Federal Investment in Cutting Edge Agricultural Technology Leading to Solutions for Global Food Security

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Cooperative State Research, Education and Extension Service (CSREES)

United States Department of Agriculture (USDA)

NAS

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Government-University-Industry Research Roundtable

POLICY AND GLOBAL AFFAIRS

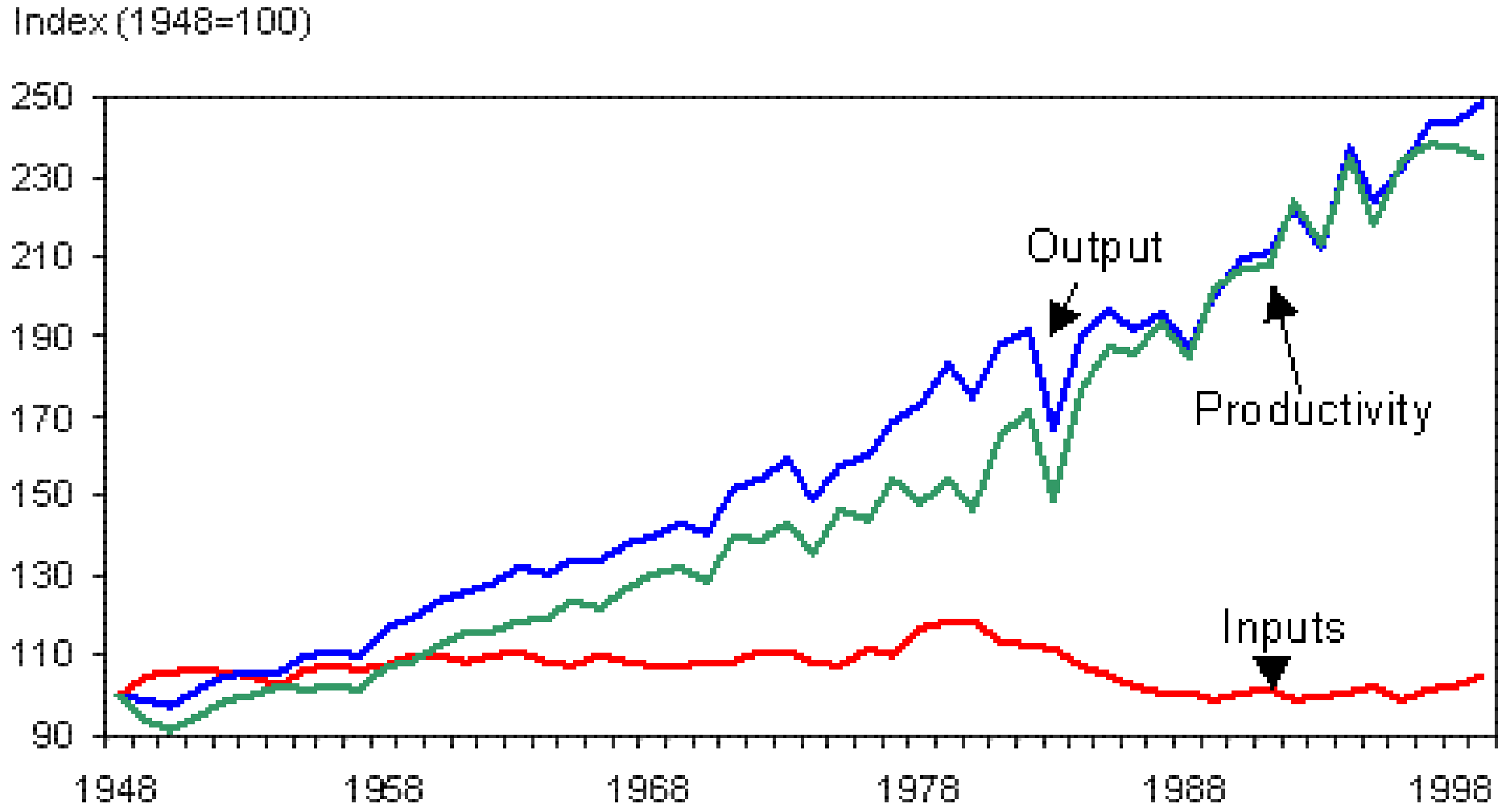
The foundation of past, today and tomorrow

"AGRICULTURE IS THE FOUNDATION OF MANUFACTURE AND COMMERCE."

Background

- The world faces grand societal challenges now and decades ahead – relevance to agriculture and food
  - Sustainability – resolving diminishing natural resources against increasing demands of growing world population
  - Vulnerability – food safety, biosecurity, and others
  - Human Health – food and nutrition related developmental and degenerative illness
  - Living conditions – improved working conditions, advanced education and learning, better environment, etc.
- Agriculture and food sector is a part of these challenges, and also could and should be a part of the solutions, provided we continue seeking appropriate research strategies.

Productivity continues to be the engine of growth in agriculture



Final data year is 2002.

Source: Economic Research Service, USDA

Public Investment in High Risk Science and Technology

- Drivers: Mission critical
  Scientifically enabling
  Potential for high return

- Focused on: Public good
  Market distance

New Science and Technology for Agriculture

- Genomics
  - Bioengineering
  - Marker-assisted breeding
  - Microbial resistence; disease processes
- Sensors and Measurement
  - Production/management
  - Environmental control
  - Agroenvironmental monitoring
  - Labor sparing, harvest technology
- Nanotechnology
  - Disease and contaminant detection
  - Nanobarcodes for monitoring and tracking
  - Food additive delivery systems

Possible Applications ... of Nanotechnology

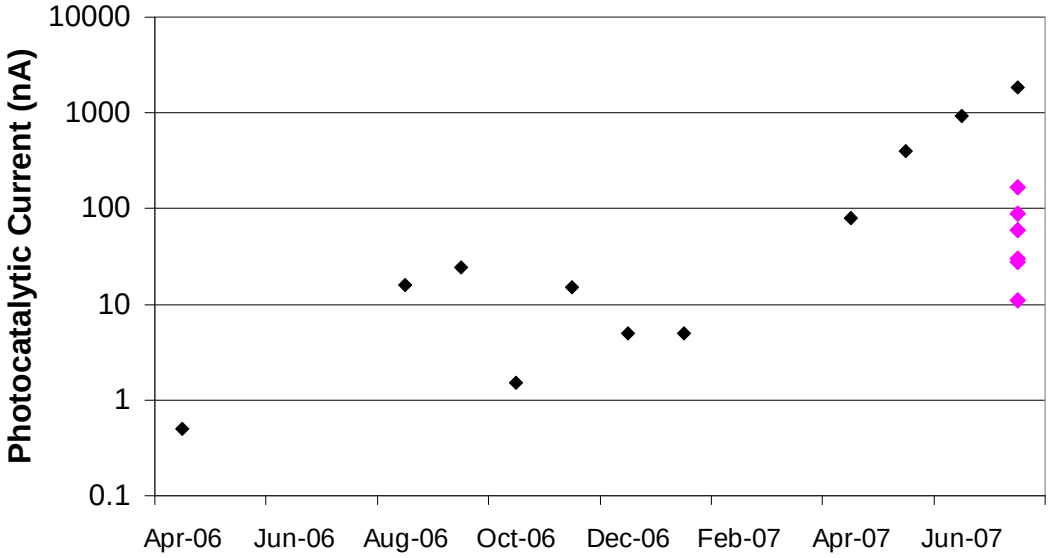
- Delivery of nutritional functions (micronutrients and bioactive compounds) through food matrix
- Controlled bio-availability of molecules
- Protect nutritional stability in the environment
- Flavor release (sensory interaction and perception)
- Taste, flavor and texture modification
- in-situ flavor & color formation
- Remove undesirable products
- Smart delivery systems
- Food quality sensors
- Nanotags (traceability)
- ...

Chen, Weiss, and Shahidi, *Food Tech*. April 2006

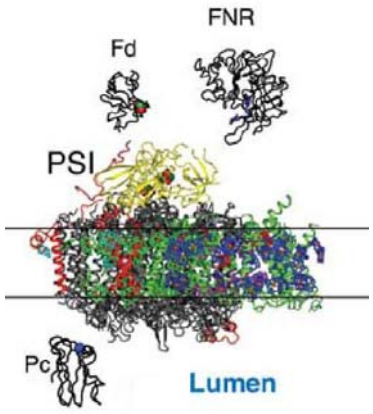
Examples of applications for new technologies in food and agriculture

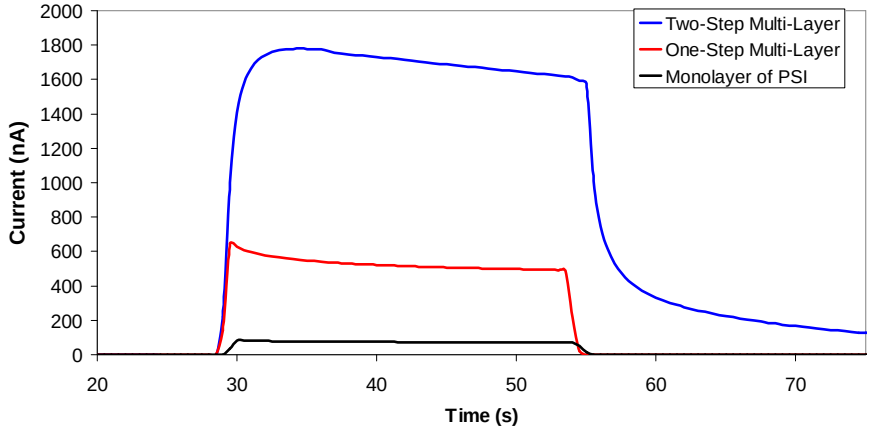
- Novel renewable energy
- Plant production enhancement
- Animal production enhancement
- Food safety and agro-biosecurity
- Enhance food quality and nutritional value – improve human health
- Minimize environmental footprints, including water and soil
- Manage/understand climate change
- …

#1: Photosystem I Nanoscale Photodiodes For Creating Photoelectrochemical Devices, G. Kane Jennings, David E. Cliffel, Vanderbilt University

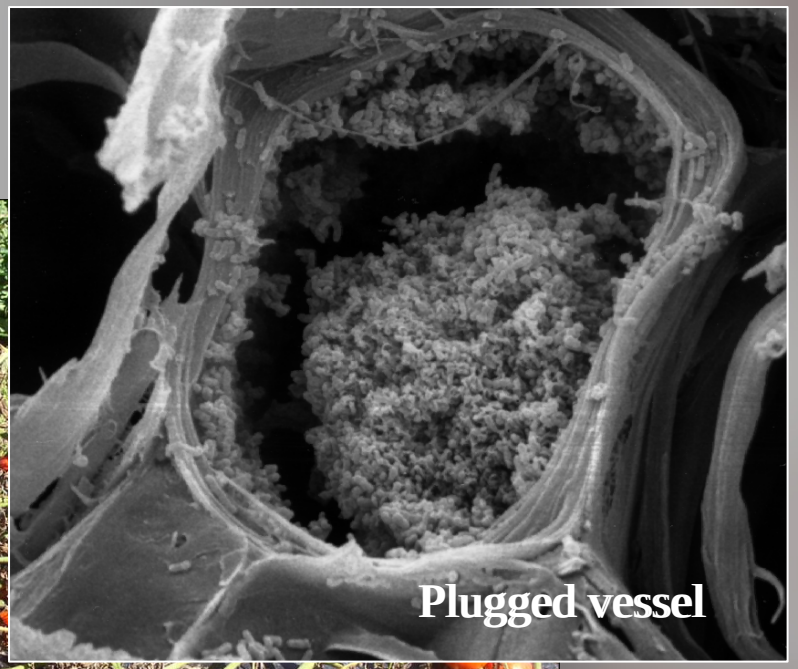


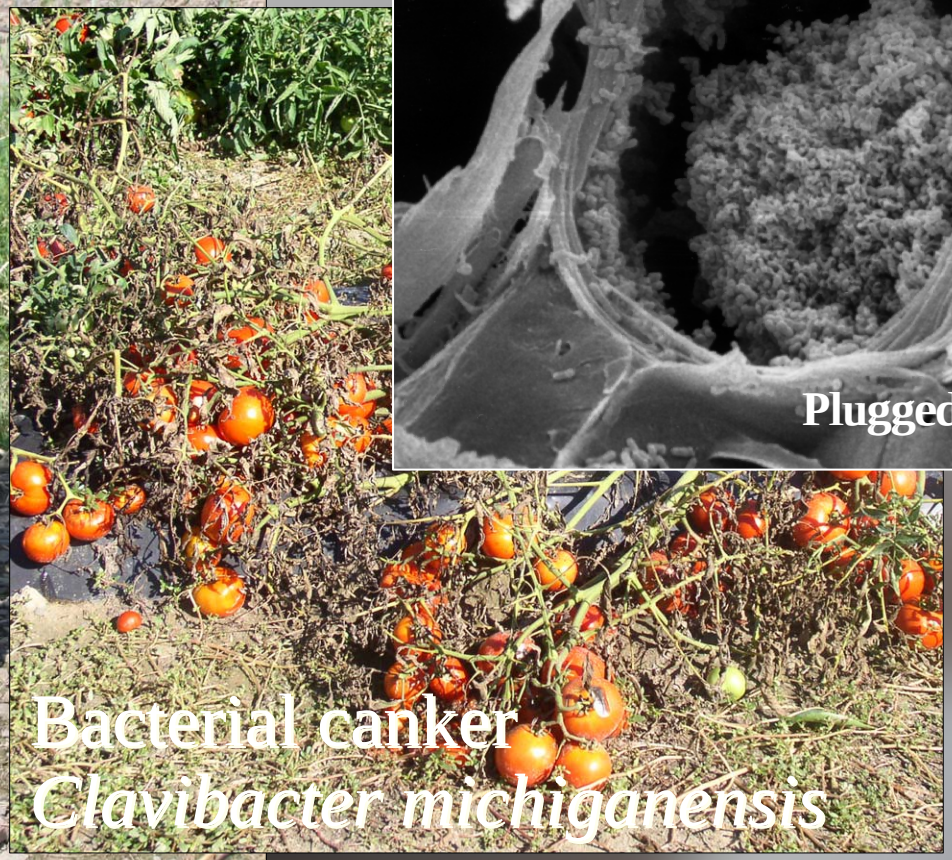
- 12 x 9 nm (~500 kDa) protein complex
- Achieves charge transfer in 10 - 30 ps
- >97% efficiency of excitation transfer





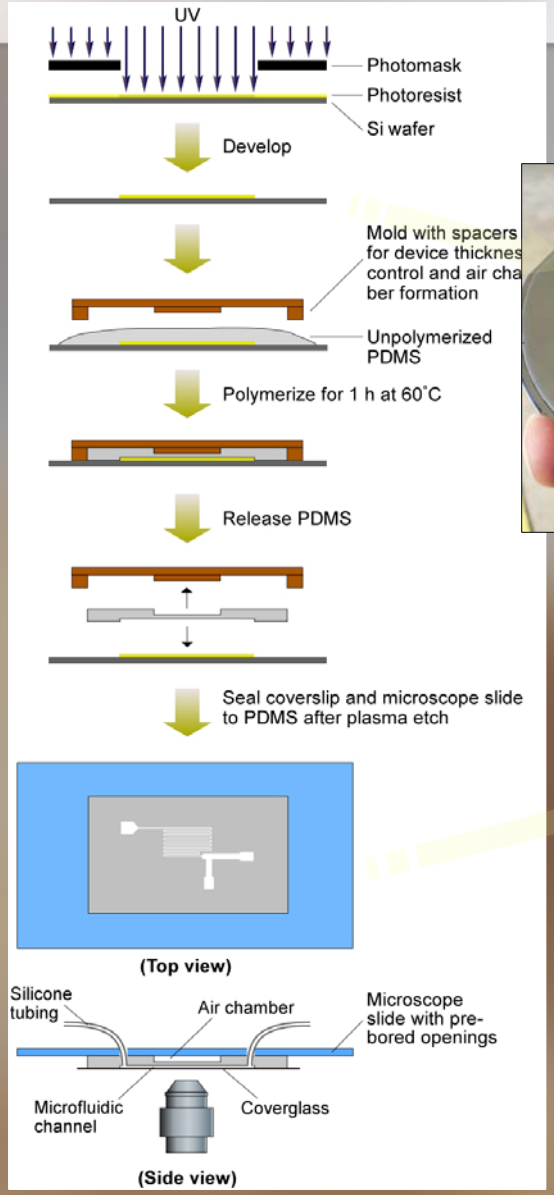
Use Nano-Fabricated Surfaces to Study Colonization and Dispersal of Bacteria in Plant Vessels

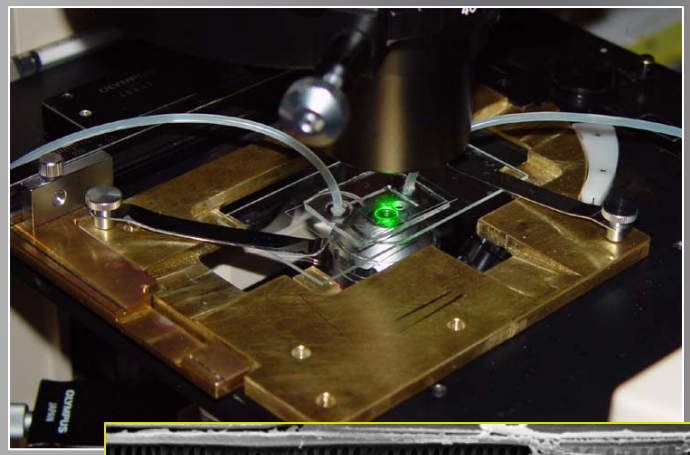


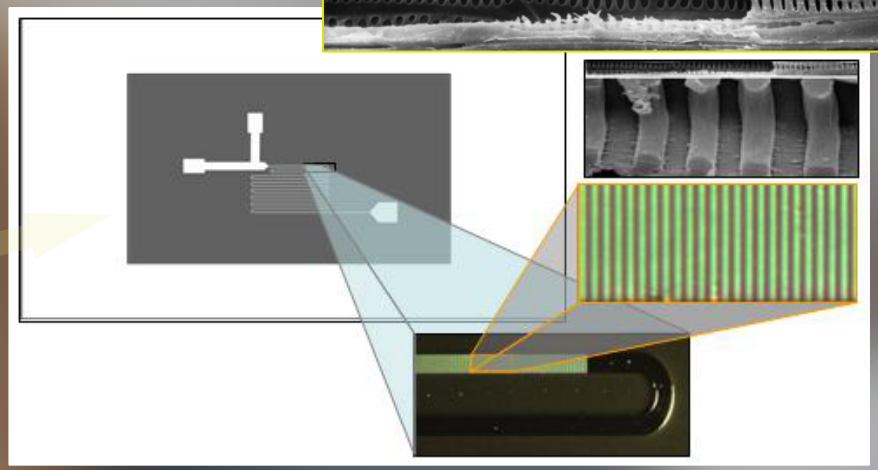


(Hoch, Cornell U. 2004-04436)

Use of Nano-Fabricated Surfaces to Study Bacteria in Plant Vessels



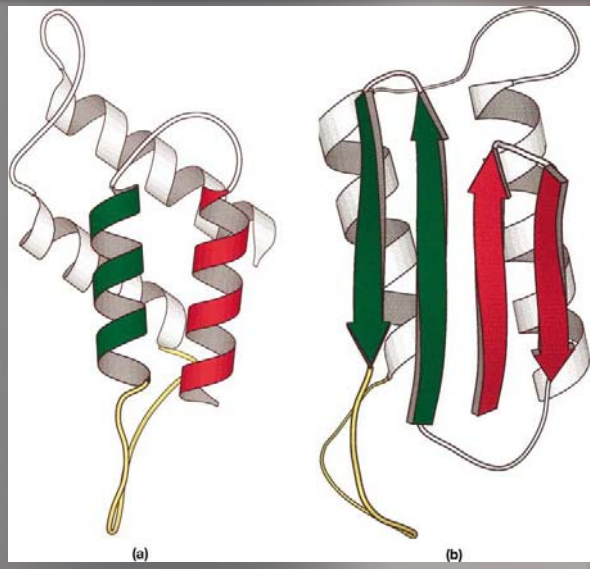




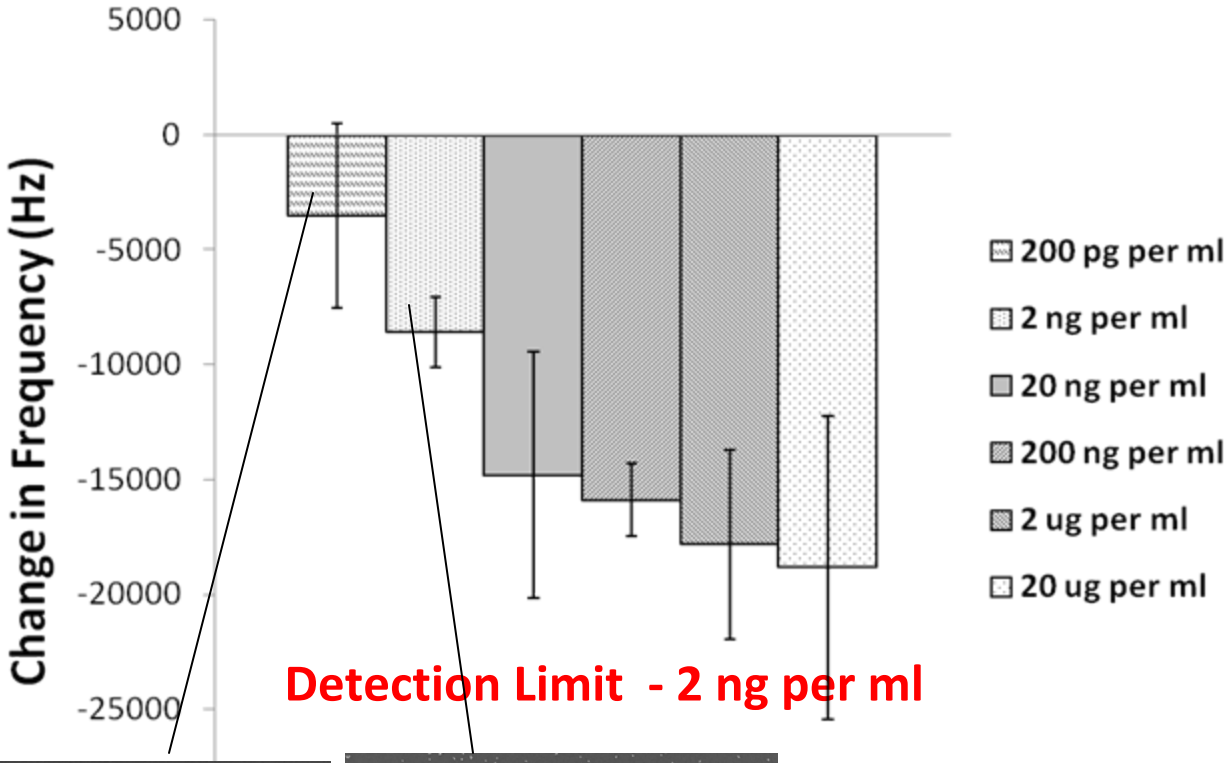
(Hoch, Cornell U. 2004-04436)

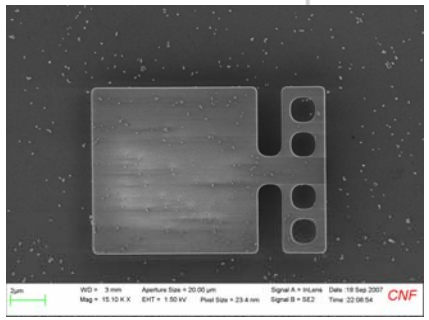
Detection of Zoonotic Diseases

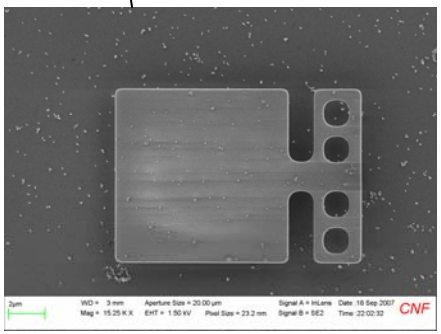
- Protein Structure Sensors through Molecular Imprinting: Applications towards Prion Detection and Correction (Britt, Utah State U., 2004-04447)
- Development of Blood Protein Assays for Prions in Mammalian TSEs (Lewis, U. Wyoming, 2005-02962)
- Detection of Food-Borne Toxins with Multifunctional Nanoparticles (Kennedy, UC Davis, 2005-02977)
- Self-Amplifying Nanobiosensor for Direct Detection of Prions in Blood (Montagna, Innovative Biotechnologies International, Inc., 2006-02658)

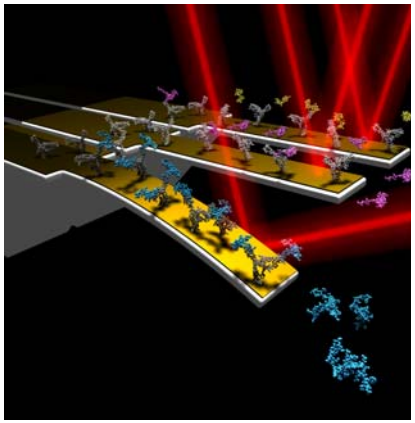


Dose Response Curve with Nanoparticles Mass Labeling





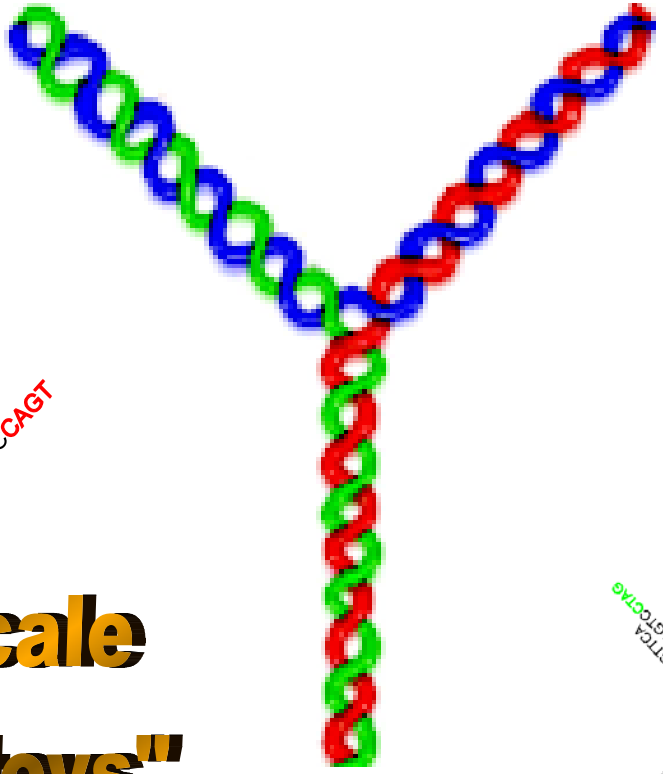


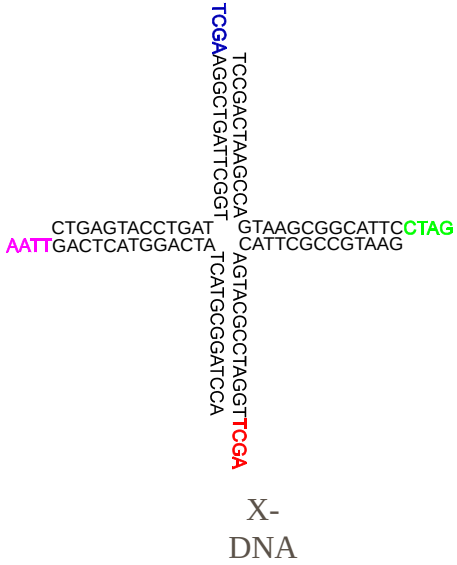


Picture: A. Majumdar

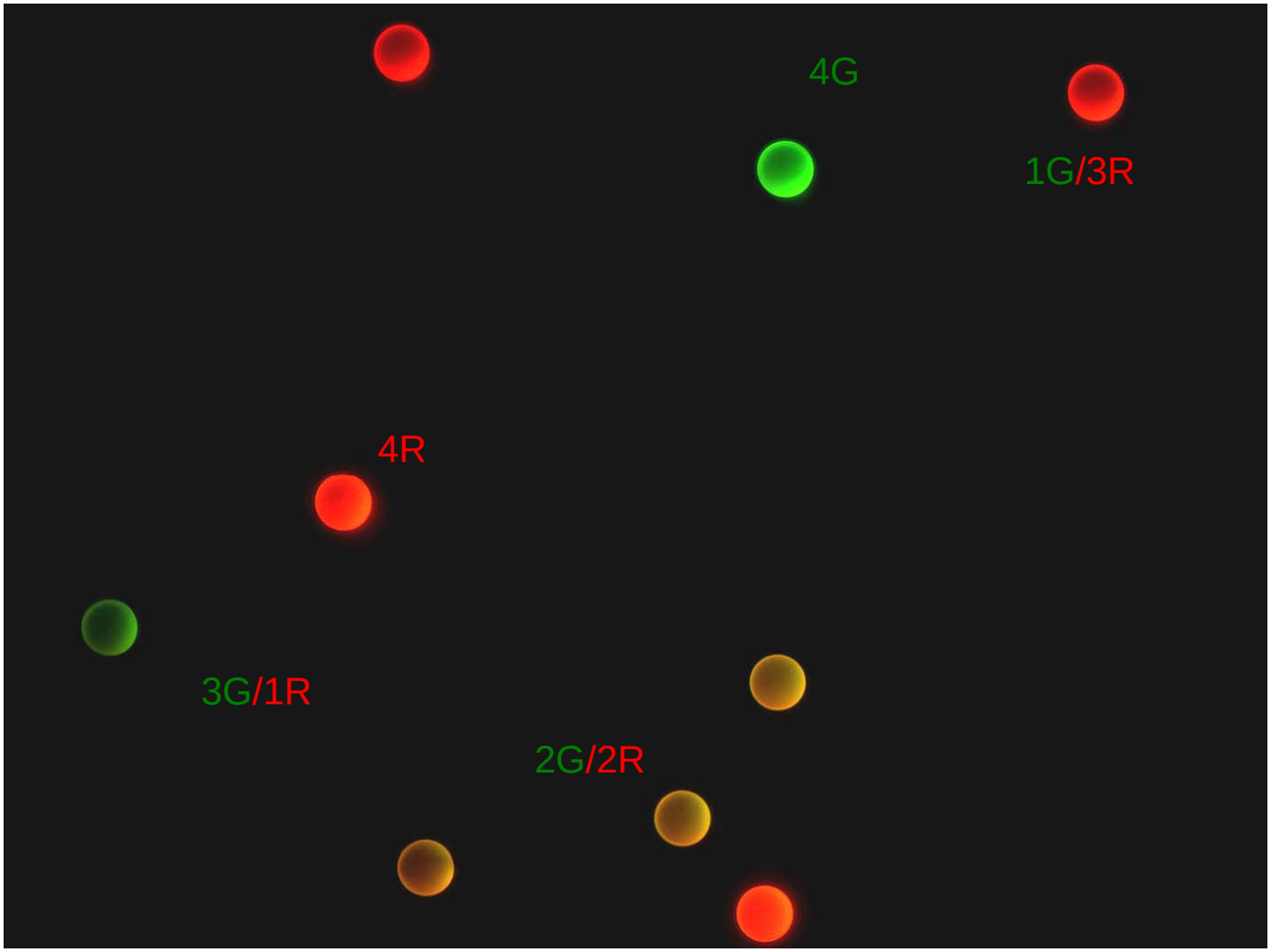
Nucleic Acid Engineering: DNA Nanobarcode

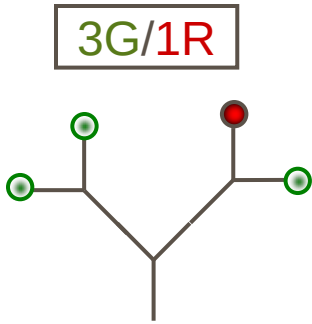
Luo, Cornell University

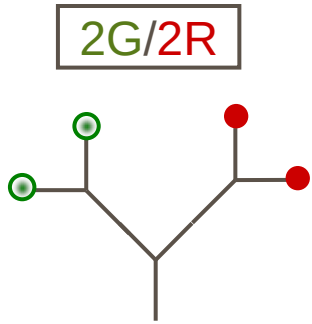


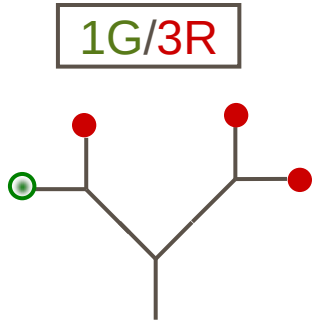


Barcode decoding via fluorescent microscopy



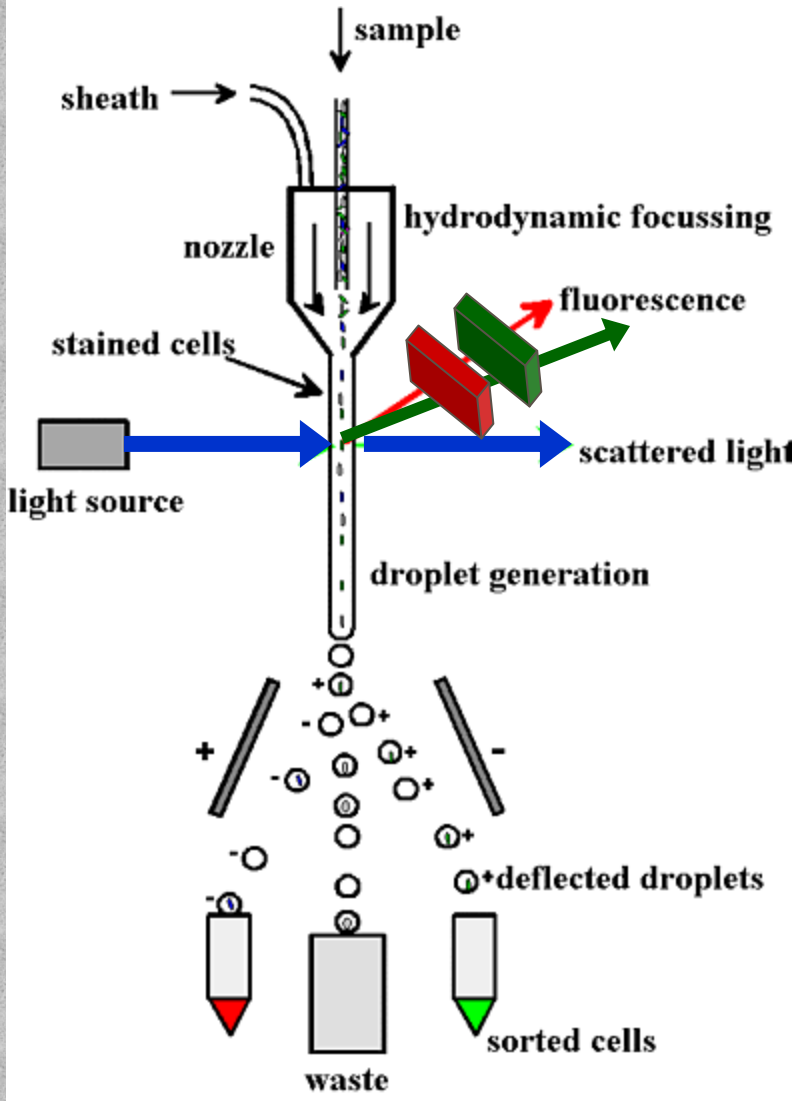


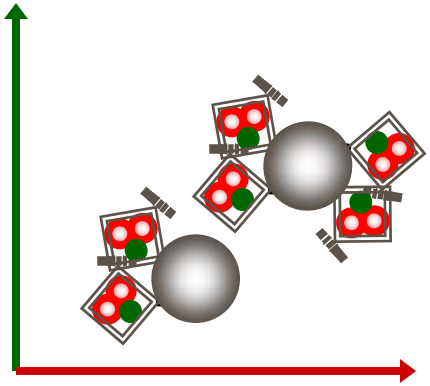




Y. Li, Y. Cu and D. Luo, *Nature Biotechnology*, **23**, 885-889, (2005)
Um. et. al. *Nature Protocols* **in press** (2006)

Barcode decoding via flow cytometry

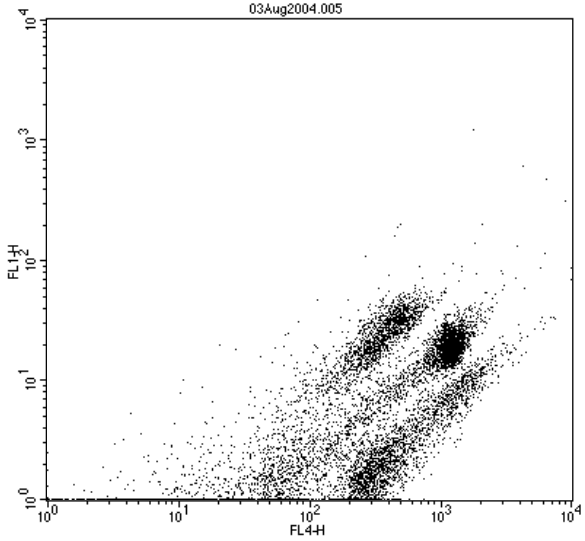




$$\frac{I_R}{I_B} = k_{barcode}$$

$$\ln(I_R) = \ln(I_B) + \ln(k_{barcode})$$

y=1.06x-5.0
y=0.99x-5.9
y=1.00x-3.3

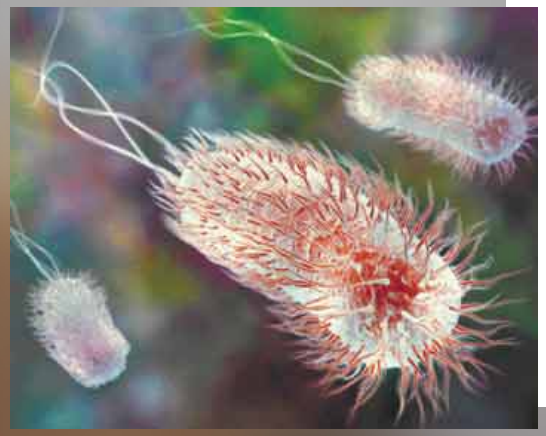


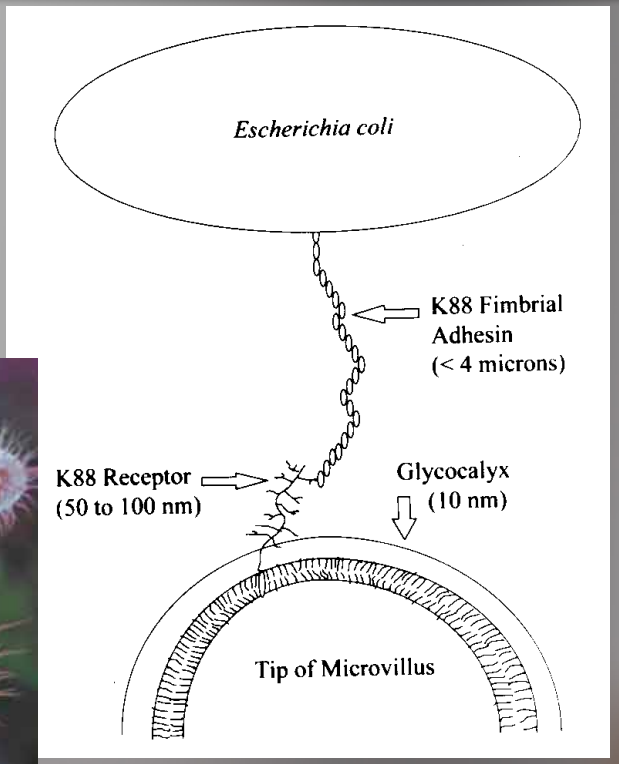
Three different DNA species from Anthrax, Ebola and SARS were detected simultaneously with 3 DL-DNA-based nanobarcodes using commercial polystyrene microbeads. Detection limit: 10^{-18} mole (attomole). Detection speed: 30 seconds.

Y. Li, Y. Cu and **D. Luo,** *Nature Biotechnology,* **23,** 885-889, (2005)

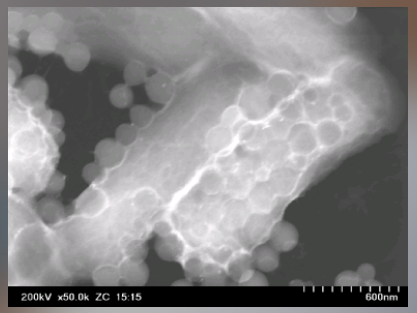
Food Safety Intervention

- ***ADHESIN-SPECIFIC NANOPARTICLES FOR REMOVAL OF PATHOGENIC BACTERIA FROM POULTRY***
  - Latour, R. A., etc., Clemson Univ. 2000-05336



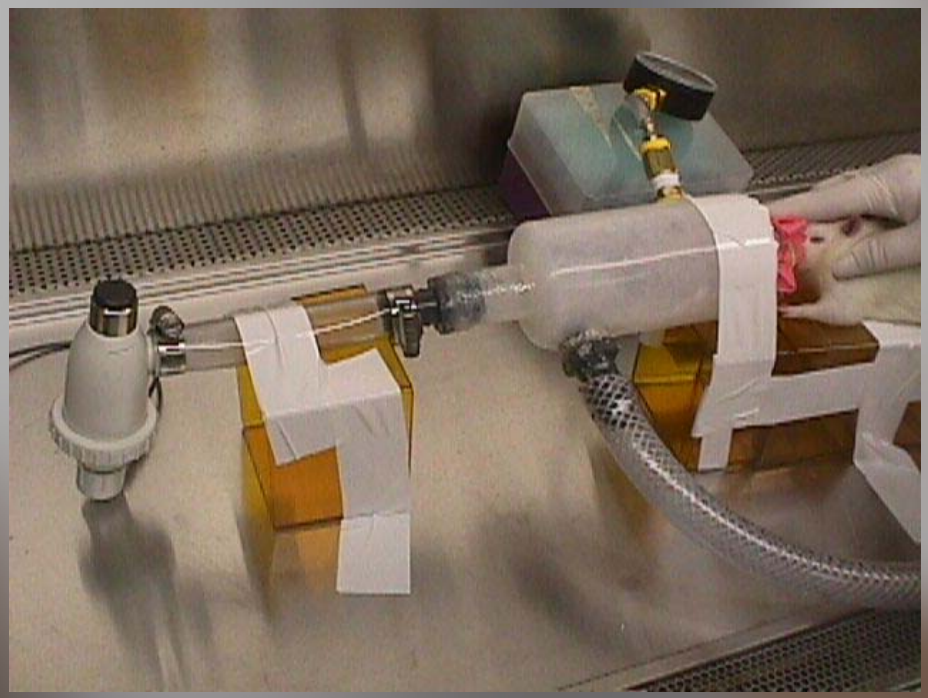


Bacterial Binding to Host is Mediated by Adhesins



Acute Nanoparticle Exposure Sensitivity Studies

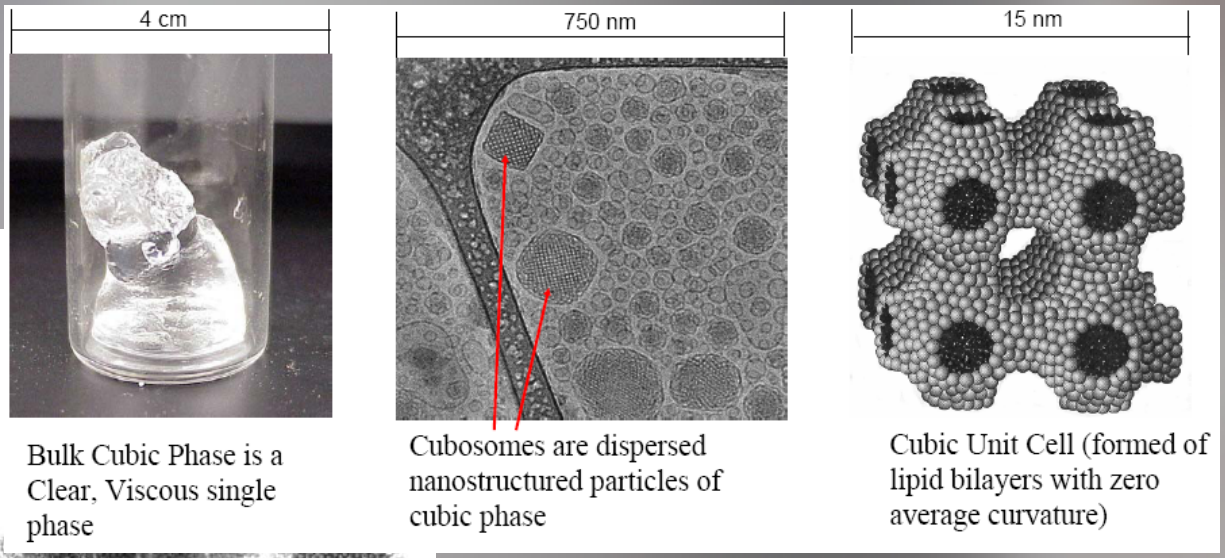
- In vitro studies
  - cell toxicity studies
- In vivo studies
  - Skin (rabbit)
  - Ocular (rabbit)
  - Inhalation (rat)
  - Ingestion (rat)
- In vivo studies: poultry

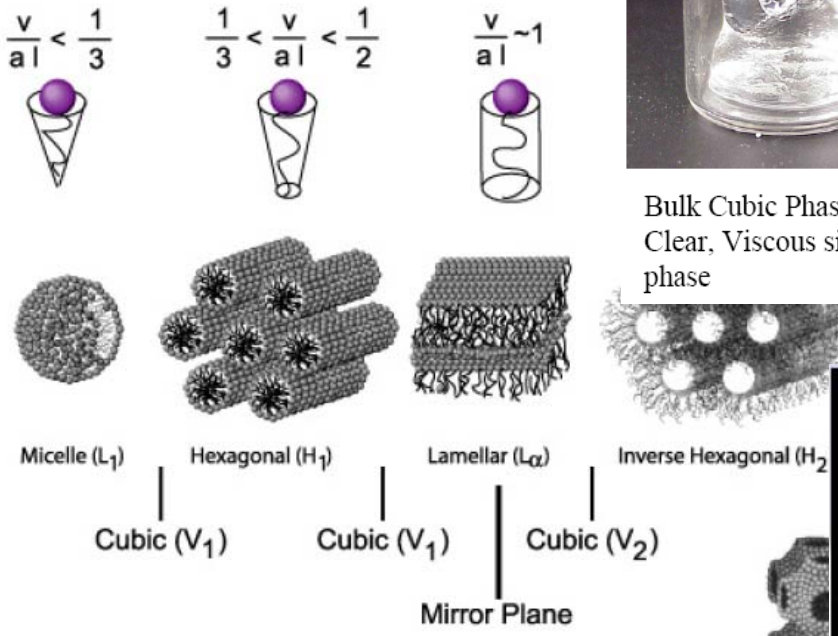


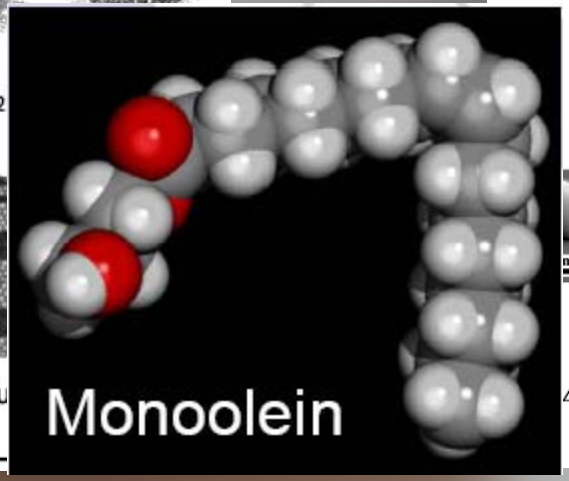
(Latour, etc. Clemson University)

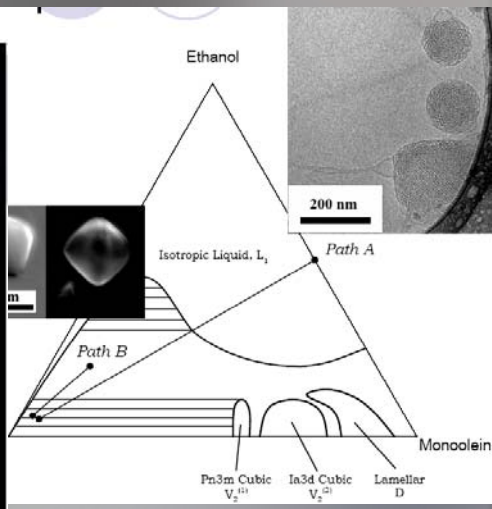
Nanostructured Fluids

(After Patrick Spicer, Procter & Gamble, Co.)

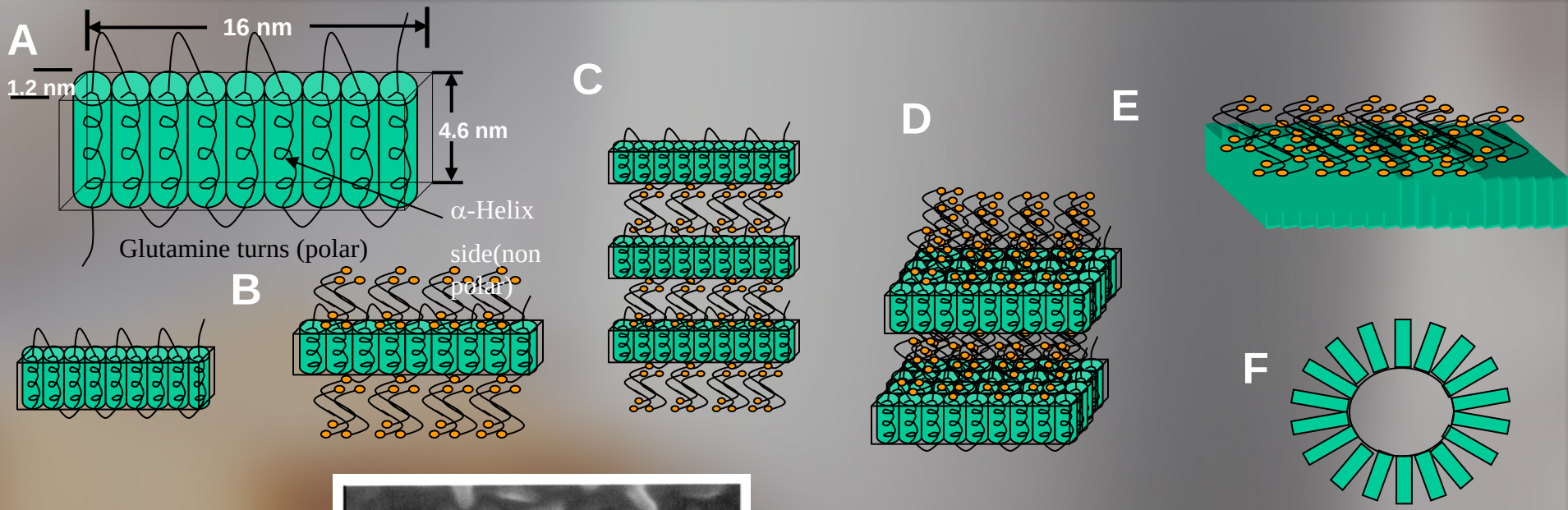


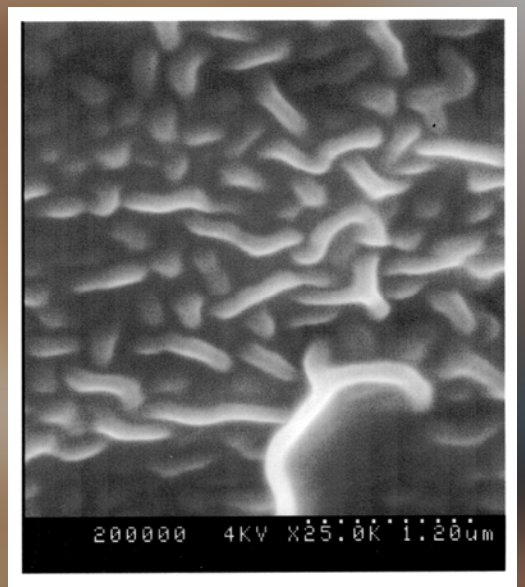






Zein-Nanofabricated Biomaterials for Tissue Scaffolding and Others





An SEM image of the zein-oleic acid film surface. It appears to show an entanglement of fibers or rods.

Padua, U. Illinois,
USDA/CSREES
2005-02970

Nanocomposite Polymer Films Improved Packaging Materials

- Improvements in oxygen and water vapor transmission barrier properties
- Improvements in mechanical properties
  - Young's modulus and tensile strength
- Improvements in thermal stability (100°C)
- TEM and X-ray showed high degree of intercalation/exfoliation in 7.5% clay
- LDPE/Clay (7.5%) Nanocomposites showed better modulus and oxygen barrier than existing meal bag
- Gregory Sotzing, U. Conn.: Using conjugated/conductive polymer nanosensor to detect amines - food spoilage and diseases (breath)

Consequences for Investment in Nanoscale Science and Technology

- Exciting potentials has been demonstrated
  - Fertile ground for novel ideas and innovation
  - Accelerate R&D to benefit people and national

    Economy – collaborative efforts of industry, government and academia to move cutting edge research to realization of its impact
  - International collaborations and multidisciplinary approaches accelerated the pace of R&D
  - Strengthen education, outreach, safety, and societal dimensions.

Closing thoughts

- Nanoscale Science and Nanotechnology for food application is still in its infancy
  - Exciting potentials has been demonstrated
  - Fertile ground for novel ideas and innovation
  - Accelerate R&D to benefit people and national economy – collaborative efforts of industry, government and academia to move cutting edge research to realization of its impact
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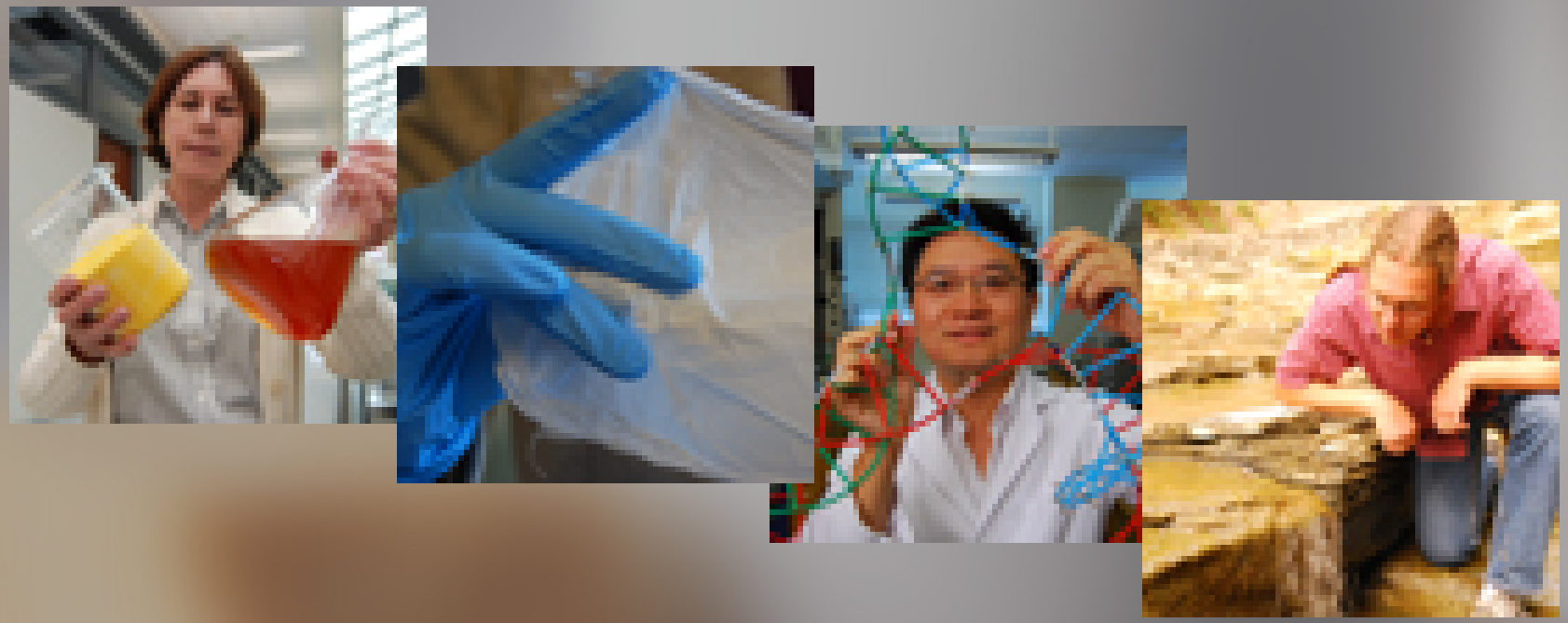
The Science of Small



- http://www.csrees.usda.gov/newsroom/partners/21/nanotechnology.html
- http://nano.gov/

Thank You!

http://www.csrees.usda.gov