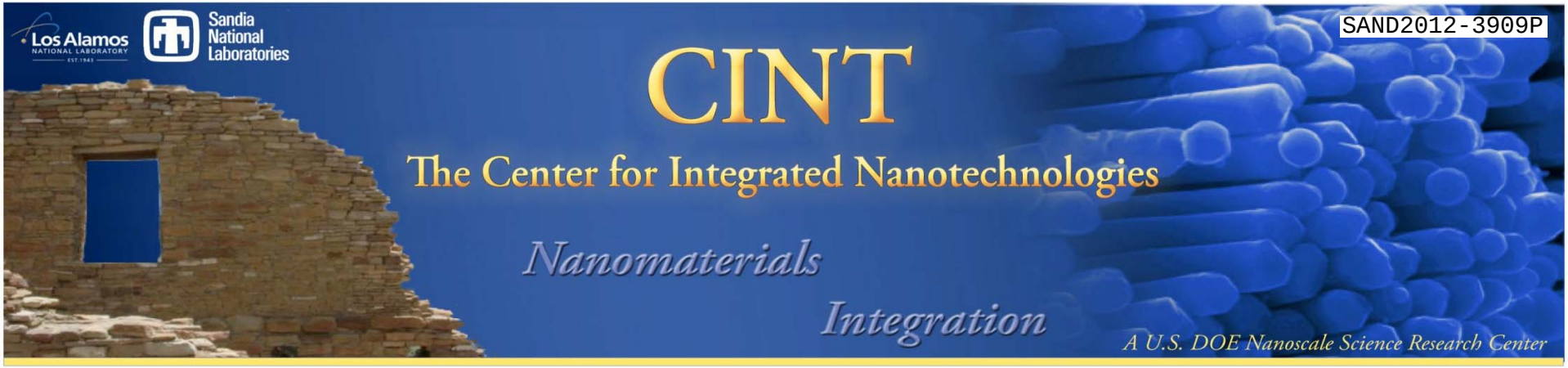

"Softer" Perspectives on Nanoscience Integration

George D. Bachand, Ph.D.
Center for Integrated Nanotechnologies

April 17, 2012

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Brief Biography

Education & Training:

- B.S., Biology, 1992, Biology, Elizabethtown College, Elizabethtown, PA
- Ph.D., Virology, 1997, State University of New York (SUNY), Syracuse, NY
- Post-doc, Immunology and Molecular Biology, 1997, SUNY Upstate Medical Center, Syracuse, NY

Professional:

- Partner Science Leader, 2011-present, SBCN Thrust, Center for Integrated Nanotechnologies
- Adjunct Professor, 2006-present, Cell Biology & Physiology, Univ. New Mexico, Health Sciences Center
- Principal Member of the Technical Staff, 2001-present, Sandia National Laboratories
- Acting Level I Manager, 2007, Biomolecular Interfaces and Systems, Sandia National Laboratories
- Research Associate, 1998-2001, Biological and Environmental Engineering, Cornell University

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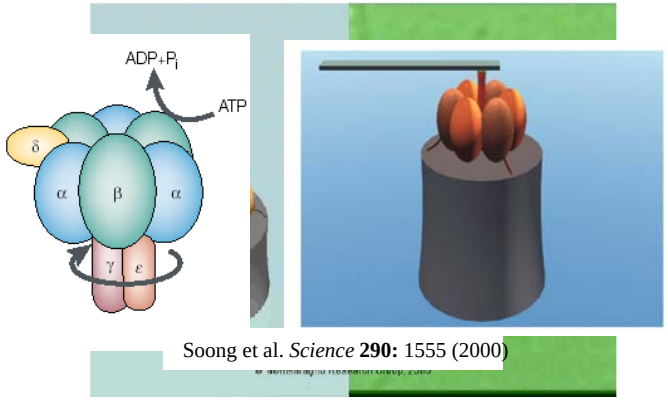
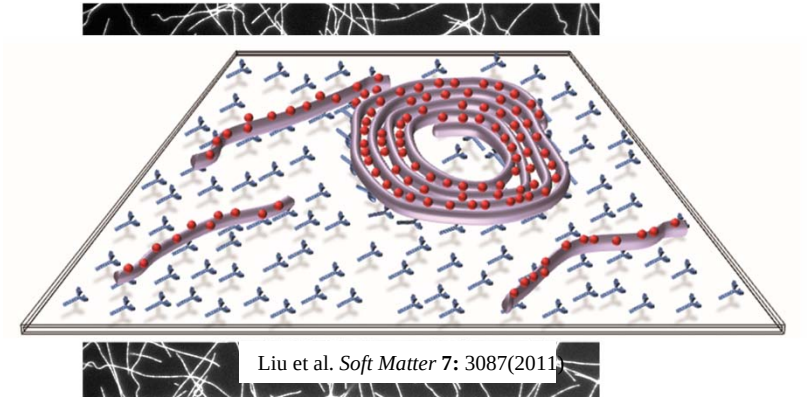
Research Interests

Development of hybrid nanomaterials, devices, and systems:

- Strategies & principles found in living systems
- Use of biological components as structural/functional components



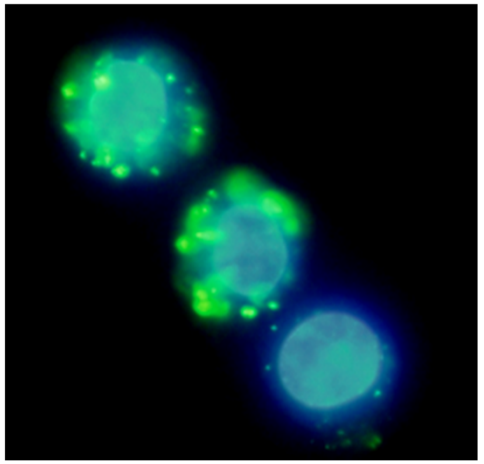
Soong et al. *Science* **290:** 1555 (2000)



Liu et al. *Soft Matter* **7:** 3087(2011)

Applying nanoscience/technology to understand, control, and manipulate biomolecular processes

- How nanomaterials interact with biomolecular materials
- New nano-enabled "tools" for studying biological processes



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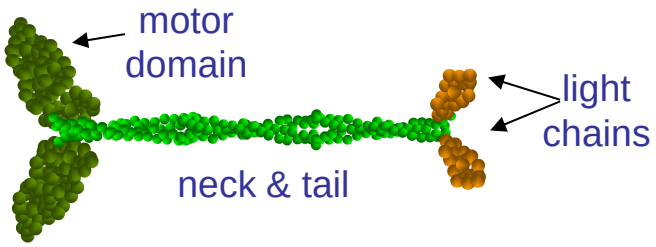
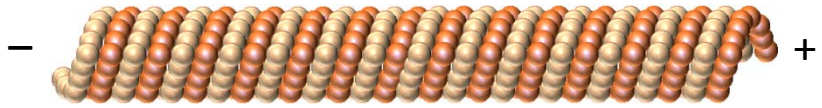
Hybrid nanomaterials, devices, and systems

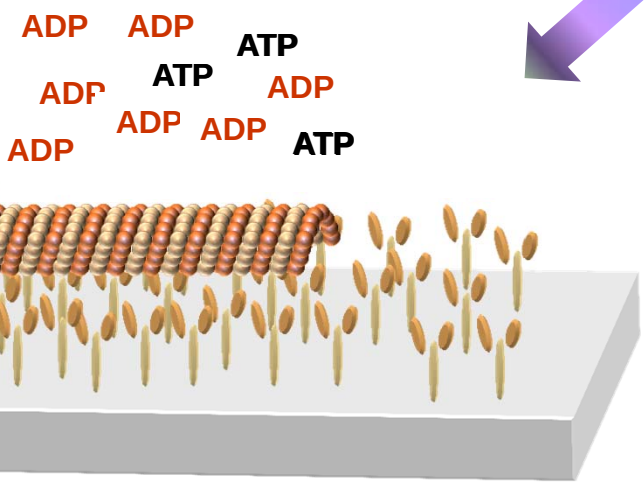
Nanoscale transport in cells is achieve based on motor proteins; such systems may be re-constructed *ex vivo* and used for nanoscience integration.

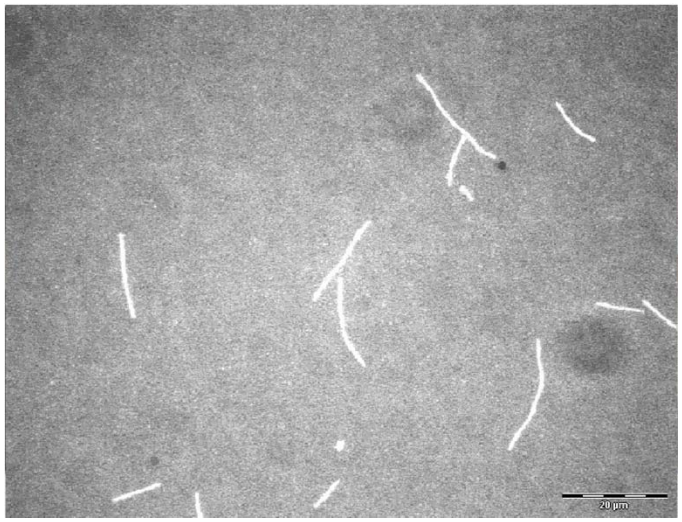
Kinesin motor proteins



Microtubule filaments







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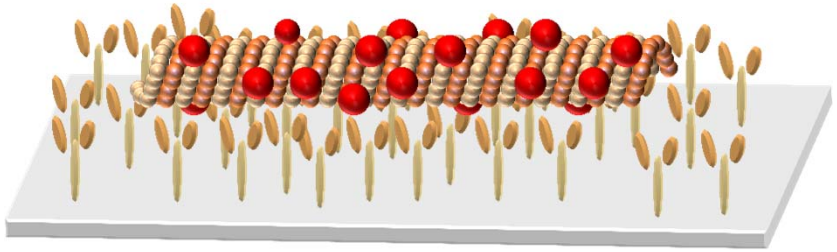
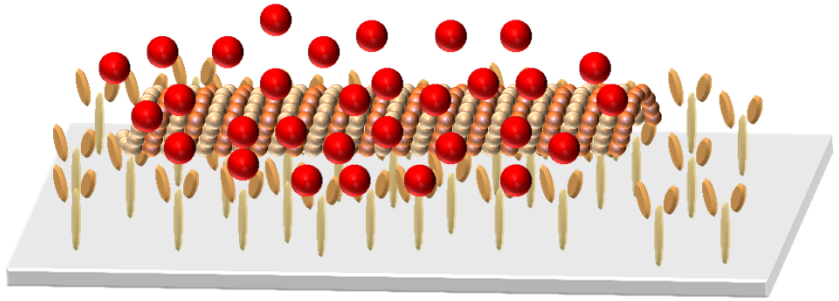
Dynamic Assembly of Ring Composites

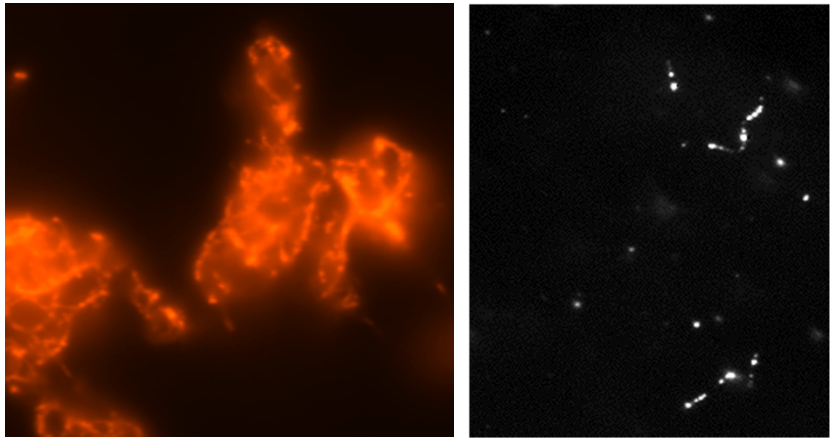
Energy-dissipation via kinesin transport leads to dynamic assembly of nanoparticles on microtubule filaments.

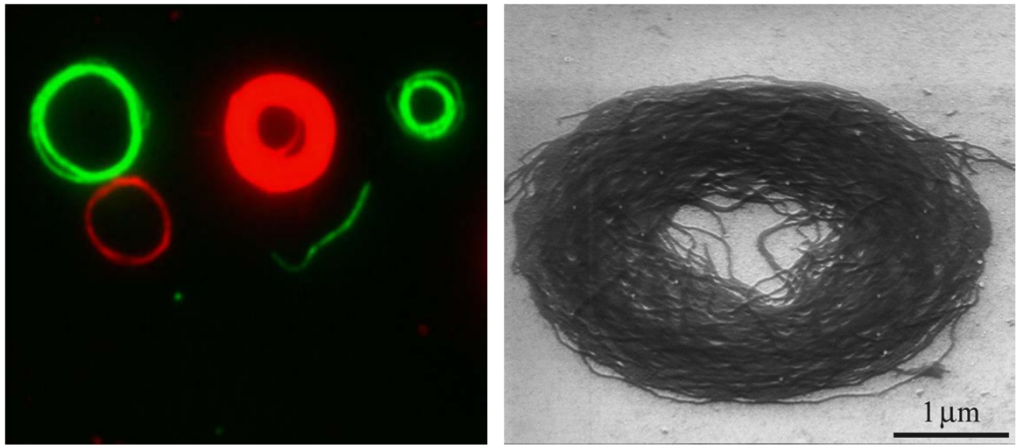


Solution Assembly
(thermodynamic)



Kinesin-Driven Assembly
(thermodynamic + energy dissipation)

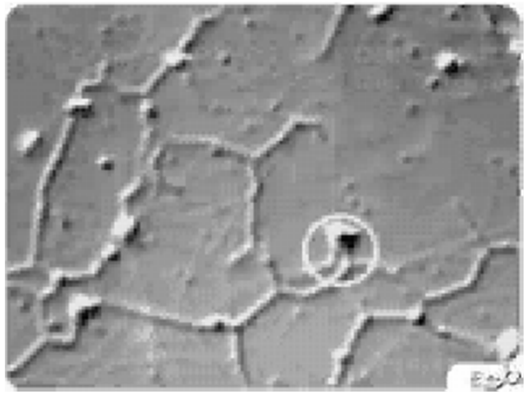


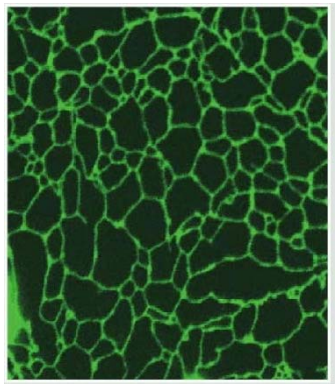


Liu & Bachand, 2011, *Soft Matter*, **7**, 3087; Liu et al., 2008, *Adv. Mater.* **20**, 4076; Boal et al., 2006, *Nanotechnology*, **17**, 349; Bachand et al., 2005, *J. Nanosci. Nanotech.*, **5**, 718 ; Hess & Bachand, 2005, *Mater. Today* **8**, 22; Bachand et al., 2004, *Nano Lett.* **4**, 817

Dynamic Assembly of Lipid Networks

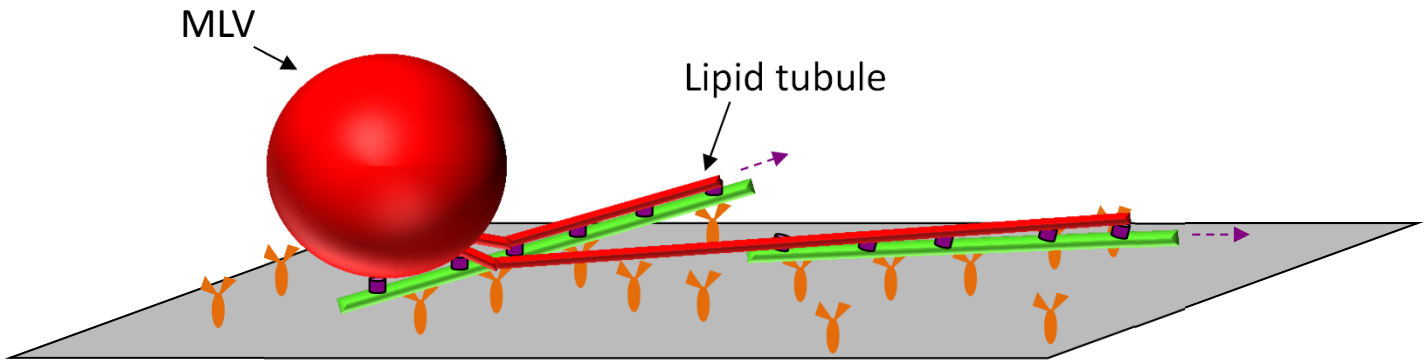
Kinesin transport is critical to the assembly and dynamic reorganization of intracellular organelles including the endoplasmic reticulum and Golgi apparatus.





Cortical network of ER sheets and tubules within the cell

Petra Boevink and Chris Hawes, NIH



Can we mimic such a self-assembly system *in vitro?*

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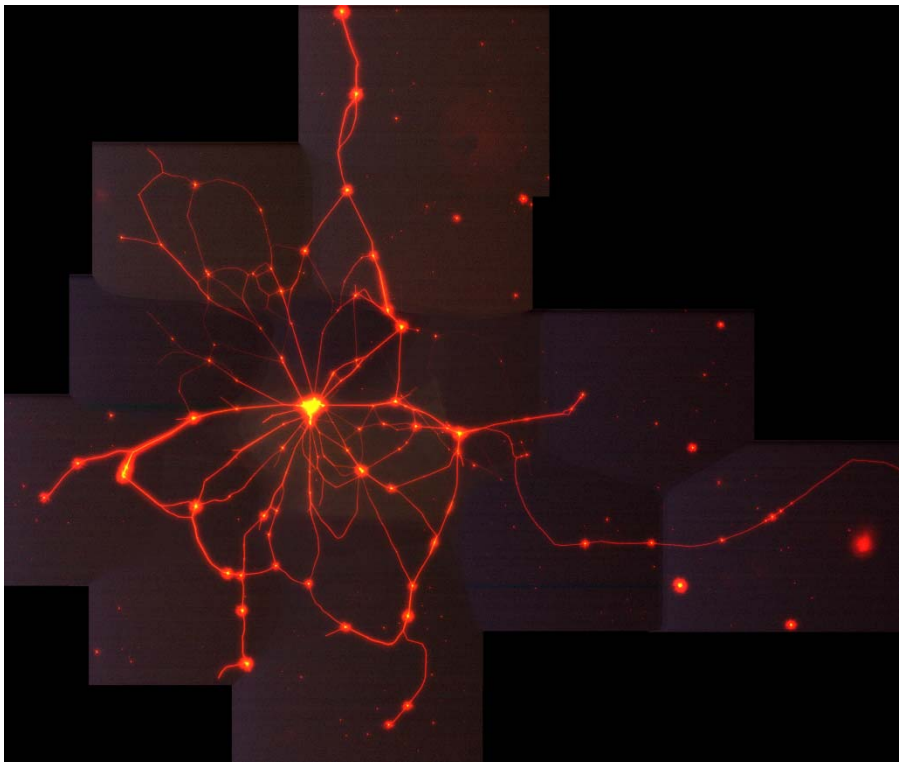
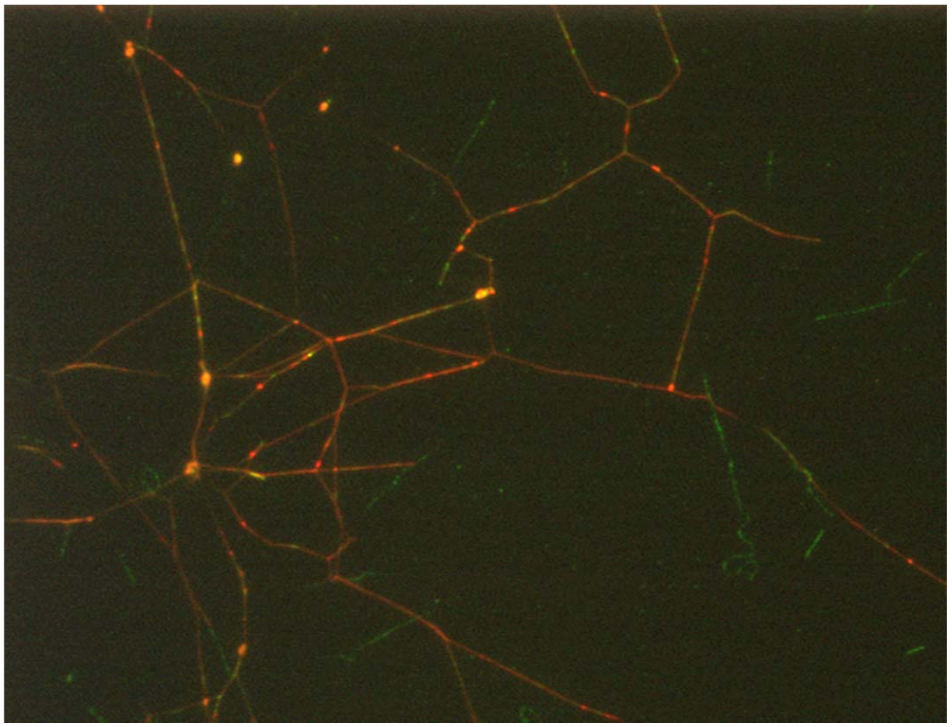
Dynamic Assembly of Lipid Networks

Lipid nanotube networks serve as highly connected highways for diffusive transport of nanoparticles.





525 and 605nm Qdot surfing on lipid tubes

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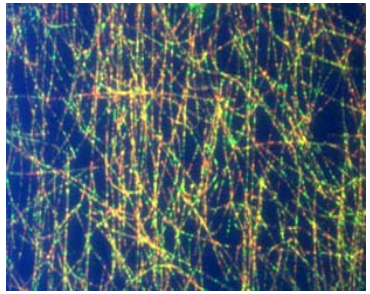
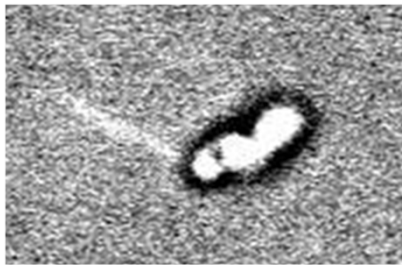
Kinesin Transport in Nanodevices

Kinesin transport used to capture, transport, and tag bioanalytes (proteins, bacteria, and viruses) in nanoscale sensors (DARPA).

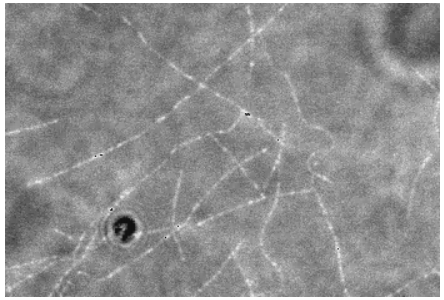
IL-2 & TNF-α (protein)



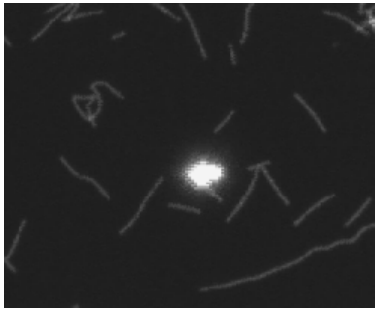
Escherichia coli (bacterium)



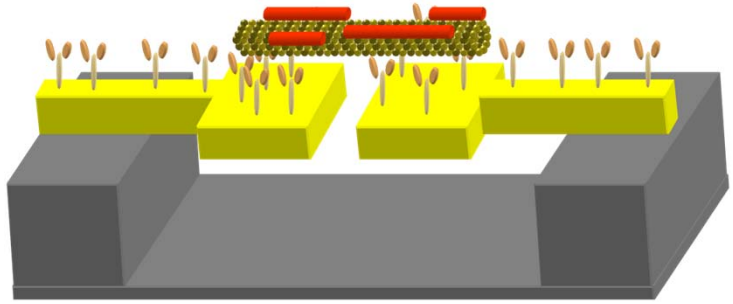
Bacillus globiggi (bacterial spore)



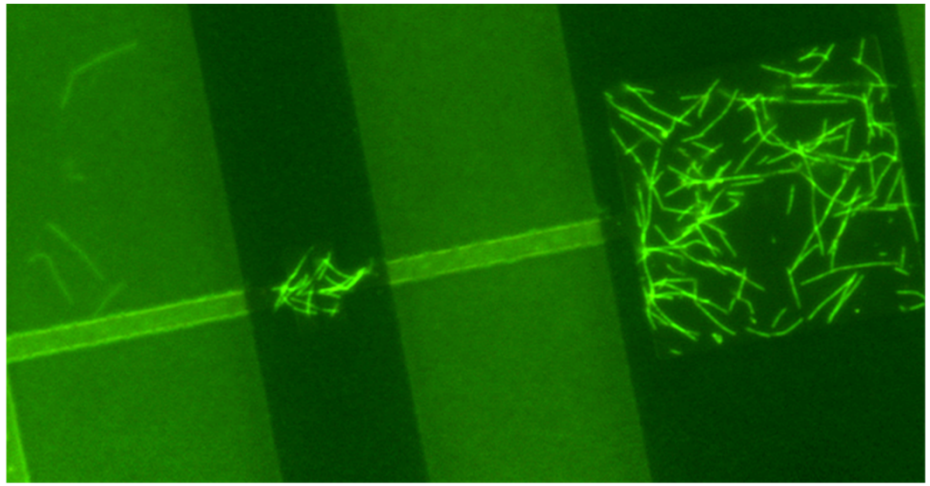
Tobacco mosaic virus



Kinesin transport used to create carbon nanotube interconnects across gold electrodes (CINT).



MT fluorescence (FITC)

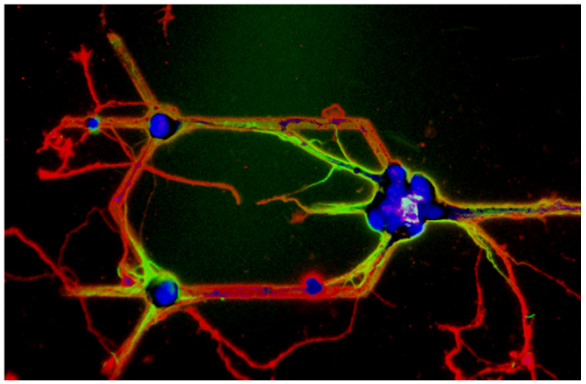


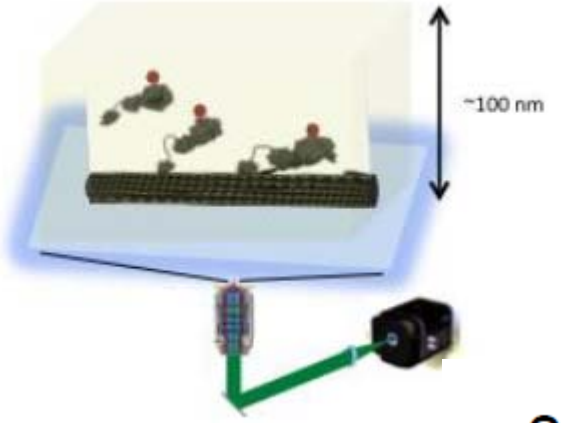
Bachand et al., 2006, *Small* **2**, 381**;** Ramachandran et al., 2006, *Small* **2**, 330; Boal et al., 2006, *Small* **2**, 793; Rios & Bachand, 2009, *Lab Chip* **9**, 1005; Bachand et al., 2009, Lab Chip **9**, 1661; Carroll-Portillo & Bachand, 2009, *Biotechnol. Bioeng*. **104**, 1182; Bachand & Bachand, 2012, *Nanoscale* (in review).

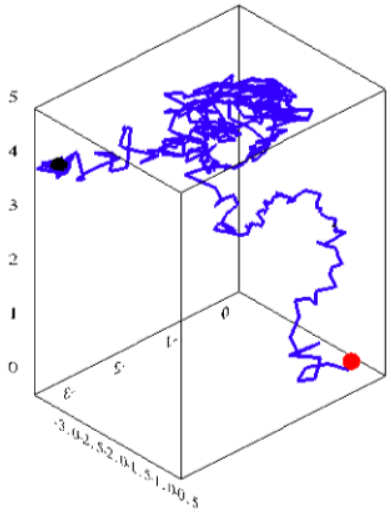
Nano Approaches for Biomolecular Processes

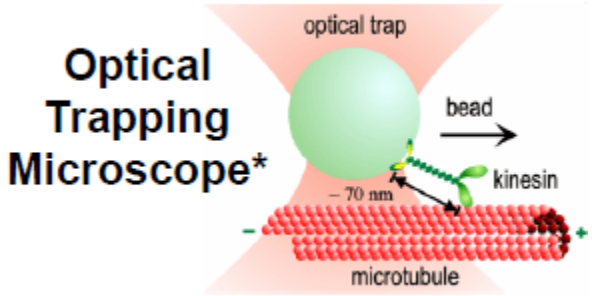
Applying nanoscience/technology to understand, control, and manipulate biomolecular processes

- How nanomaterials interact with biomolecular materials
- New nano-enabled "tools" for studying biological processes









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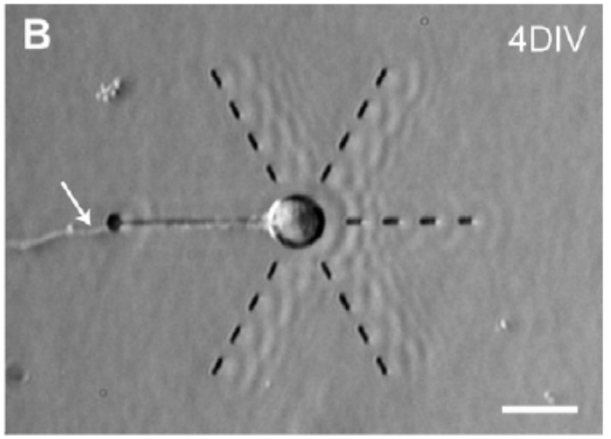
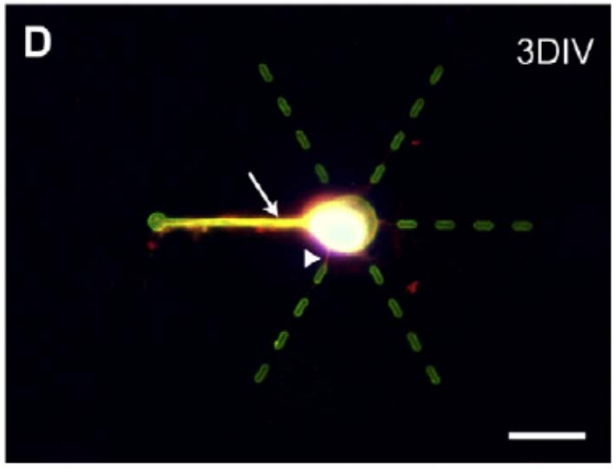
Cell Differentiation Based on Interfaces

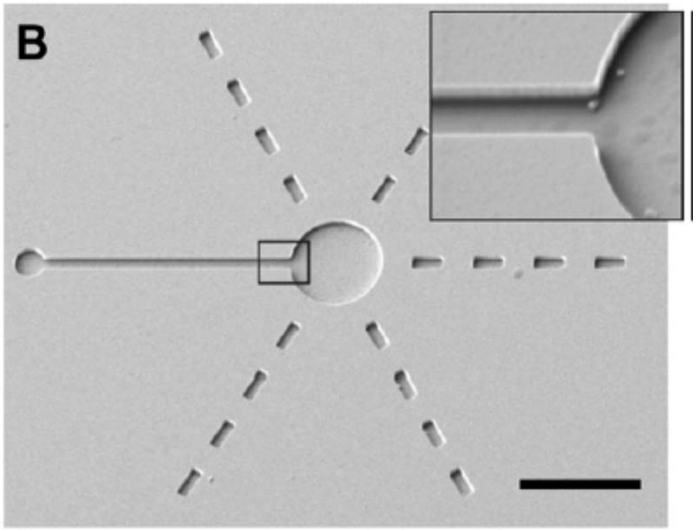
Hybrid interfaces – combined chemically bifunctional and topographically defined surface direct the polarization and morphogenesis of neurons.

- Differential surface chemistry (hydrophobic vs. charged/hydrophilic) directed cell adhesion and growth

- Topographic features direct polarization and process development/morphogenesis







Greene et al., 2011,. *Biomaterials* ***32***, 8860-8869 (CINT User Project).

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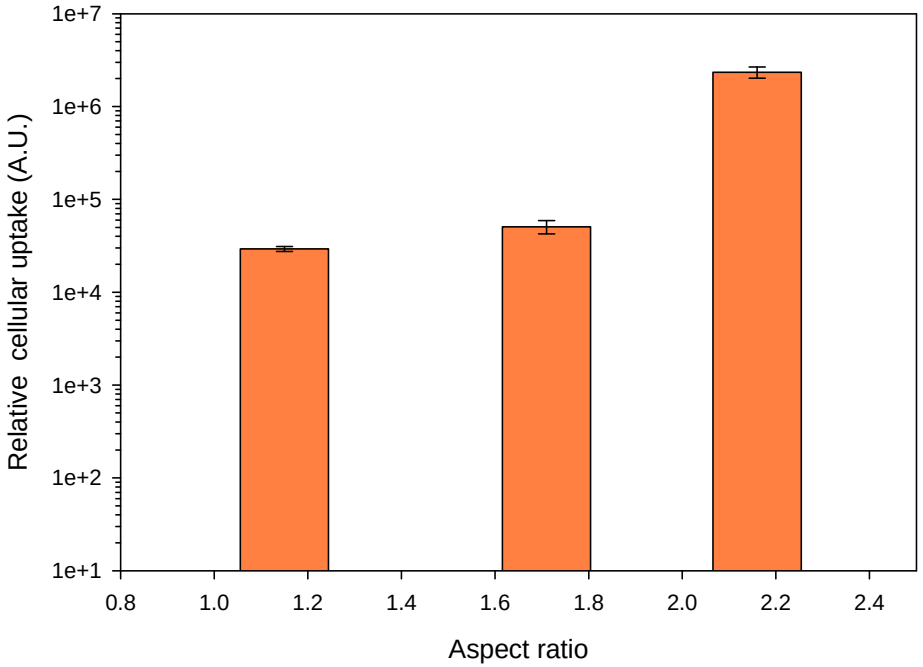
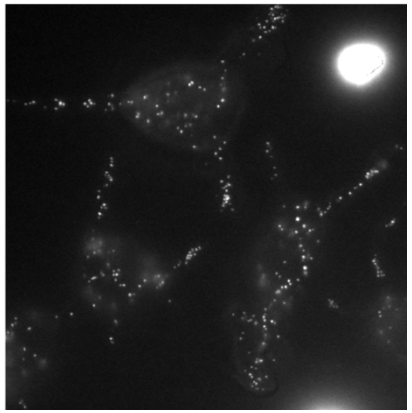
Cell – Nanoparticle Interactions

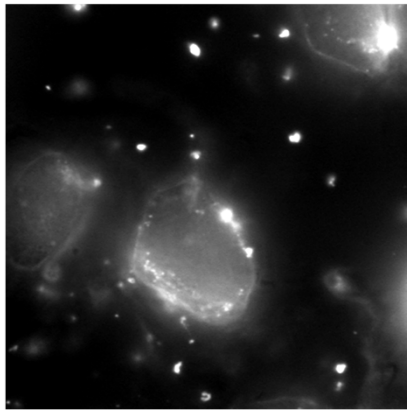
Interactions among cells and nanoparticles governed by the physical and chemical properties of the nanoparticle.

- Aspect ratio of 2-3 = maximum uptake
- Increased biomolecular response with increased uptake

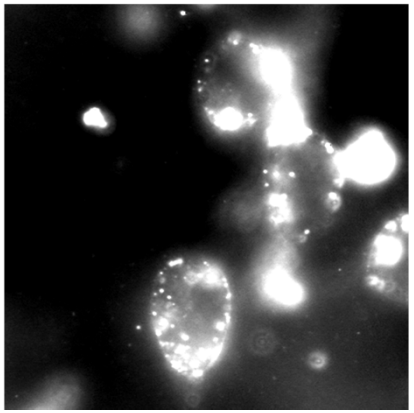




Qdot 545 (1.15)



Qdot 655 (1.71)



Qdot 605 (2.16)

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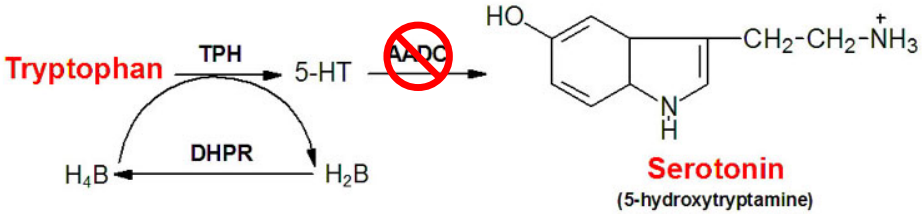
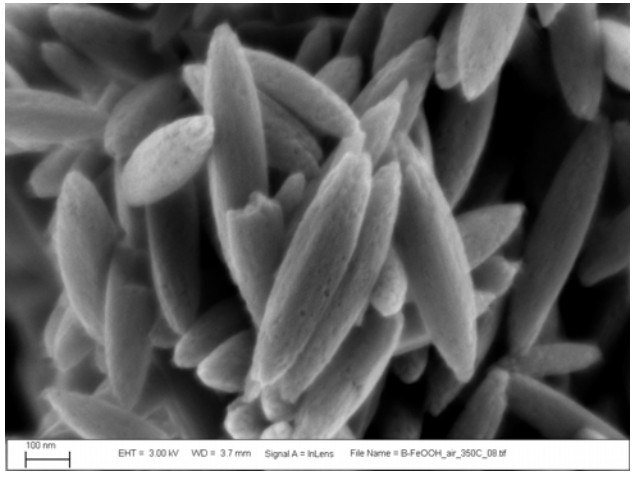
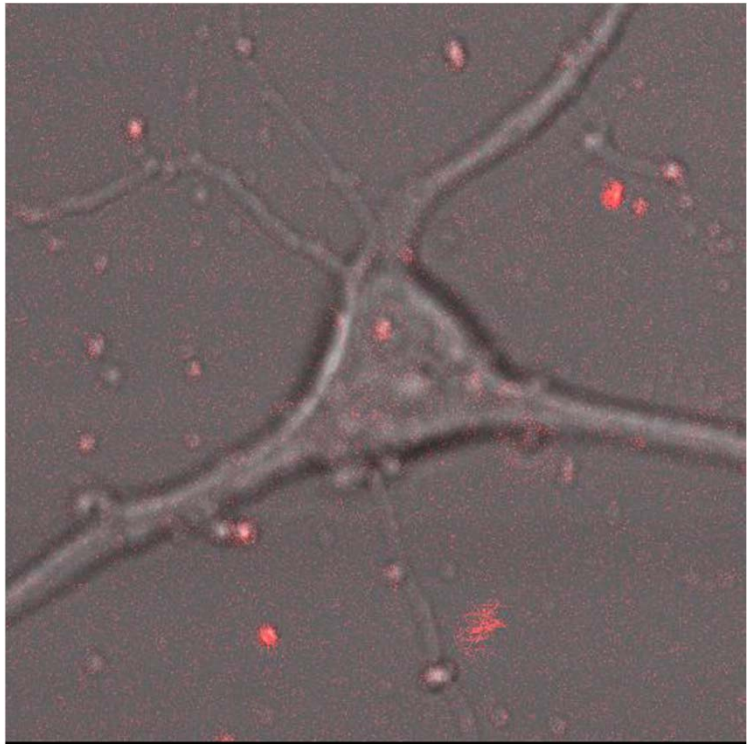
Delivery of Biomolecular Effectors

Lipid-encased nanoparticles – delivery and release of effectors (e.g., siRNA) of biomolecular processes



- Understand functional relationships and pathways
- Transiently regulate processes (therapeutics)





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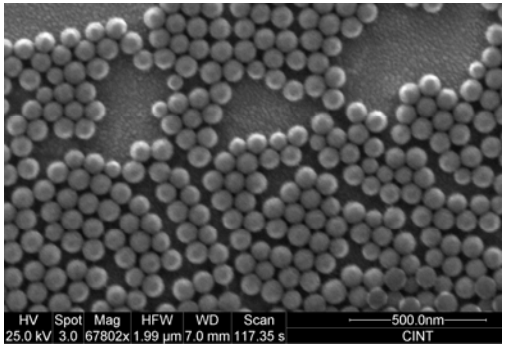
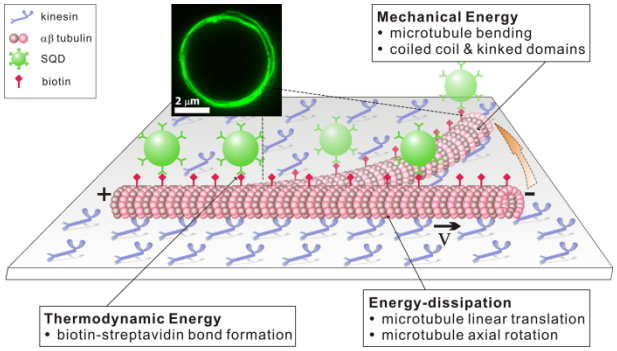
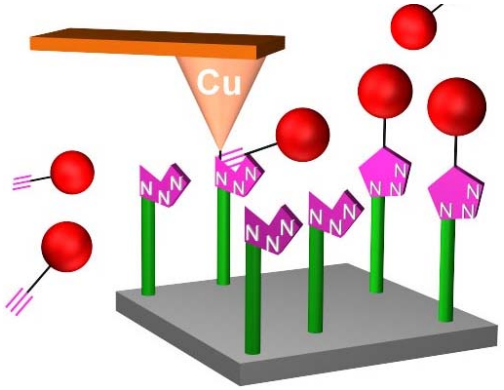
SBCN Vision

Thrust Focus:

Enabling new function from integration strategies of soft and/or biological nanomaterials through solution-based synthesis, “bottom-up” assembly and processing







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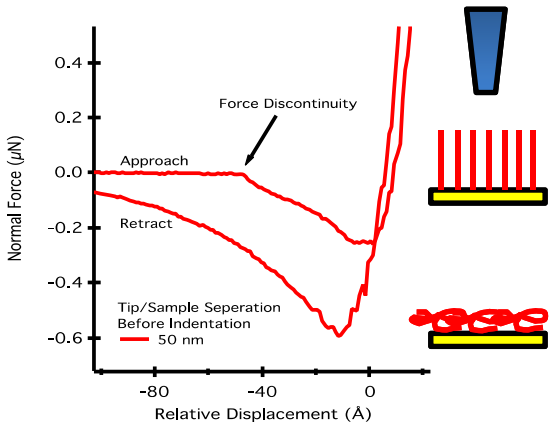

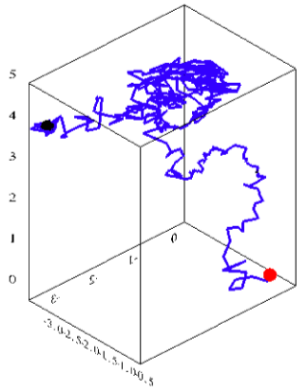

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Vision: Integration Inspired by Nature

0.1 nm | 1 nm | 10 nm | 100 nm | 1 µm | 10 µm | 100 µm

Molecular chemistry →

← Lithography

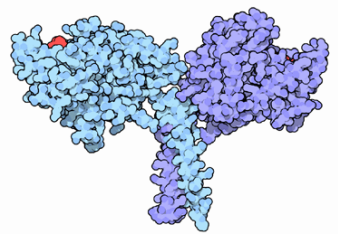
Supramolecular chemistry →

Macromolecular (polymer) chemistry →

Self-assembly/ organization →

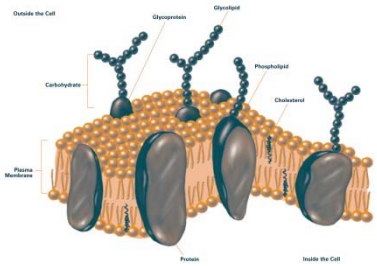
Optical imaging →

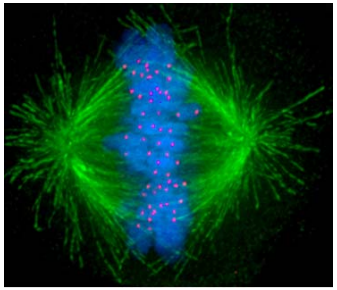
Scanning probe characterization →



Proteins

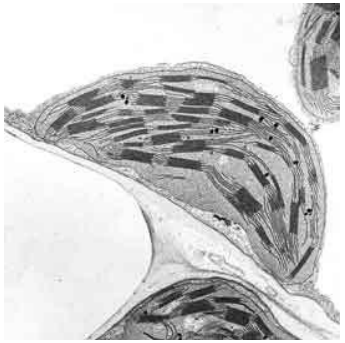
Protein assemblies
Protein/DNA complexes

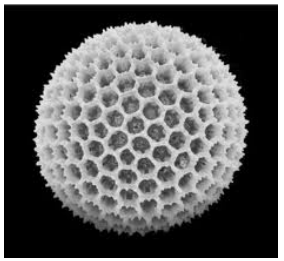




Cytoskeletal structures

Organelles





Cells

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Mimicking Natural Assemblies

- Adaptable – Sense and respond to changes in environment; evolution
- Functional – Energy/signal transducing, catalytic, mechanical, electrical or optical, ...
- Dynamic & reconfigurable – Exist far-from-equilibrium
- Redundancy – Robustness, “fail-safe” operation
- Self-organization – Parallel assembly via multiple stochastic interactions
- Multicomponent and multiscale – Subtle changes in chemical constituents influence overall structure and function

Challenge:
How to reproduce these features in integrated and/or composite assemblies?

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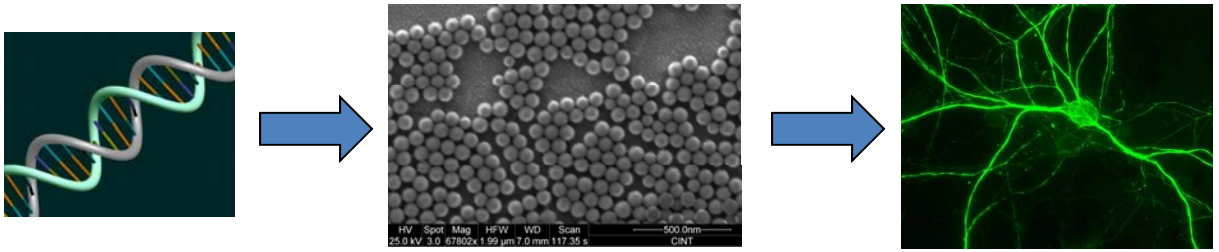
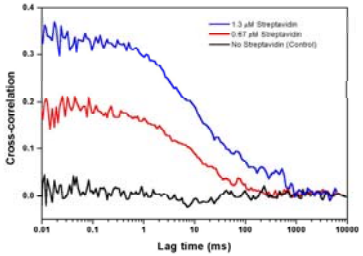
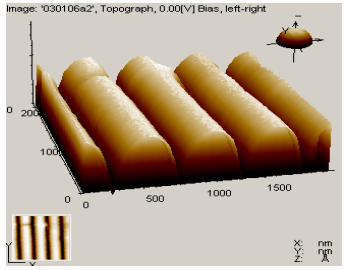
Key SBCN Science Topics

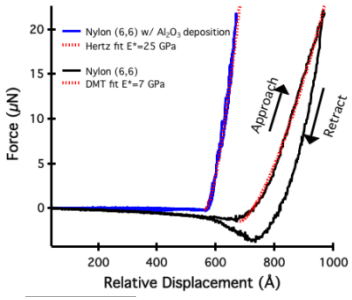
- Designing and manipulating interfaces among disparate materials across length scales



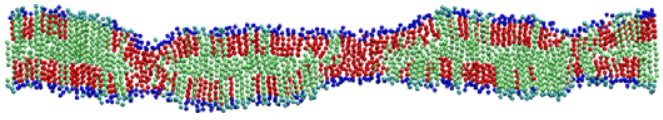
- Characterizing soft, biological and composite systems on multiple length- and time-scales

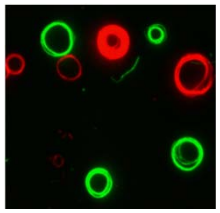






- Understanding and controlling dynamics and disorder in composite materials





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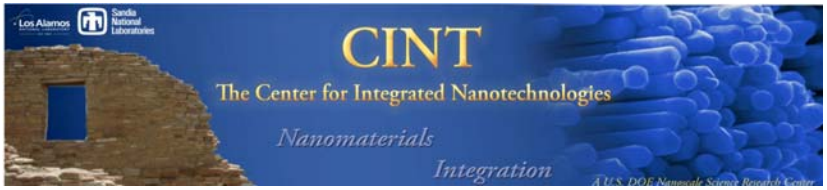
Programmatic Goals

- Triennial review – 2013
  - Strategic planning
  - Research document
  - Review presentation
- Thrust interactions
  - Monthly thrust communication meetings
  - Foster New IFAs or other collaborative efforts
- SBCN leadership in NSRC community
  - Lead NSRC workshop in soft/bio
  - Reciprocal staff visits
  - Research highlights
- User program
  - Increasing local user interactions
  - “Equipment users” vs. collaborators
  - Strategic hires to support user needs



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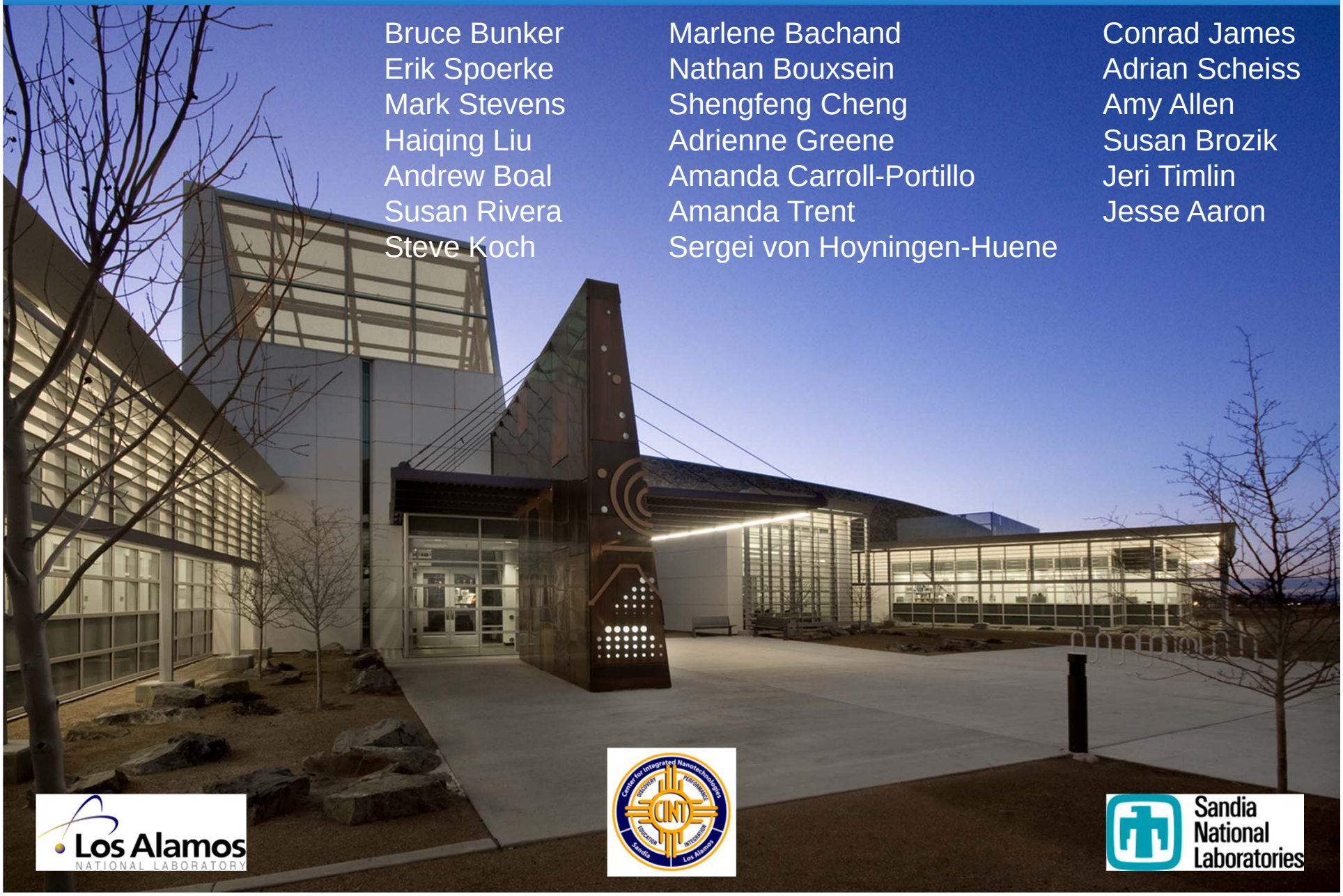
Acknowledgments

Bruce Bunker
Erik Spoerke
Mark Stevens
Haiqing Liu
Andrew Boal
Susan Rivera
Steve Koch

Marlene Bachand
Nathan Bouxsein
Shengfeng Cheng
Adrienne Greene
Amanda Carroll-Portillo
Amanda Trent
Sergei von Hoyningen-Huene

Conrad James
Adrian Scheiss
Amy Allen
Susan Brozik
Jeri Timlin
Jesse Aaron



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