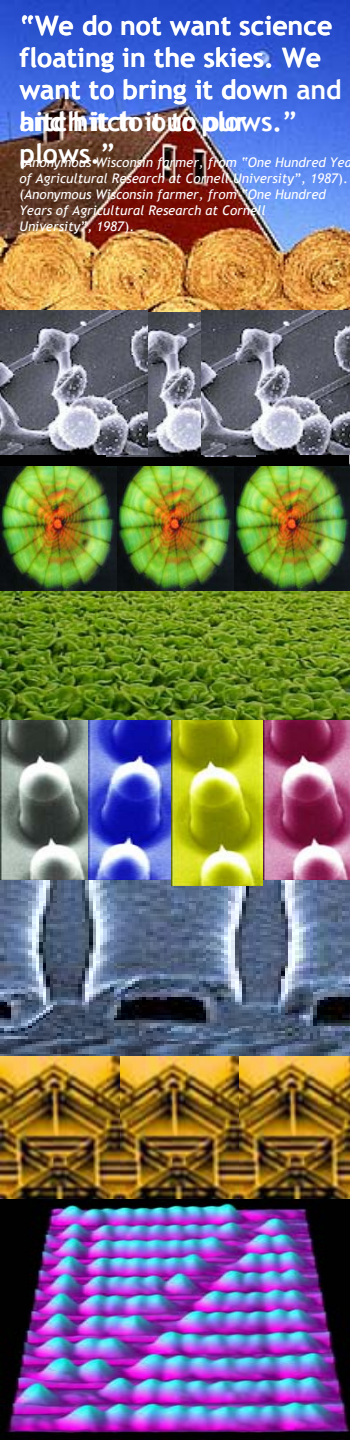

NANOSCALE SCIENCE AND ENGINEERING FOR AGRICULTURE AND FOOD SYSTEMS

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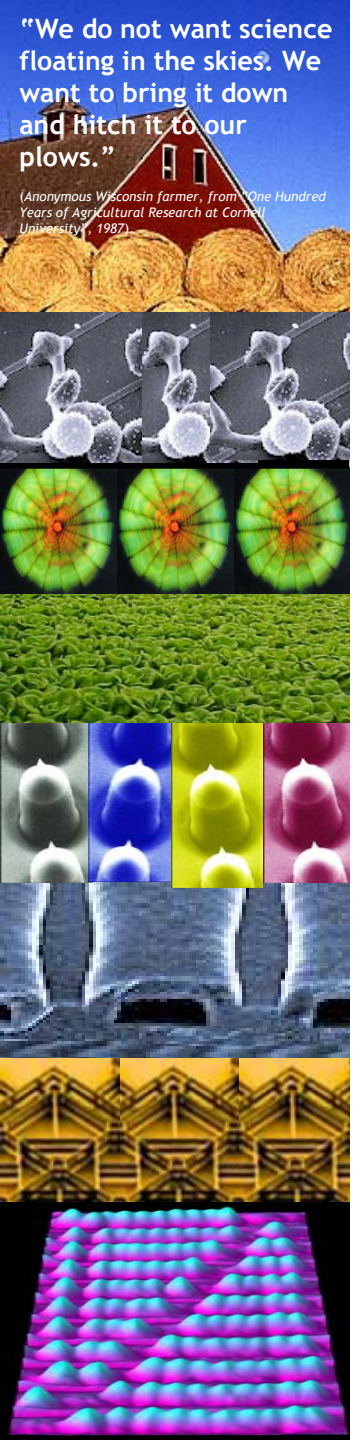


A National Planning Workshop:

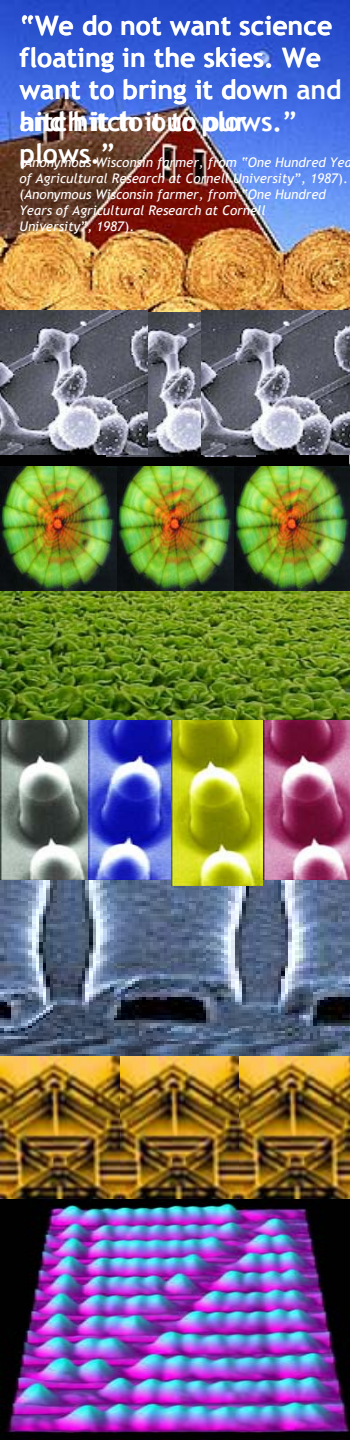
NANOSCALE SCIENCE AND ENGINEERING FOR AGRICULTURE AND FOOD SYSTEMS

November 18 – 19, 2002
Washington, D.C.

Hongda Chen, USDA

Norman R. Scott, Cornell University

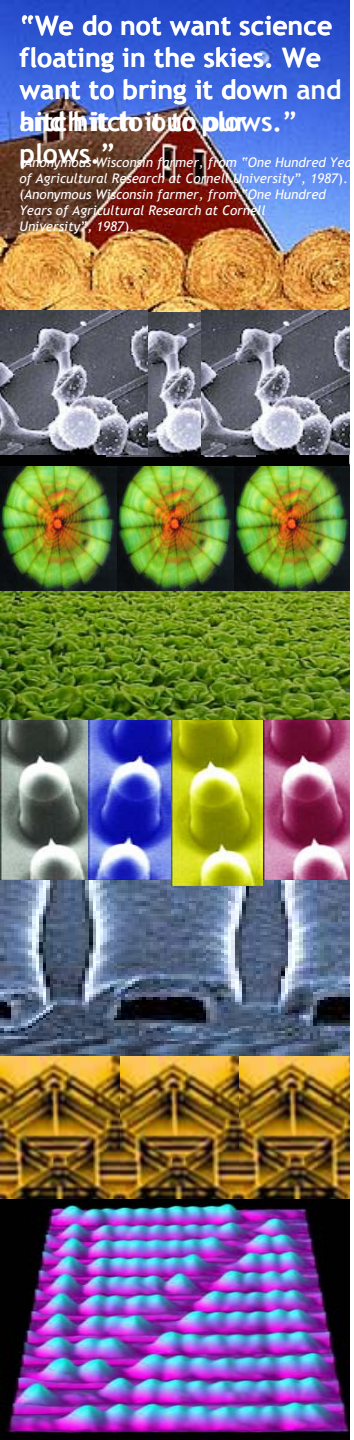
www.nseafs.cornell.edu



A NEW SCIENTIFIC FRONTIER

Broad spectrum of opportunities

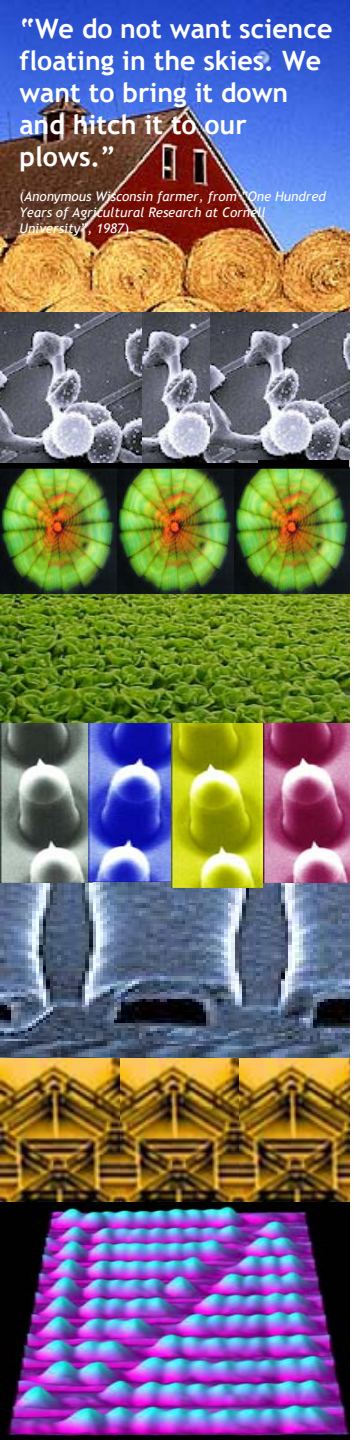
- Research community
- Industrial development



Significant focus for federal research investment

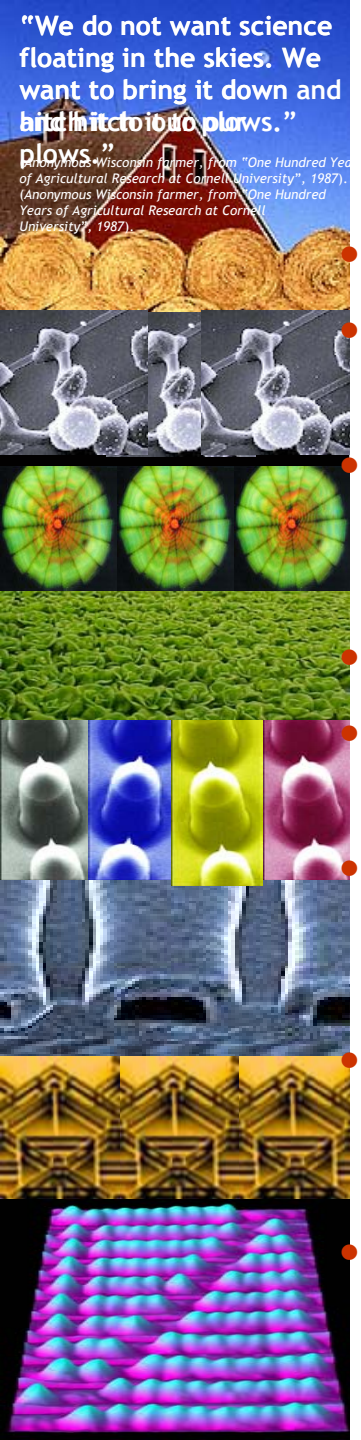
National Nanotechnology Initiative (NNI)

- Formed in 2000
- Involving 10 federal departments and agencies
- Emphasizes long-term, fundamental research
- Focused on discovering novel phenomena, processes, and tools
- Supports new interdisciplinary centers and networks of excellence, shared user facilities
- FY 2003 Congressional appropriations: $ 774M
- FY 2004 President's budget request $ 847M
- **USDA increase from $1M to $10M (2004)**



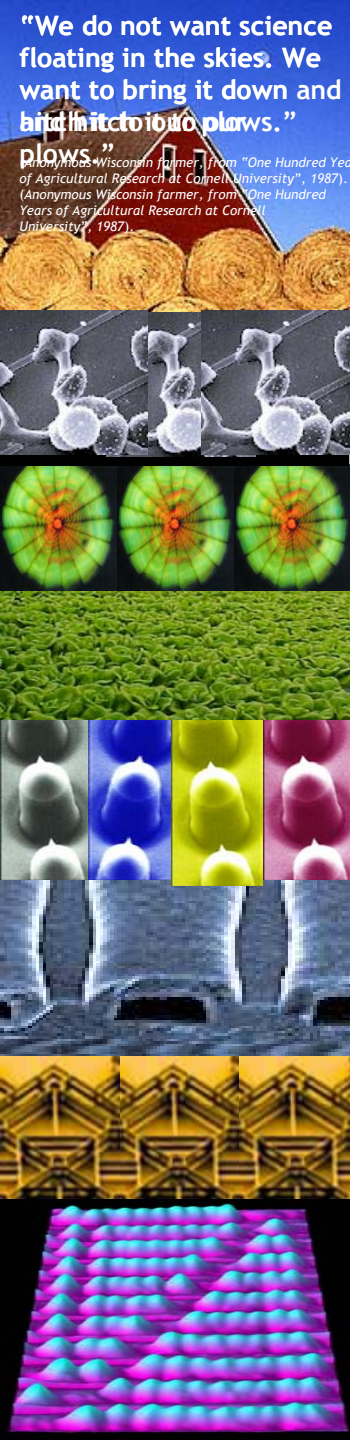
National Nanotechnology Initiative President's 2004 R & D Budget

	2003	2004	Difference from 2003 to 2004	Percent Difference from 2003 to 2004
National Science Foundation	221	247	26	11.8%
Defense	243	222	-20	-8.3%
Energy	133	197	64	48.1%
National Institutes of Health	65	70	5	7.7%
Commerce	69	62	-7	-10.1%
NASA	33	31	-2	-6.1%
Agriculture	1	10	9	900.0%
EPA	6	5	-1	-16.7%
Homeland Security	2	2	0	0.0%
Justice	1	1	0	0.0%
TOTAL	774	847	74	9.5%



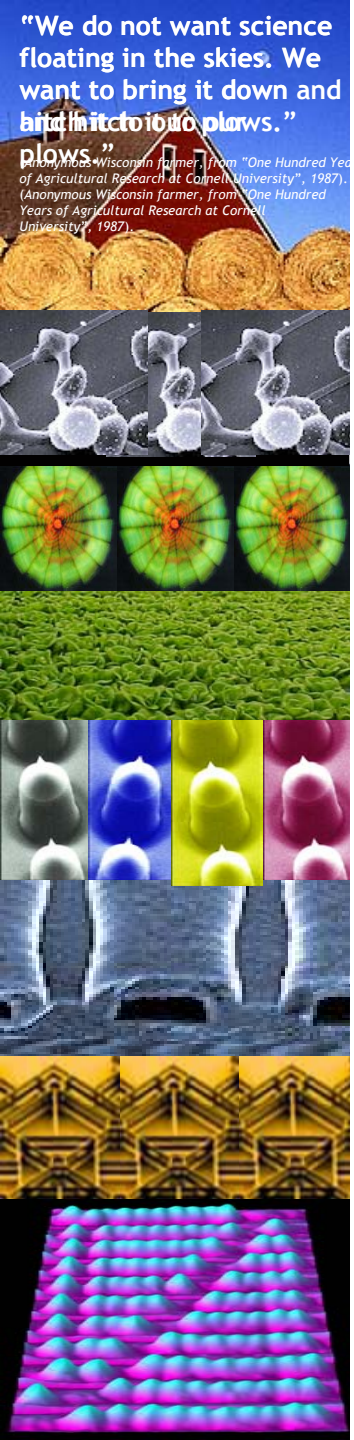
Potential to revolutionize agriculture and food systems

- **Microfluidics**, micro/nanoanalysis, lab on a chip
- **BioNEMS**, bionanoelectromechanical systems biodevices, levers, sensors, pumps, rotors, motors
- **Drug delivery/biochips**, nanocapsules, nanoporous materials, antiviral/antibacterial nanoparticles, nanotubes, nanoprosthetics
- **Nucleic acid bioengineering**, nucleic acid segregation
- **Nanobioprocessing**, cellular manipulation, self-assembly, biotissue/bioproducts manufacture
- **Biosensors** for food safety and environmental assessment, sensing, monitoring, and controlling bioprocesses in agriculture and food systems
- **Nanomaterials**, biopolymer composites, nanomembranes, nanowires, nanostructured materials from agricultural substrates
- **Bioselective surfaces**, bioseparation technologies



"We do not want science floating in the skies. We want to bring it down and hitch it to our plows."

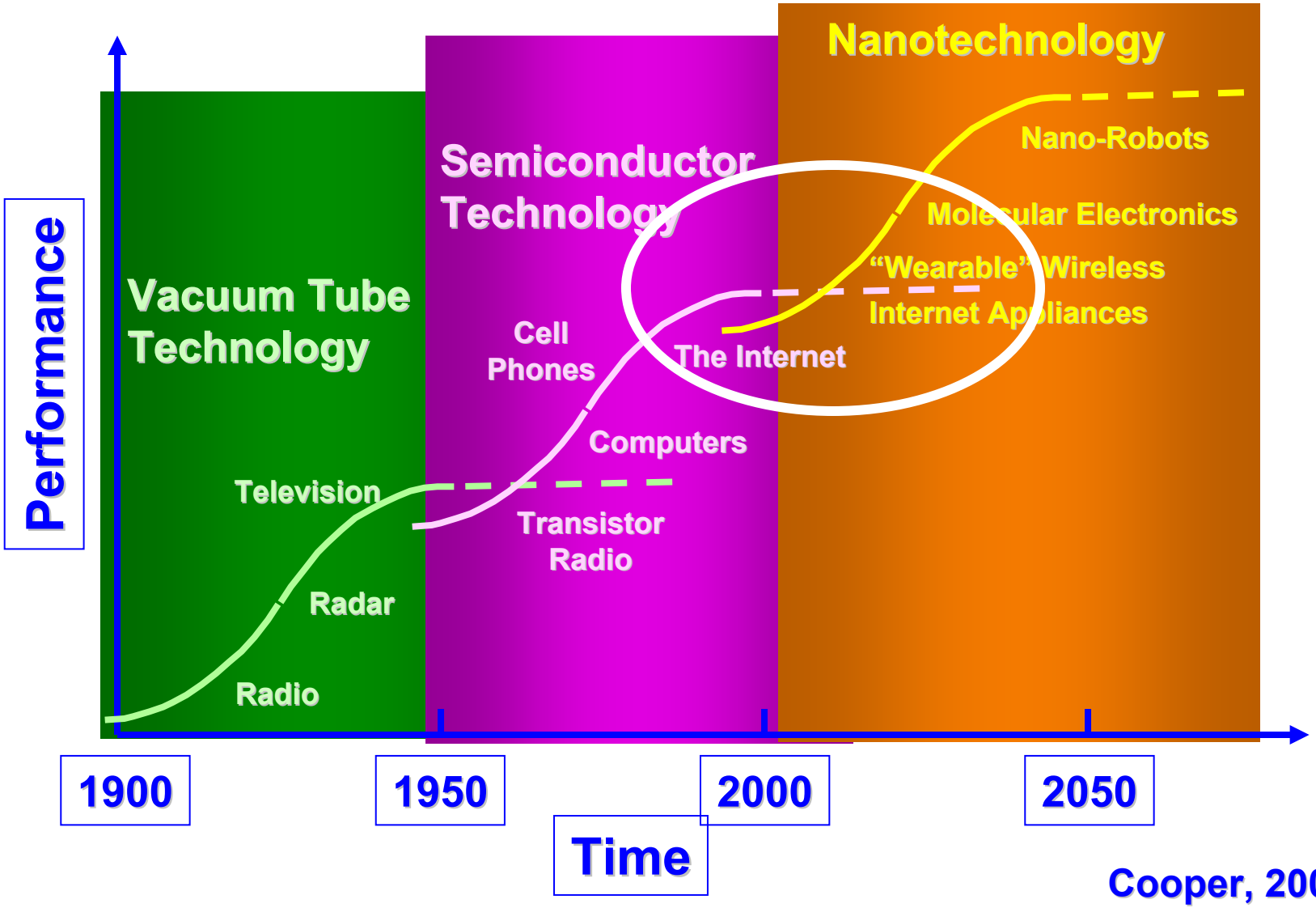
(*Anonymous Wisconsin farmer, from "One Hundred Years of Agricultural Research at Cornell University", 1987*).



Nanotechnology Science & Engineering in Agriculture and Food Systems

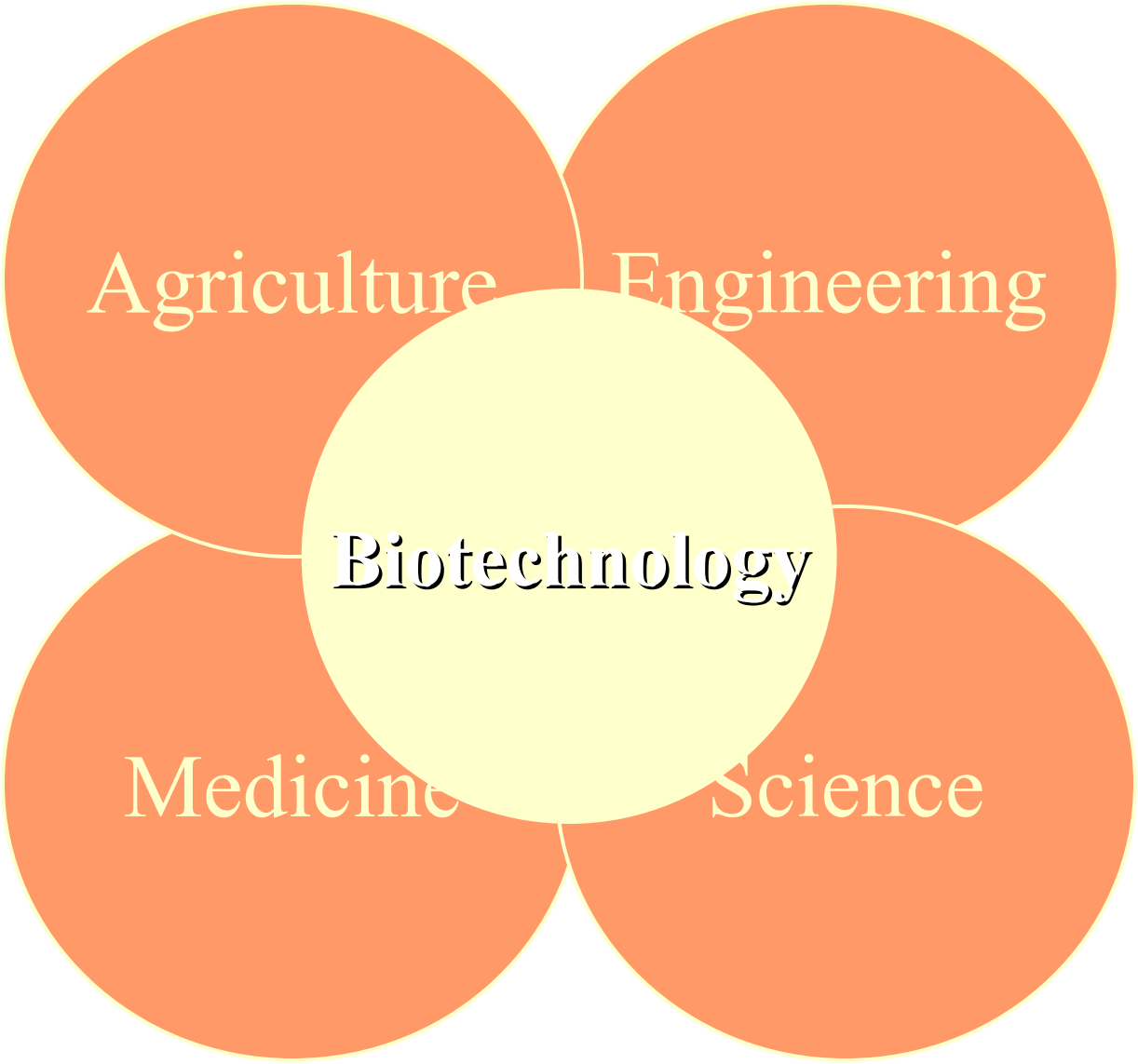
- Food supply can be monitored and protected by using nanotechnology
- Production, processing and shipment of food products can be made more secure through pathogen & contaminant detection
- Nanodevices can allow historical environmental records & location tracking
- "Smart systems" provide sensing, localization, reporting and remote control

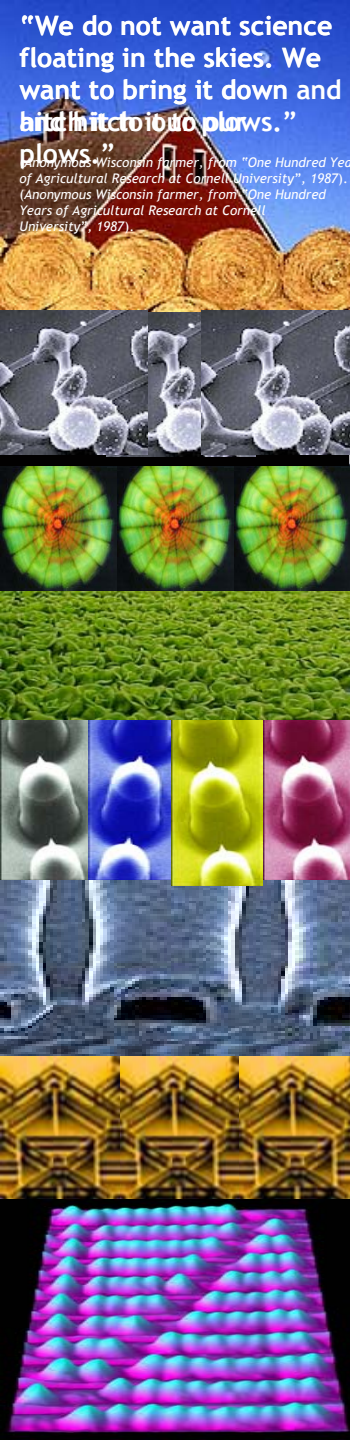
Evolution of Technologies



Cooper, 2001

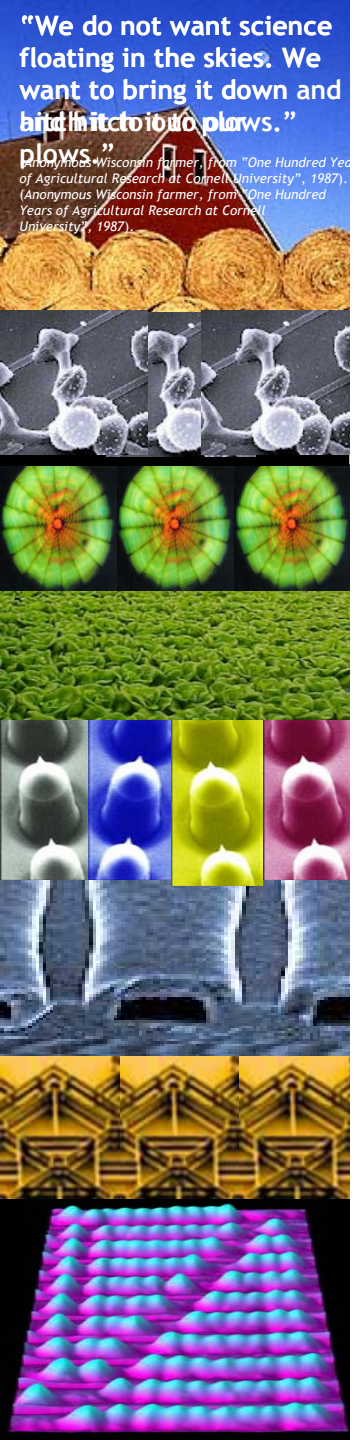
Multi-disciplinary





Planning Workshop Objective

The **planning workshop objective** was to develop a science roadmap (strategic plan) with recommendations for implementation of a new program in nanotechnologies in the USDA (as a partner in the federal NNI) for agriculture and food systems.



Agency Presentations

National Nanotechnology Initiative

Dr. Mihail C. Roco, Senior Advisor, NSF and Chairman, National Science and Technology Council's Subcommittee on Nanoscale Science, Engineering and Technology (NSET)

Defense University Research on Nanotechnology

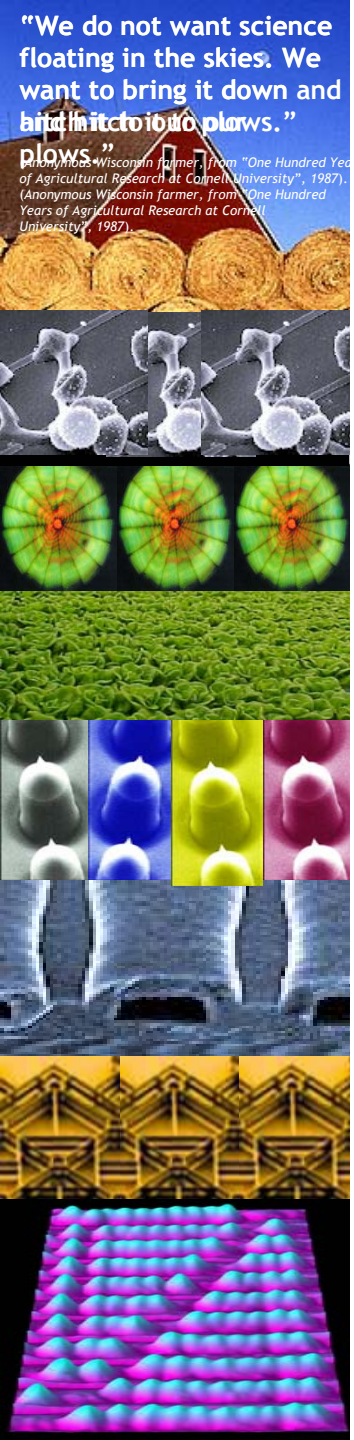
Dr.Cliff Lau, Office of Basic Research, Deputy Under Secretary of Defense, Department of Defense

Nanoscale Science, Engineering, and Technology in the DOE

Dr. Walter J. Stevens, Office of Basic Energy Science, Department of Energy

Nanoscience and Nanotechnology Programs at NIH

Dr. Eleni Kousvelari, Chief, Cellular & Molecular Biology, Physiology & Biotechnology Branch, Division of Basic and Translational Sciences, National Institute of Dental and Craniofacial Research, NIH



Agency Presentations

The Convergence of Bio and Nano Technologies: A NASA Perspective

Dr. Minoo N. Dastoor, Senior Advisor to Associate Administrator, Office of Aerospace Technology, NASA

Measurements and Standards for Nanotechnology

Dr. Michael P. Casassa, Director, Program Office, National Institute of Standards and Technology, Department of Commerce

Nanotech at EPA: Applications and Implications

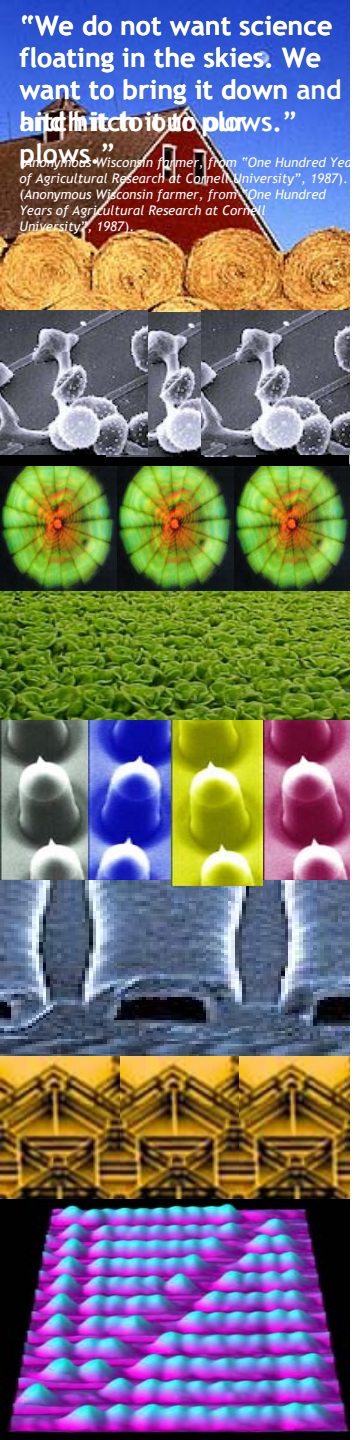
Dr. Barbara Karn, National Center for Environmental Research, ORD, EPA

Regulatory Considerations for Nanotechnology in Public Health

Dr. Norris Alderson, Senior Associate Commissioner for Science, Office of Science and Communication, FDA

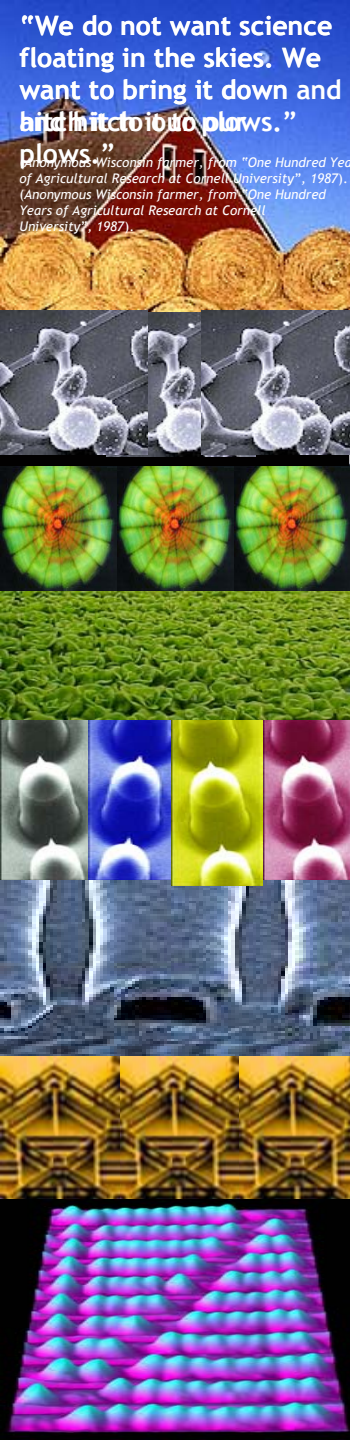
The NNI Grand Challenges - Selection, Investment Strategy and Metrics

Dr. James S. Murday, Director, National Nanotechnology Coordinating Office (NNCO)



AGRICULTURAL NANOTECHNOLOGY THEMES

- **Microfluidics** (Matthew Wheeler)
- **BioNEMS** (Michael Ladisch)
- **Drug Delivery/Biochips** (Mauro Ferrari)
- **Nucleic Acid Bioengineering** (Dan Luo)
- **Nanobioprocessing** (Larry Walker)
- **Biosensors** (Antje Baeumner)
- **Nanomaterials** (Alexandra Navrotsky)
- **Bioselective Surfaces** (Harvey Hoch)



Opportunities for Nanotechnology in Agriculture and Food Systems Research

1. Food and water supply monitoring:

-presence of residues, trace chemicals, antibiotics, pathogens, toxins;

- integrated, rapid DNA sequencing to identify genetic variation and GMO's;

-integrity of food during transportation and storage

2. Animals health monitoring:

-developmental biology;

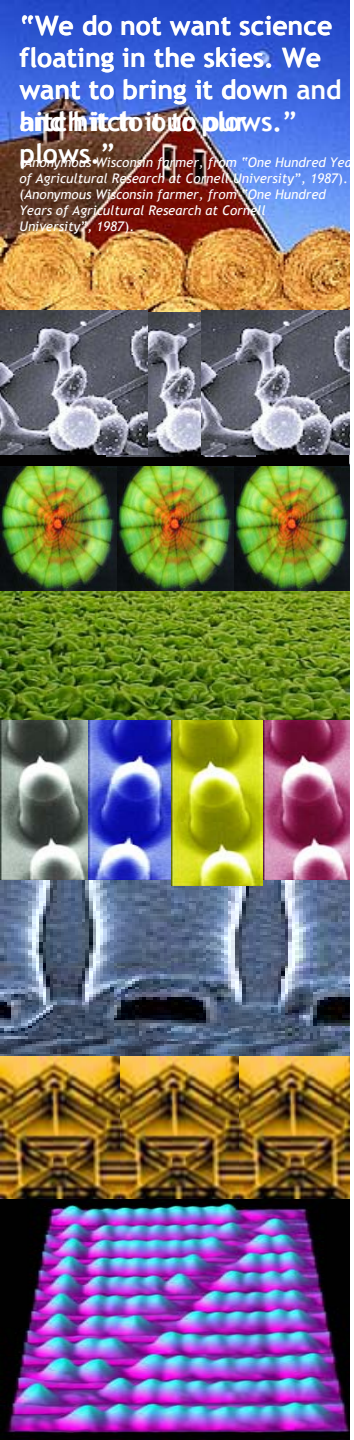
-presence of residues, antibiotics, pathogens, toxins;

-biosensors

3. Environment monitoring:

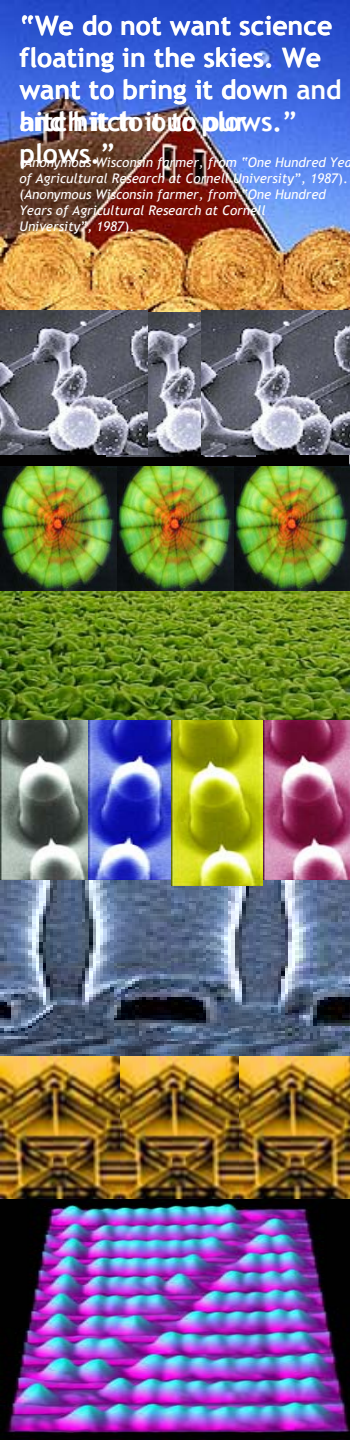
-land, water and air pollution;

-remote/distributed sensing



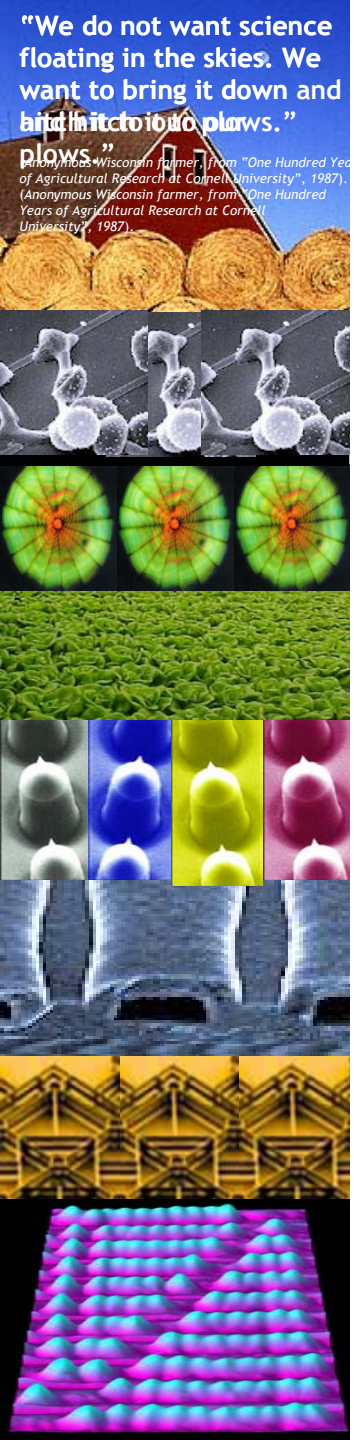
Areas of Focus

- Pathogen & contaminant detection
- Nanodevices for identity preservation & tracking
- Nanodevices for smart treatment delivery systems
- Smart systems integration: sensing, localization, reporting & control
- Nanodevices for molecular and cellular biology
- Nanoscale materials science & engineering, environmental issues, agricultural waste & nanoparticles in the enviroment



Other Chapters

- A Nanotechnology primer
- Relationship of nanotechnology to science and engineering in agriculture & food systems
- Educating the public and future workforce
- Budgetary considerations



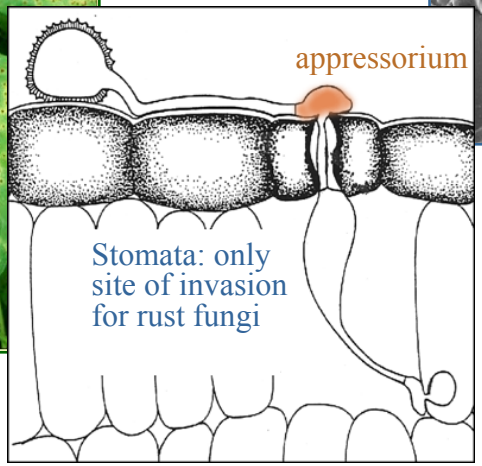
Proposed Budget

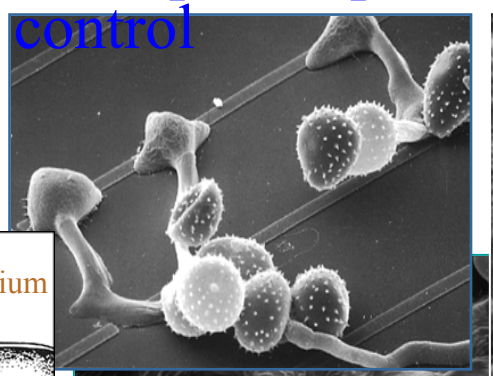
	Million $
Fundamental Research (Principal Investigator Initiated) 6 areas @ 3 projects per area x $250K/project	**4.5**
Theme Area Challenge (Multidisciplinary) 6 areas @ 2 projects per area x $350K/project	**4.2**
Centers of Excellence 4 regional Centers @ $5 Million/year Public Outreach/Educ. 1% of budget=$50K/y/Center	**20.0**
Research Infrastructure Specialized equipment @$5 Million/year	**5.0**
Education Graduate Fellowships ($32K/y * 50/y) = 1.6 Postdoctoral Training ($60K/y * 15/y) = 0.9 Professional Development ($10K * 10/y) = 0.1 Public Outreach & Education (see Centers of Excellence)	**2.6**

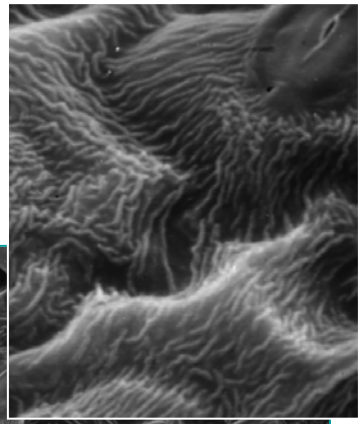
TOTAL $36.3 M/yr.

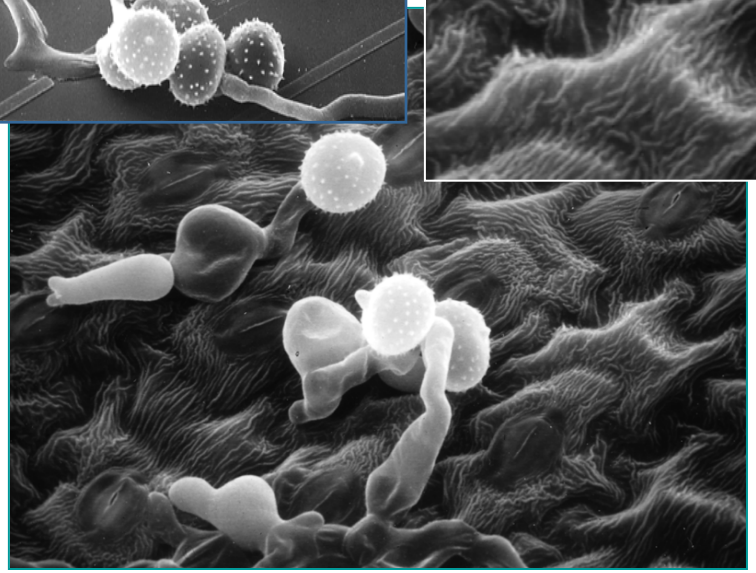
Bioselective Surfaces

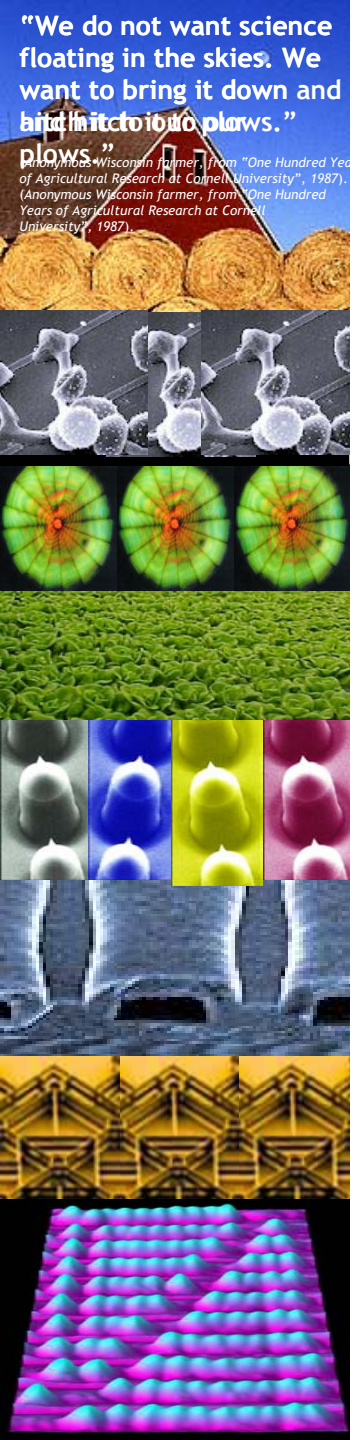
- Biology of pathogen/pest/host interactions--e.g., basic studies lead to concepts for possible approach to plant rust disease control











Microfluidics Applications

- MIT technology review (2001) - "one of technologies that will change the world"
- Markets
  - Point of care diagnostics
  - Discovery/screening (not just
  - DNA manipulation and proce
  - Analytical instruments
  - Drug delivery
  - Sensing
  - **Assisted Reproduction**
  - Bioproduction
  - Chemical engineering
  - Chemistry

Surface Logix

caliper

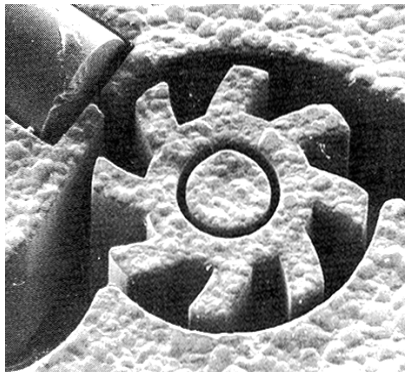
Vitae

fluidigm™
Soft microfluidics.
Extraordinary science.™

MICRONICS

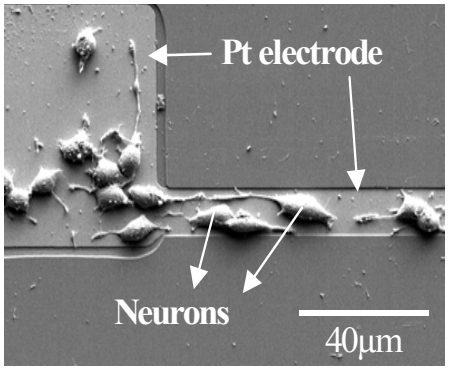
Branches of Nanotechnology

Micro-Mechanical Systems (MEMS)



Electronic Nanotechnology

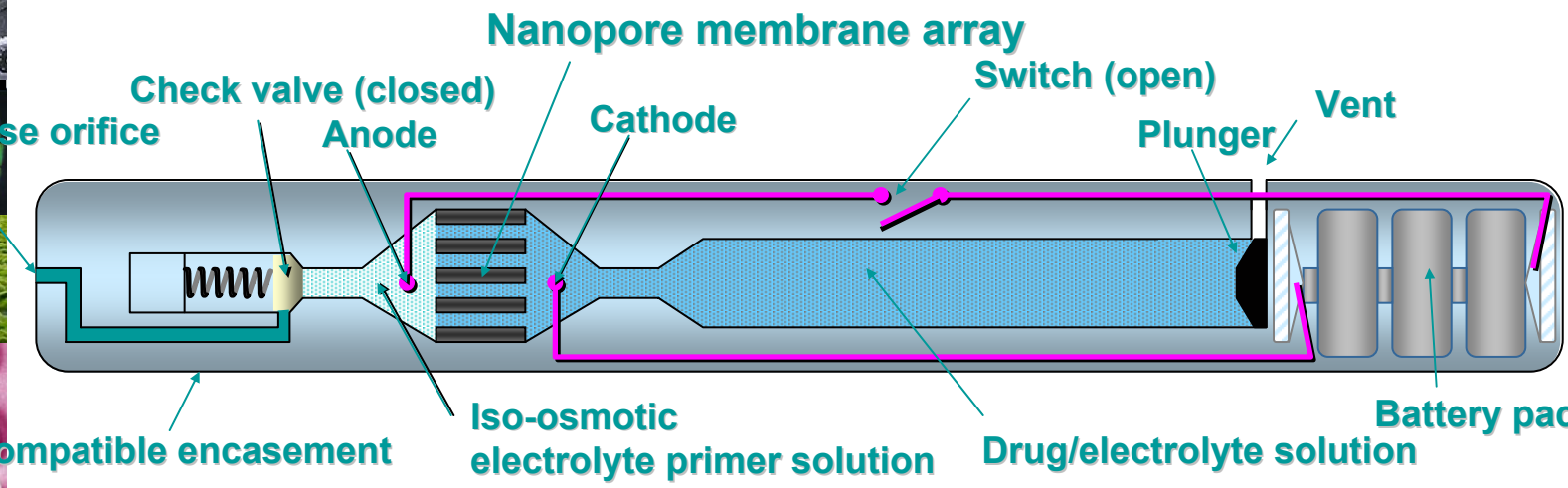
Microfluidics & Bio-Chips

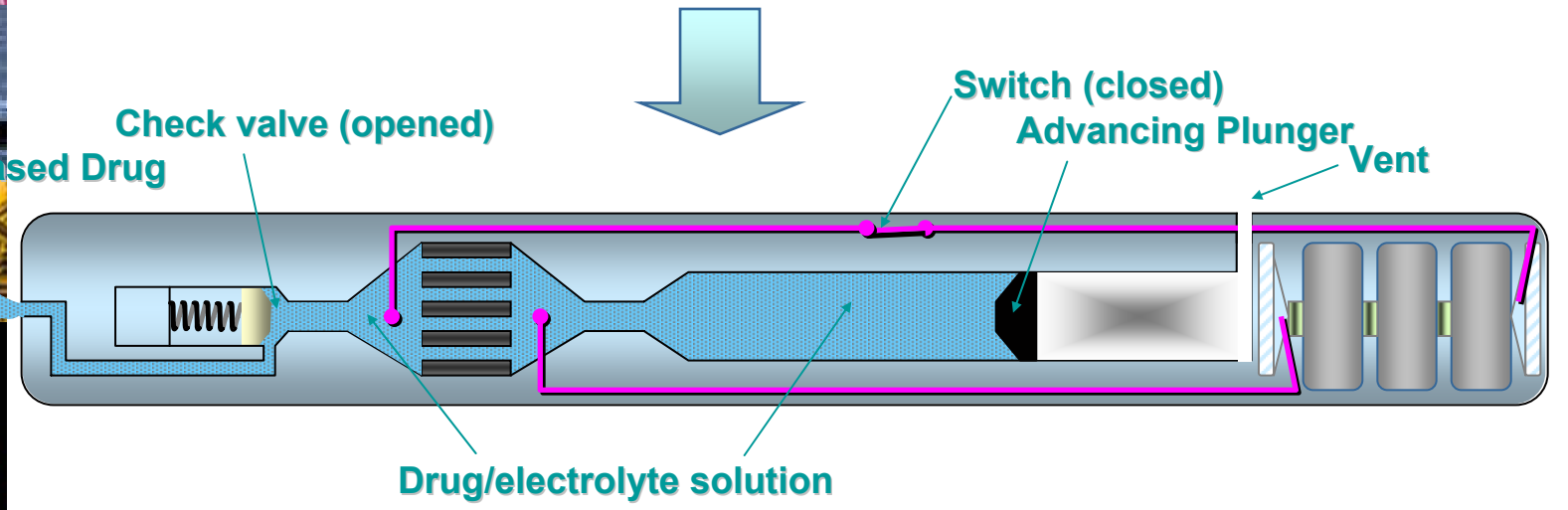


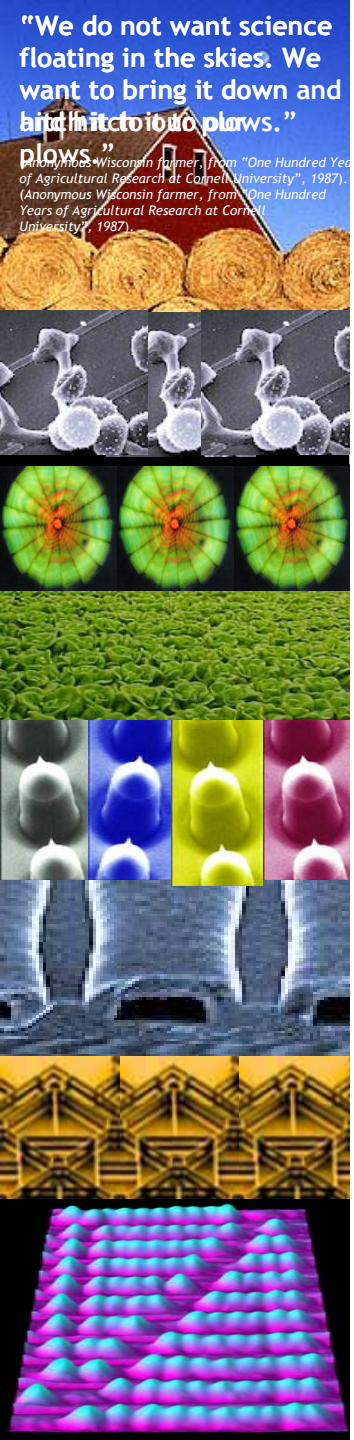
"We do not want science floating in the skies. We want to bring it down and attach it to the plows."

(Anonymous Wisconsin farmer, from "One Hundred Years of Agricultural Research at Cornell University", 1987).

NanoPUMP Implantable Drug Delivery Device





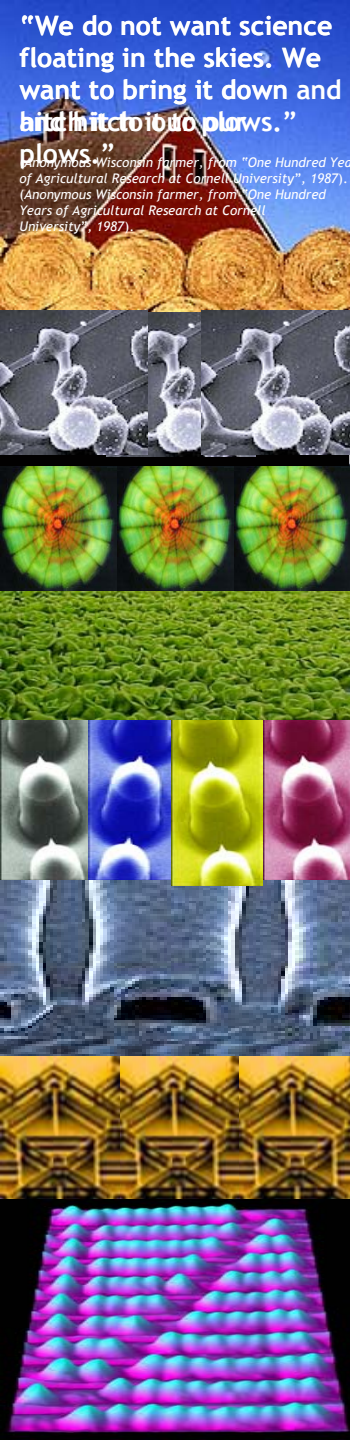


Oral Peptide Delivery:
Transport through the GI Tract

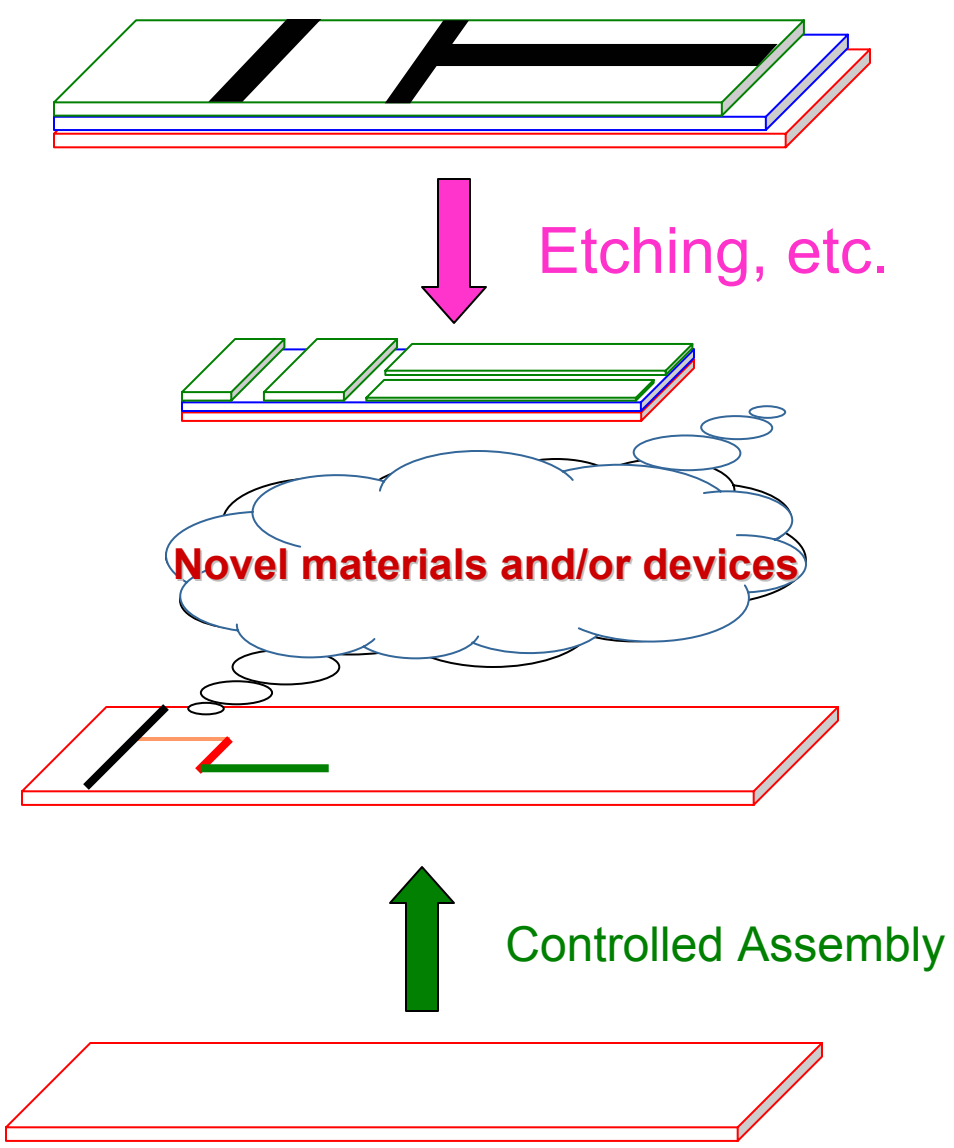
Capsule dissolves in intestines releasing drug-loaded particles

Enteric coating protects drug-loaded particles in acidic stomach

Particles adhere to intestinal wall and transport contents into the blood stream



Two Directions in Nanotechnology

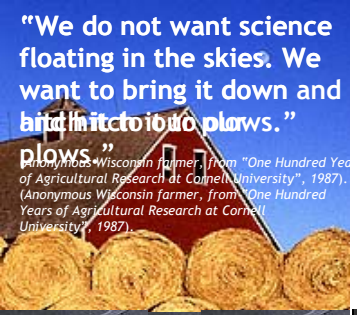


TOP – DOWN

Control the "Knife"

BOTTOM – UP

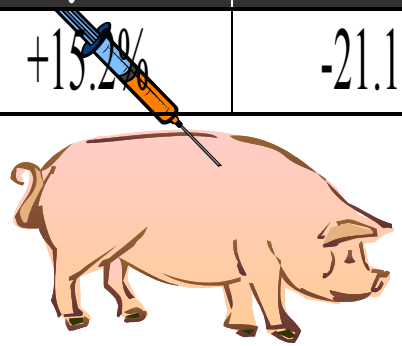
Control the "building blocks"

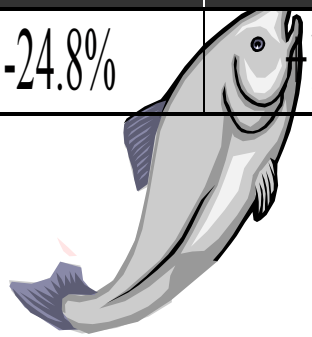


DNA Delivery to Agriculturally Important Animals

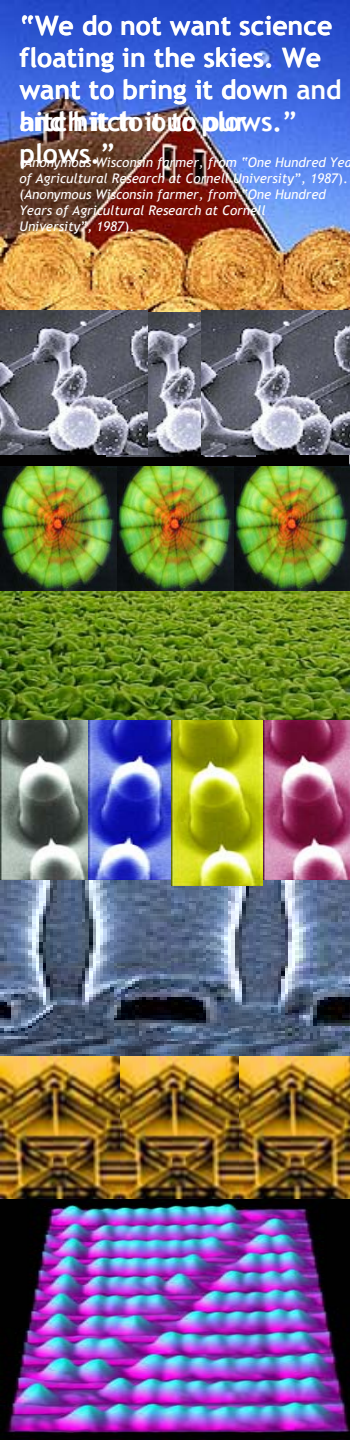
Percent changes between pST-treated pigs and controls

Daily Gain	Feed/Gain	Backfat	Loin Eye	Muscle
+15.2%	-21.1%	-24.8%	+18.5%	+9.9%



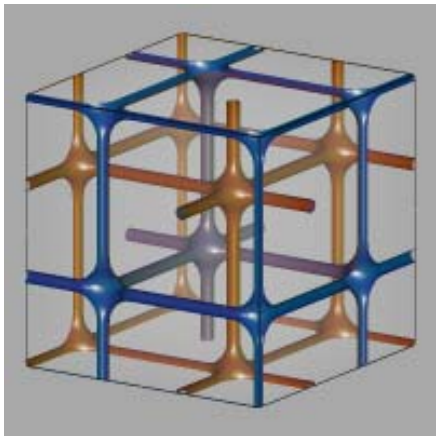


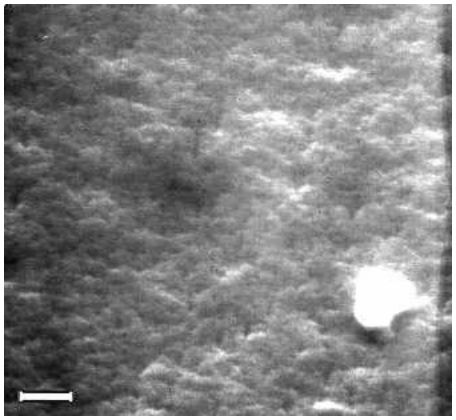
- DNA vs. Protein Delivery (cost; safety; simplicity; etc.)
- Bolus vs. Controlled Release Delivery
- DNA Encapsulation in Molded-Nanowells
- Multi-gene Delivery in Controlled Release Polymers
- DNA-polymer Hybrid Materials for Delivery

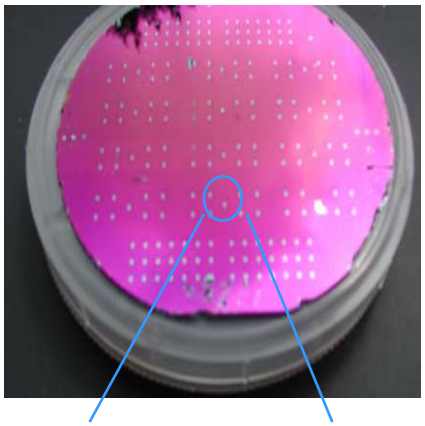


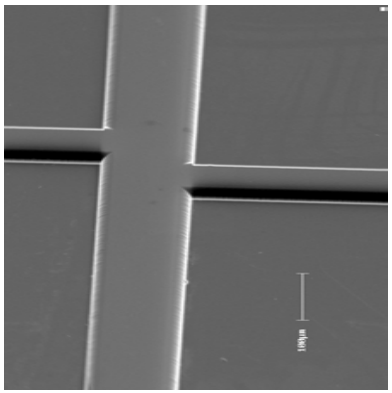
Biomolecular Devices and Analysis

Major research and development activities in the life sciences has generated the need for materials, methods, and devices for sorting, separating, and analyzing proteins, DNA and other biomolecules.

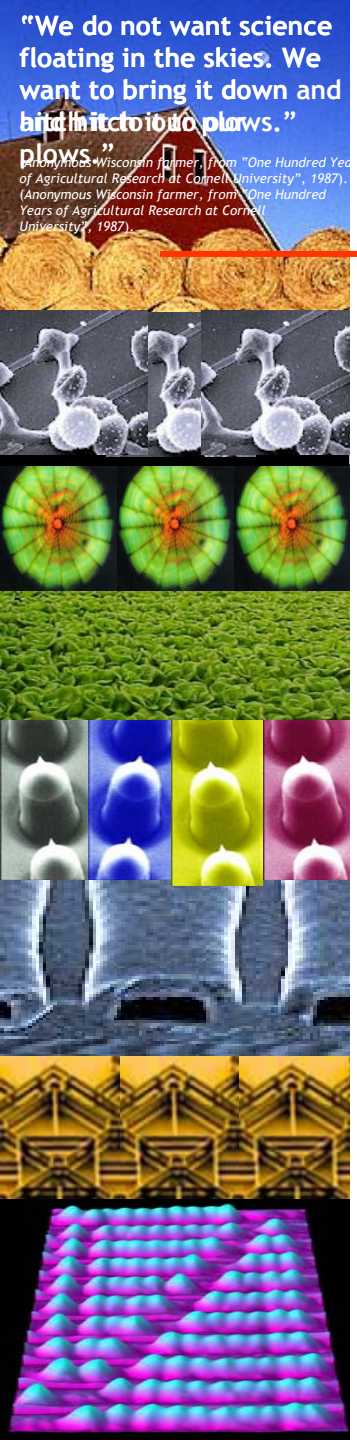








NBTC Nanobiotechnology Center



Nanobiosensors and Milking

Approach:

Location of an array of nanobiosensors directly at the inlet of the milking machine to monitor for the **presence of bacteria in the milk of each cow and reproductive state (estrus)**

Outcome and Impact:

Direct quality control of milk

Avoiding the spoilage of large quantities of milk

Requirements:

Rapid detection (seconds)

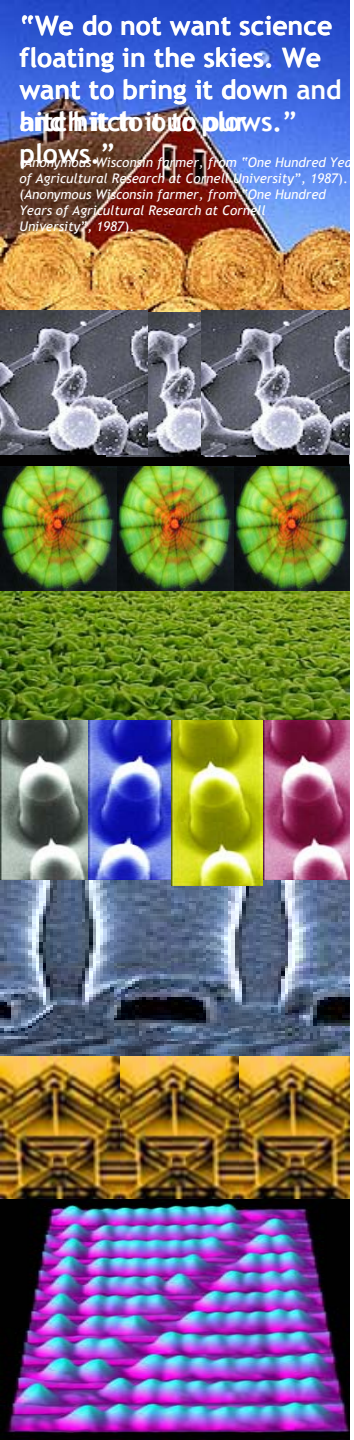
No sample pretreatment (since in-line detection)

Continuous monitoring

Remote sensing capability

Obstacles:

Not possible with current technology



Materials, Environmental, Agricultural Waste, Nanoparticles

Develop novel nano-materials

- Nanocomposite polymer films for enhanced functional properties and biodegradation
- Naturally occurred nanoparticles
- Nanocatalysts design for waste bioprocessing

Alexandra Navrotsky

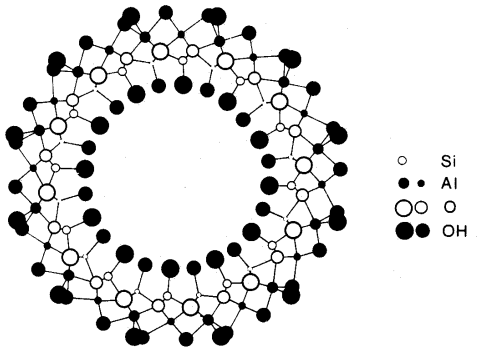
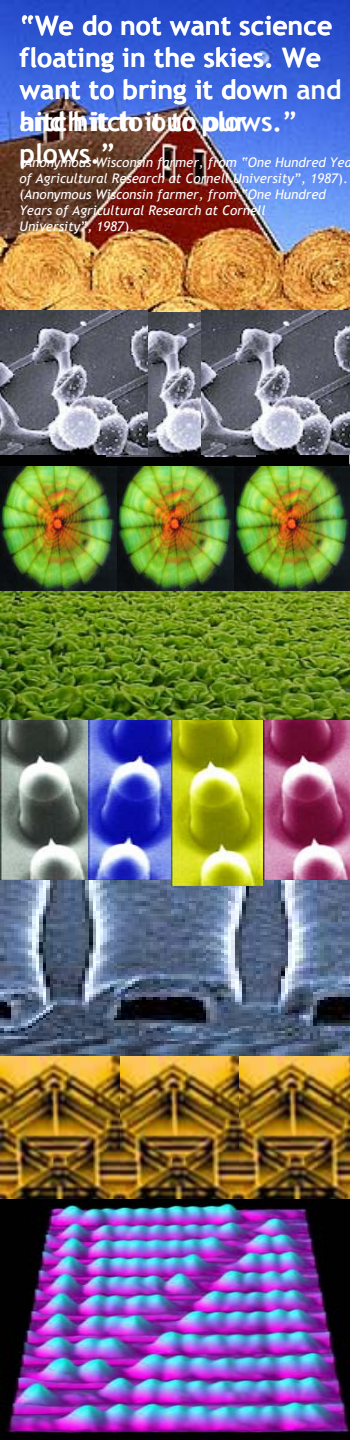


Fig. 1. A cross-section of the structure of an imogolite tube

JoAnn Ratto

Larry Walker



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Broad spectrum of opportunities

- Research community
- Industrial development