USDA

United States Department of Agriculture

National Institute of Food and Agriculture

USDA NIFA

NATIONAL INSTITUTE OF FOOD AND AGRICULTURE

Nanotechnology at the USDA

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USDA National Institute of Food and Agriculture (NIFA)

Quadrennial Review of the National Nanotechnology Initiative
NRC, Washington, DC, USA
March 14-15, 2019

Disclaimer: The views expressed in this presentation are those of the presenter and not necessarily those of the US Government or the presenter's agency.

Outline

- *Grand Societal Challenges Facing Agriculture and Food Systems*
- *Nanotechnology in the U.S. Department of Agriculture*
- *Nanotechnology in National Institute of Food and Agriculture (NIFA)*

Interstellar, The Movie

- ***"The world doesn't need any more engineers. We didn't run out of planes and television sets… we ran out of food."***
  - *Starring: Matthew McConaughey and Anne Hathaway*

"An Existential Threat"

Perfect Storm

http://rsd.gsfc.nasa.gov/goes/pub/goes/050828.katrina.gif

http://www.usda.gov/wps/portal/usda/usdahome?navid=USDA150

Nanotechnology in the USDA

- ***National Institute of Food and Agriculture (NIFA)***
- ***Agricultural Research Service (ARS)***
- ***Forest Service (FS)***

	2017 Actual	2018 Estimated	2019 Proposed
USDA (total)	**24.2**	**23.3**	**20.7**
NIFA	15.0	15.0	15.0
ARS	3.0	3.0	2.0
FS	6.2	5.3	3.7

Source: The NNI Supplement to the President's 2019 Budget

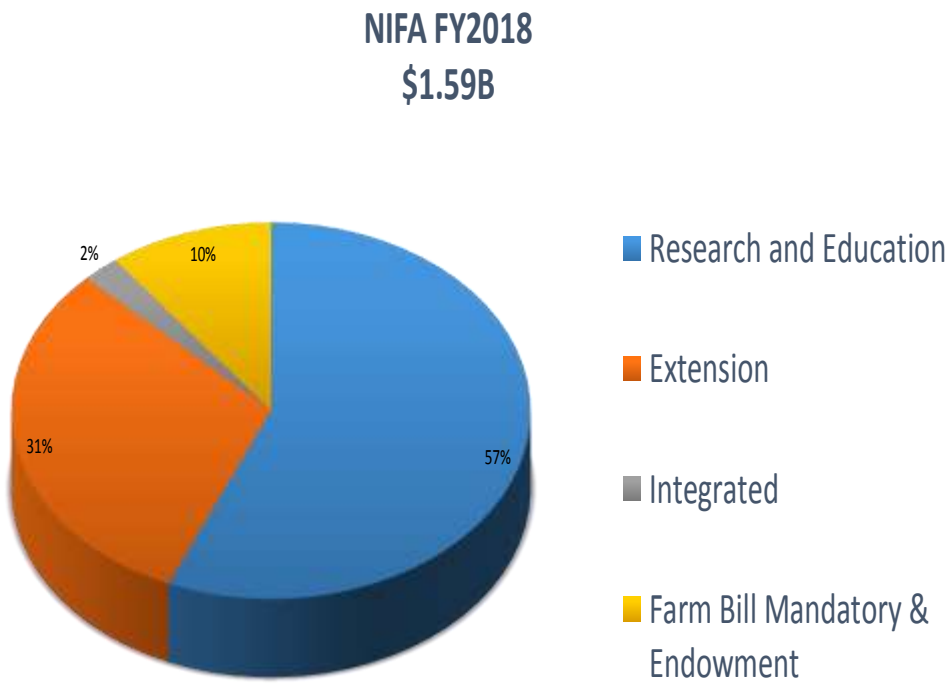
National Institute of Food and Agriculture (NIFA)

User Inspired Science Transforming Lives

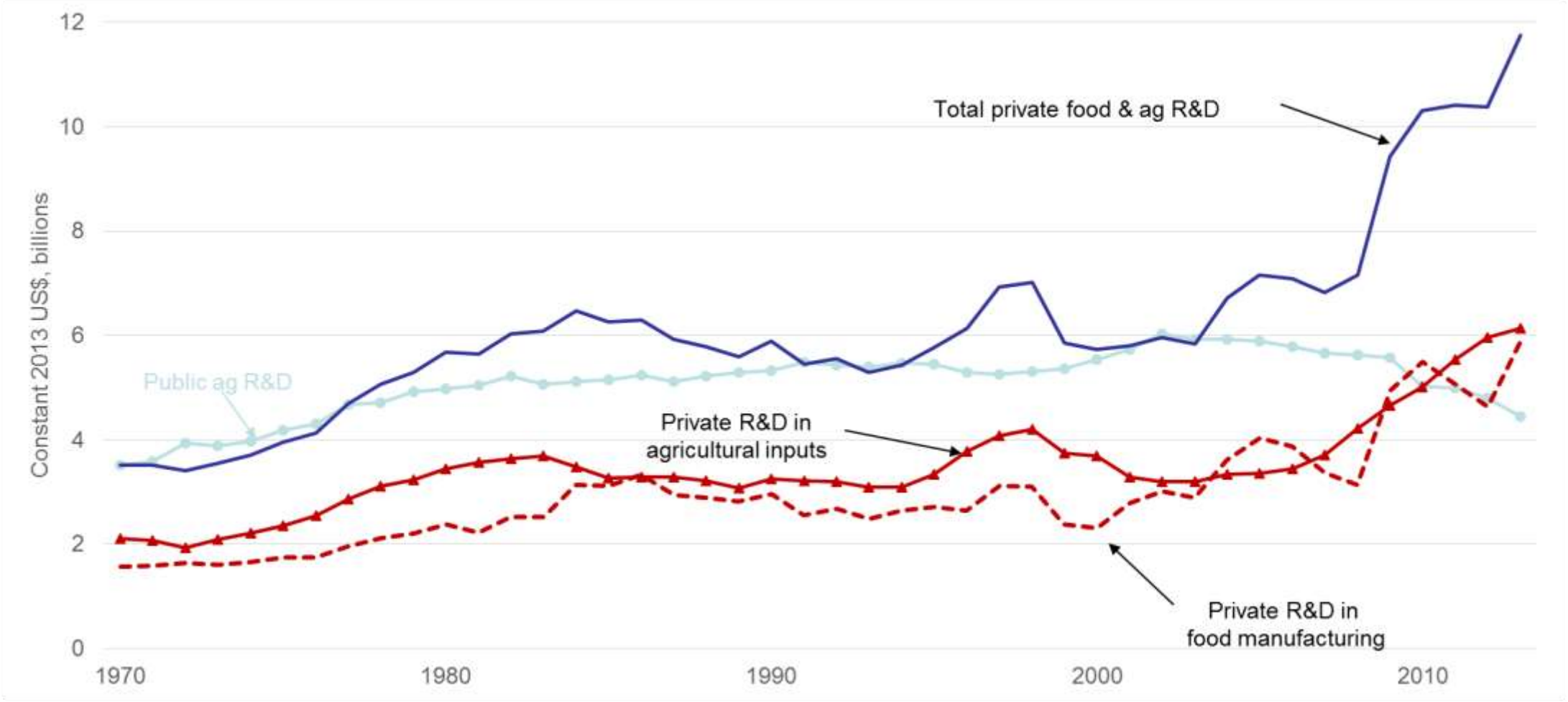
MISSION: ***Invest in and advance agricultural research, education, and extension to solve societal challenges***

VISION: ***Catalyze transformative discoveries, education, and engagement to address agricultural challenges.***

- STRATEGIC PLAN, *FY2014 - FY2018*



Public and Private Investments in Ag. R&D



Clancy, Fuglie, and Heisey, Amber Waves, ERS, Nov. 10, 2016

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

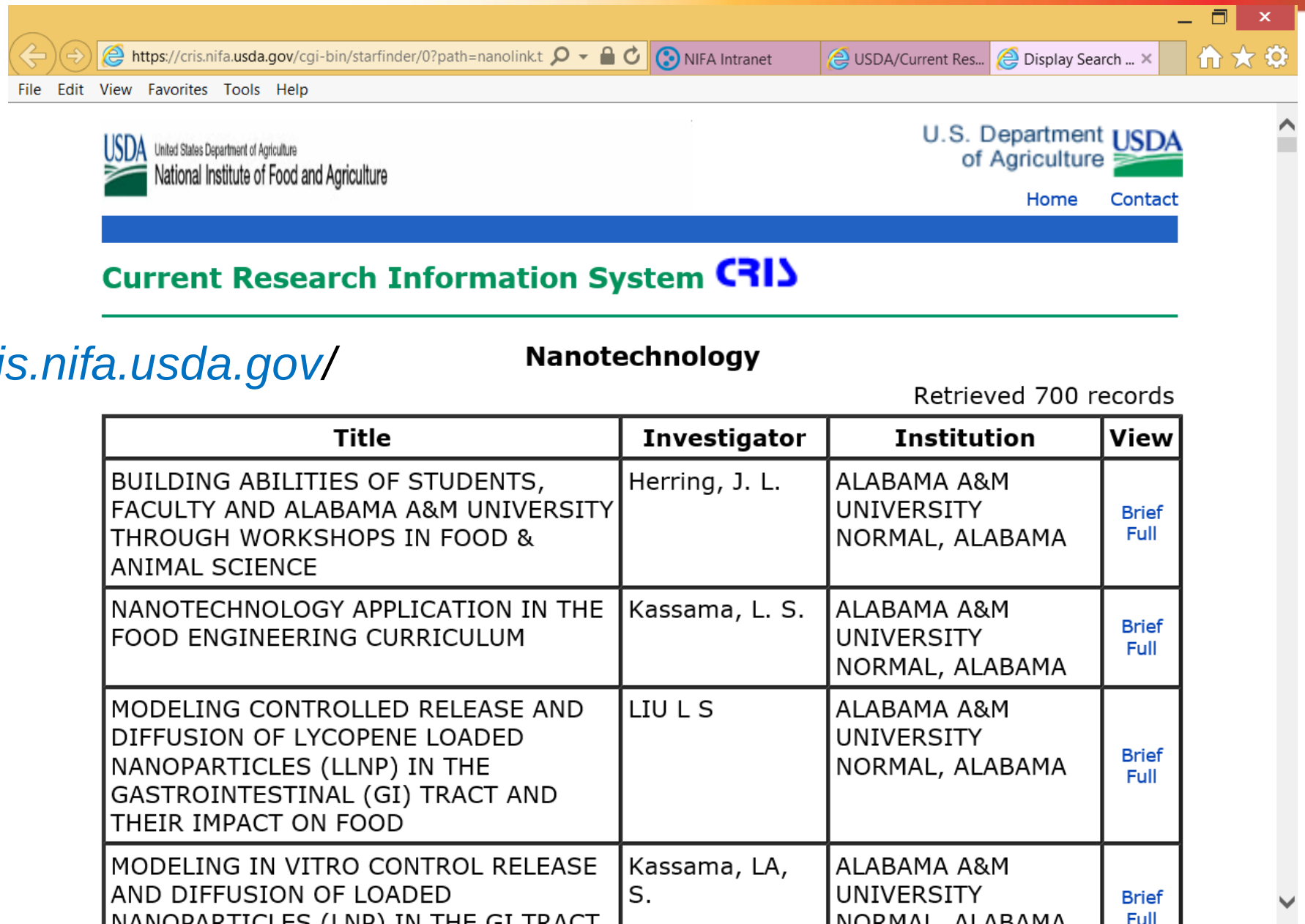
(*Anonymous Wisconsin farmer, from "One Hundred Years of Agricultural Research at Cornell University", 1987*).

CSREES-National Stakeholder Strategic Planning Workshop

November 18-19, 2002
USDA, Waterfront Center
Washington, DC

Dr. Norman R Scott
Biological & Environmental Engineering
Cornell University
&
Dr. Hongda Chen
USDA/CSREES

www.nseafs.cornell.edu



https://cris.nifa.usda.gov/

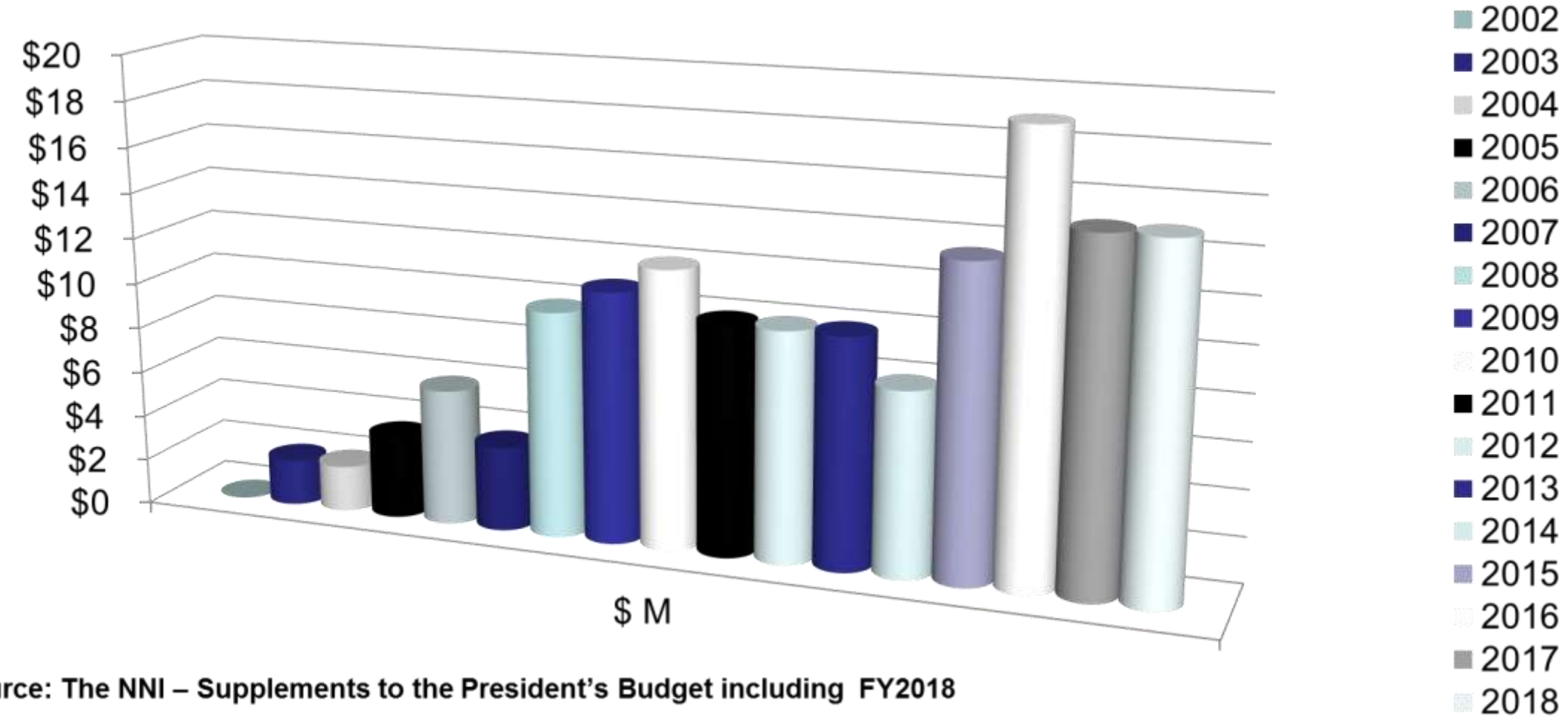
Nanotechnology

Retrieved 700 records

Title	Investigator	Institution	View
BUILDING ABILITIES OF STUDENTS, FACULTY AND ALABAMA A&M UNIVERSITY THROUGH WORKSHOPS IN FOOD & ANIMAL SCIENCE	Herring, J. L.	ALABAMA A&M UNIVERSITY NORMAL, ALABAMA	Brief Full
NANOTECHNOLOGY APPLICATION IN THE FOOD ENGINEERING CURRICULUM	Kassama, L. S.	ALABAMA A&M UNIVERSITY NORMAL, ALABAMA	Brief Full
MODELING CONTROLLED RELEASE AND DIFFUSION OF LYCOPENE LOADED NANOPARTICLES (LLNP) IN THE GASTROINTESTINAL (GI) TRACT AND THEIR IMPACT ON FOOD	LIU L S	ALABAMA A&M UNIVERSITY NORMAL, ALABAMA	Brief Full
MODELING IN VITRO CONTROL RELEASE AND DIFFUSION OF LOADED	Kassama, LA, S.	ALABAMA A&M UNIVERSITY	Brief

As of 3/14/2019

NIFA Investments in Nanotechnology R&D and Education started from zero and has grown significantly



Source: The NNI – Supplements to the President's Budget including FY2018

National Challenge Areas

- *FOOD and NUTRITION SECURITY*
- *CLIMATE VARIABILITY AND CHANGE*
- *WATER for AGRICULTURAL and FOOD SYSTEM*
- *NUTRITION and HEALTHY (CHILDHOOD OBESITY PREVENTION, AGEING)*
- *FOOD SAFETY*
- *SUSTAINABLE BIOECONOMY and BIOENERGY*

– *NIFA STRATEGIC PLAN, FY2014 - FY2018*

Grand Societal Challenges in the 21st Century: Continuation of life on the PLANET for a world more sustainable, safe, healthy and joyful

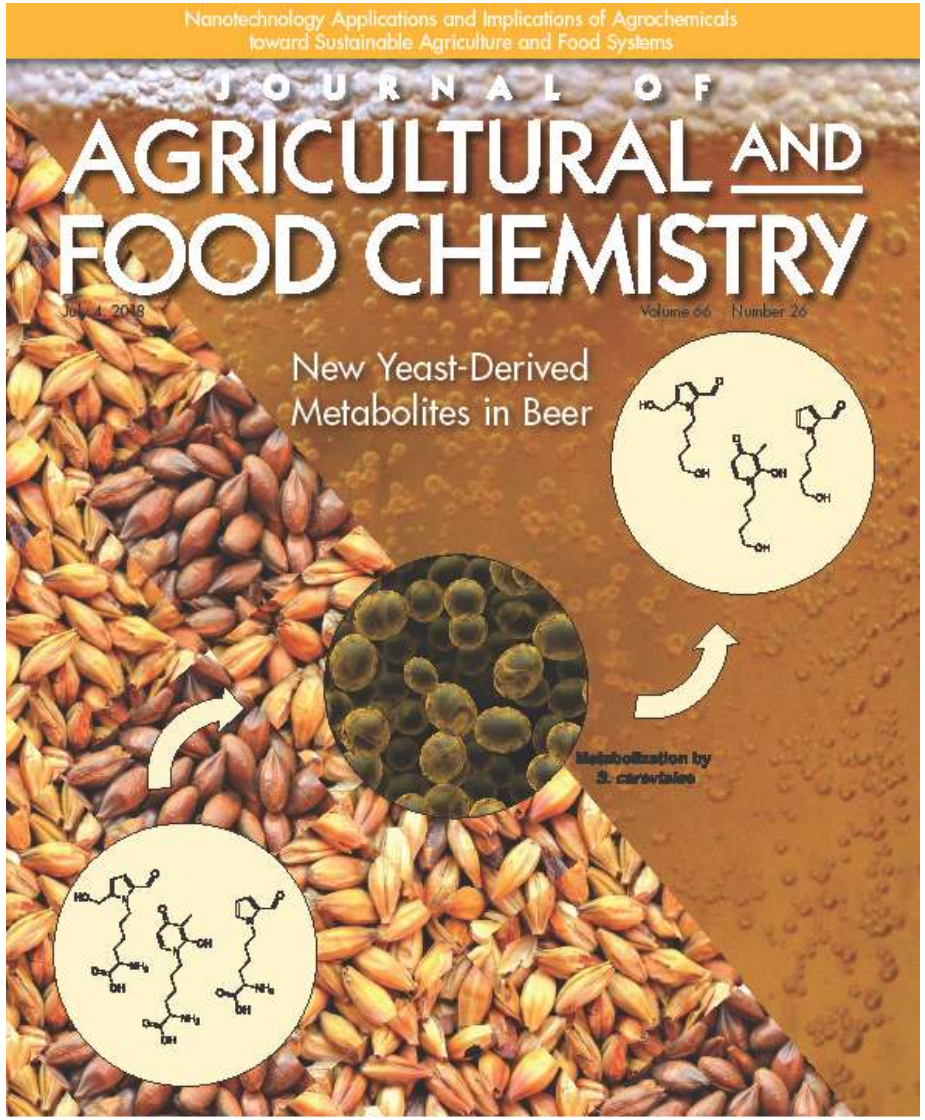
- *Sustainability* – resolving diminishing natural resources against increasing demands of the growing world population
- *Vulnerability* – food safety, biosecurity, and others
- *Human Health* – food and nutrition related developmental and degenerative illness
- *Joy of living* – food and culture, improved working condition, advanced education and learning, better environment, etc.

The National Academy of Engineering

The NNI PCAs

- PCA 1 NSIs/GC
  - Sensors
  - Water
- PCA 2 Foundational Research (including ELSI)
- PCA 3 Applications/Devices/Systems
- PCA 4 Infrastructure/Instrumentation
- PCA 5 EHS

- Nanoscale delivery of agrochemicals
- Benefits of engineered nanomaterials in crop production
- Sensors and detection for precision agriculture
- Environment, health and safety (EHS) Implications of nanoparticles
- Economic, legal and social implications (ELSI) of nanotechnology
- Communication, education and public perception



Nanotechnology Applications and Implications of Agrochemicals toward Sustainable Agriculture and Food Systems

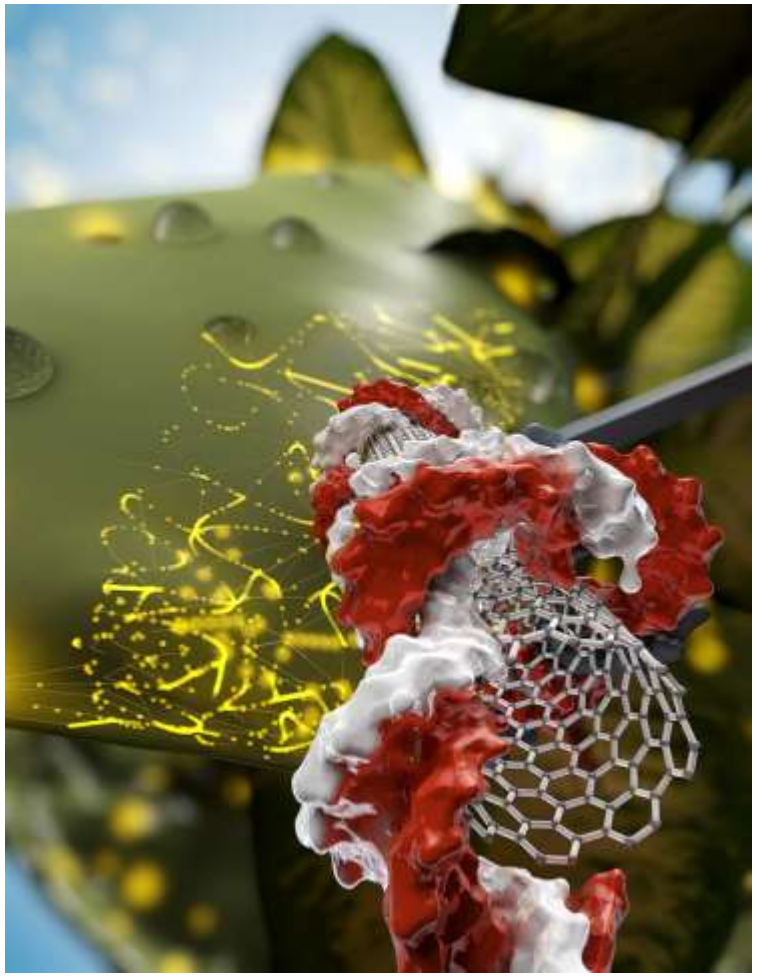
special issue, vol. 66, issue #26, 2018.

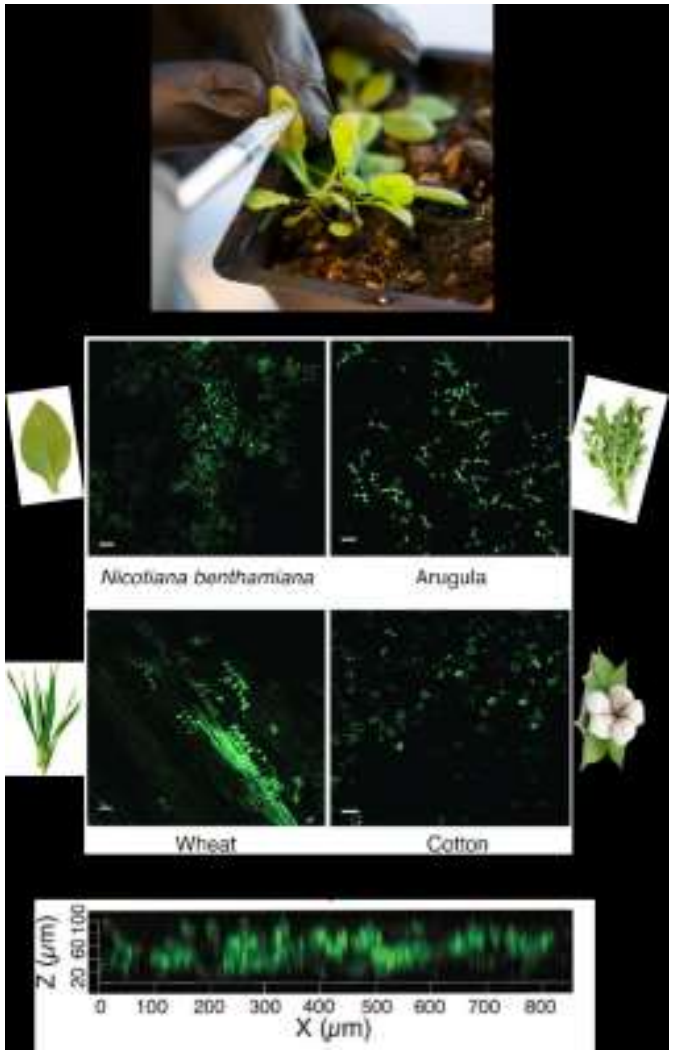
Nano-cellulose Crystals to Prevent Frost Damage in Tree Fruits

Frost-damaged cherry buds, left, and healthy cherry buds.

Healthy cherries not affected by frost damage.

High Aspect Ratio Nanomaterials Enable Biomolecule Delivery and Transgene Expression or Silencing in Mature Plants





- Landry, UC Berkeley, Nature Nanotechnology, 2/25/2019

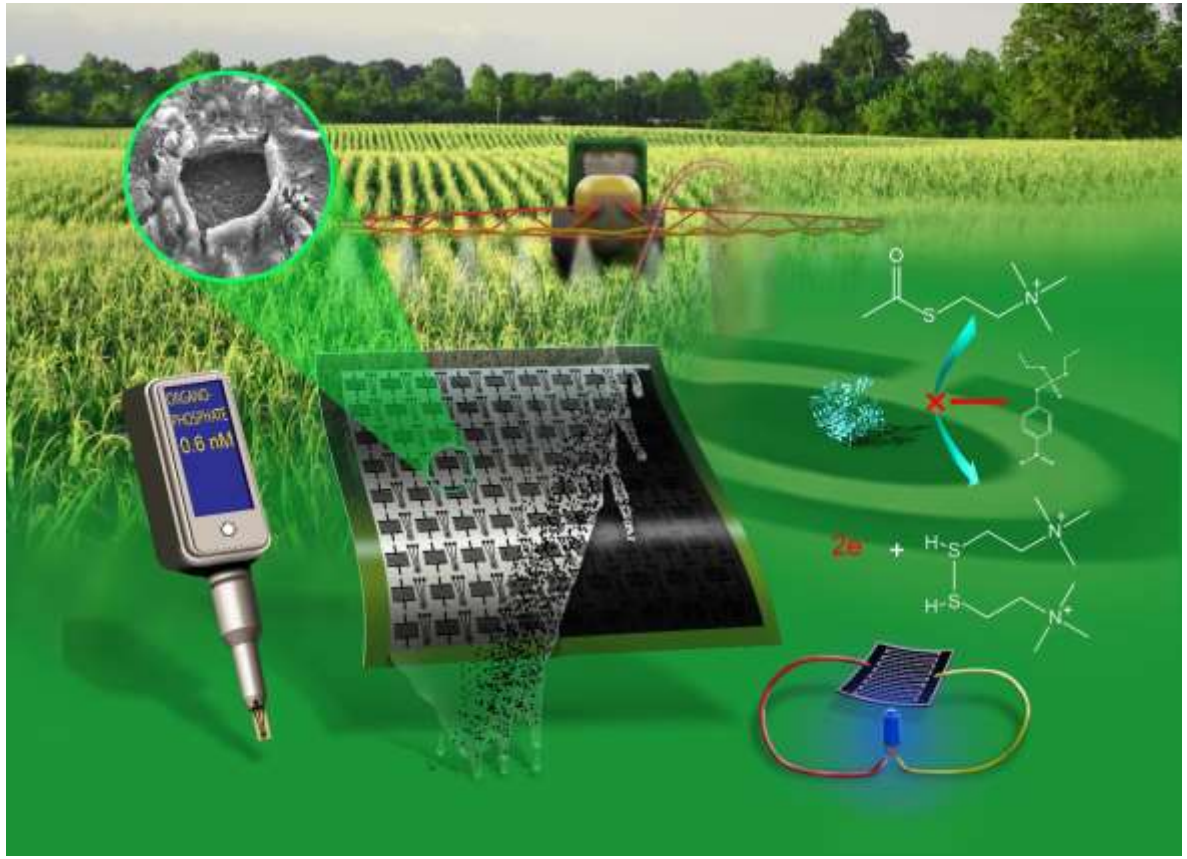
DNA-based Polymers and Functional Structures for Novel Applications

- *Nano-bio barcode*
- *Novel tool for traceability*
- *Sensors for detecting pathogens and contaminants*
- Delivery of vaccines and drugs
- Cell free high output productions of molecules

Luo, Cornell University

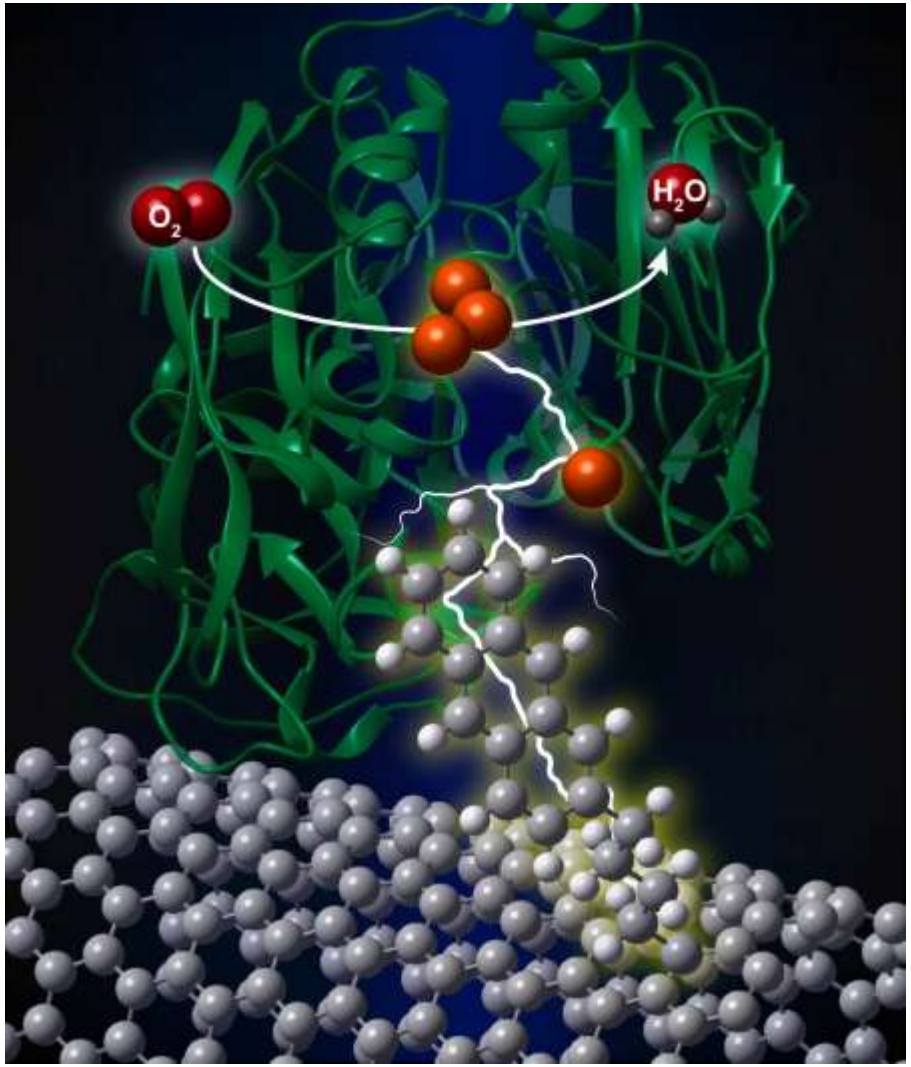
IB In Depth—Special Issue on Nanobiotechnology, Part 1, Dec. 2012, Guest Editors: Norman Scott and Hongda Chen

Enhanced electrochemical biosensor and supercapacitor with 3D porous architectured graphene via salt impregnated inkjet maskless lithography



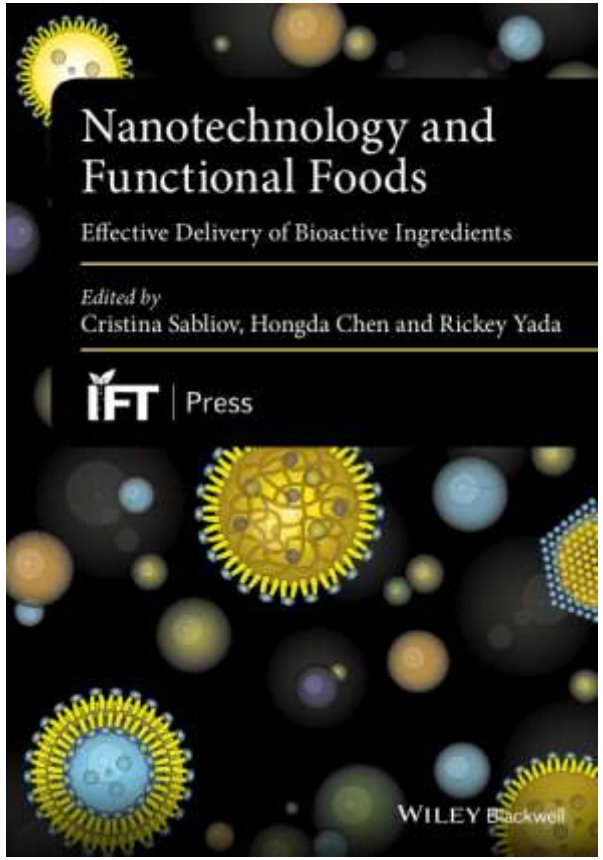
- Claussen, Iowa State University, Nanoscale Horizons, 2/27/2019

Next Generation Water Quality Sensors (Self-Powered and Portable Sensors for Detection of Toxicants)



- Minteer, University of Utah

Engineered Nanomaterials and Nanoscale Structures in Foods



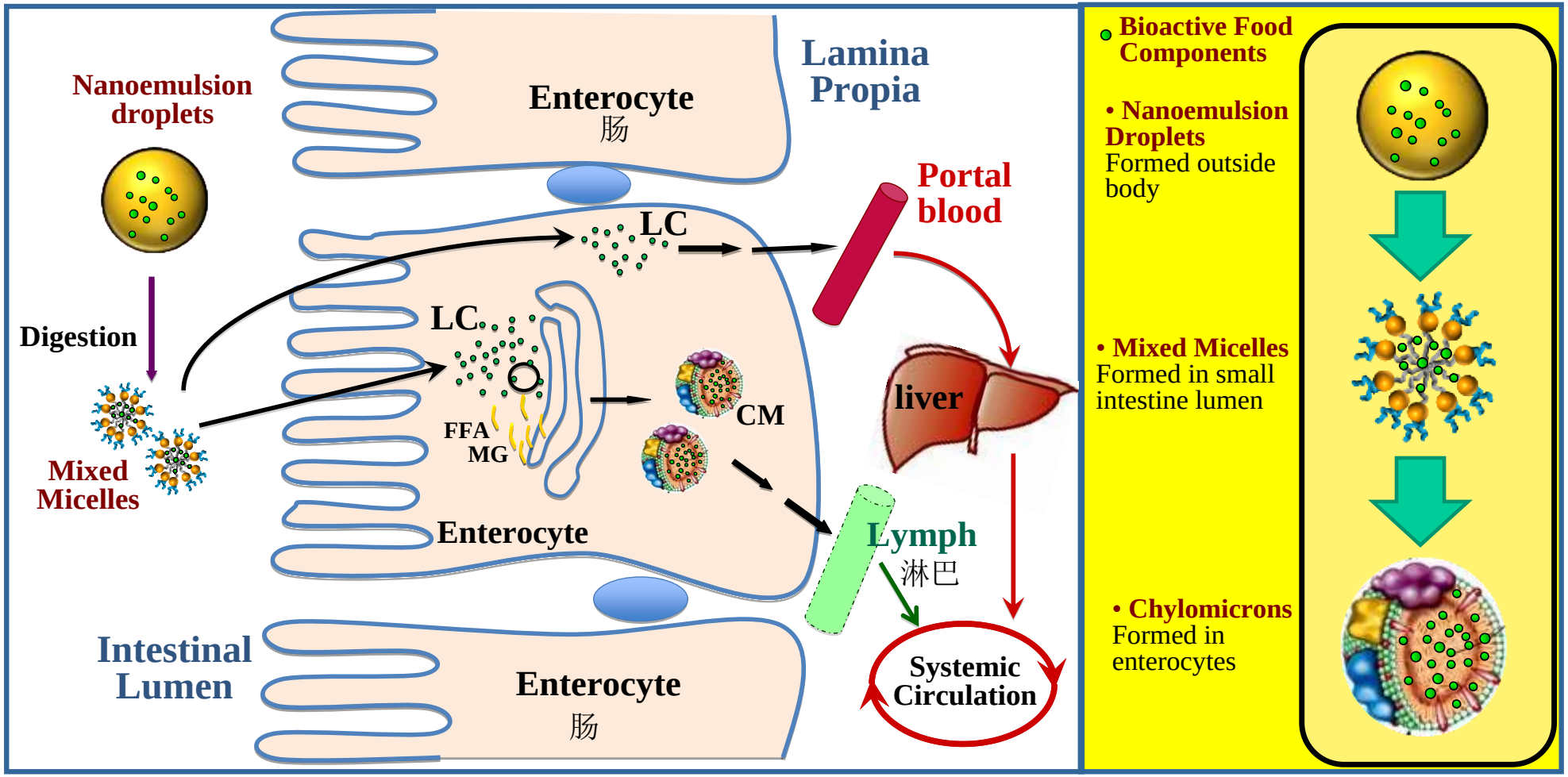
C. Sabliov, H. Chen, and R. Yada

- Emulsions
- Liposomes
- Polymeric nanoparticles
- Solid lipid nanoparticles
- Coacervates
- Bi-continuous structure
- Carbohydrate-lipid-protein complexes
- *Nano cellulosic materials*
- *…*

…

*The 2016 World Food Prize, found by Dr. Norman Borlaug, 1970 Nobel Peace Prize winner, honored four scientists for their outstanding pioneer **biofortification** (breeding micronutrient-dense staple crops).*

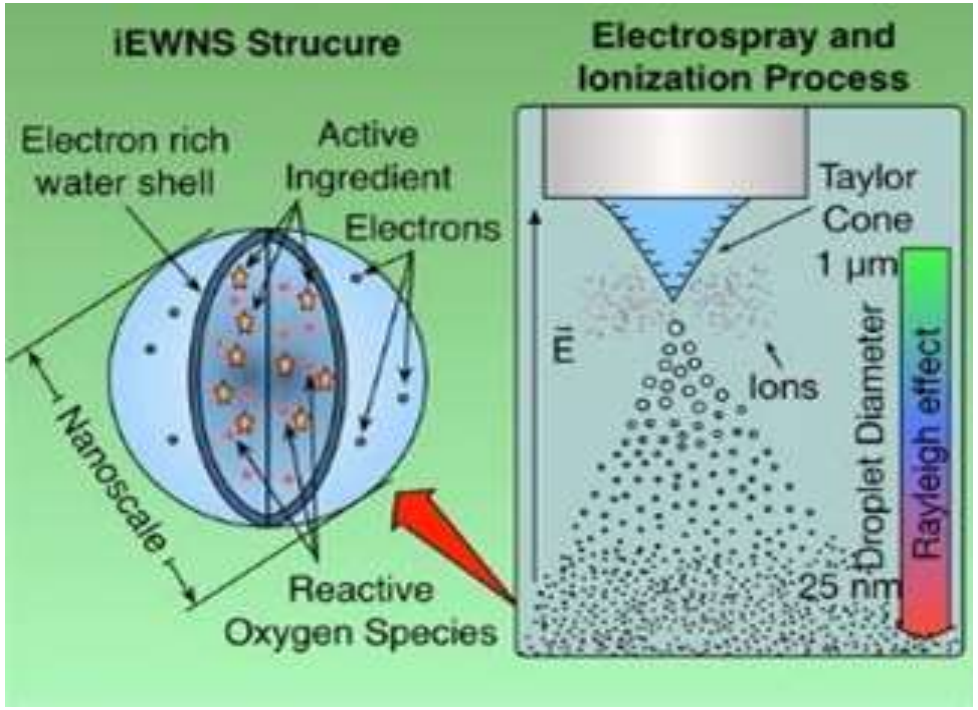
Absorption of lipophilic food components (LC) encapsulated in *nanoemulsions*

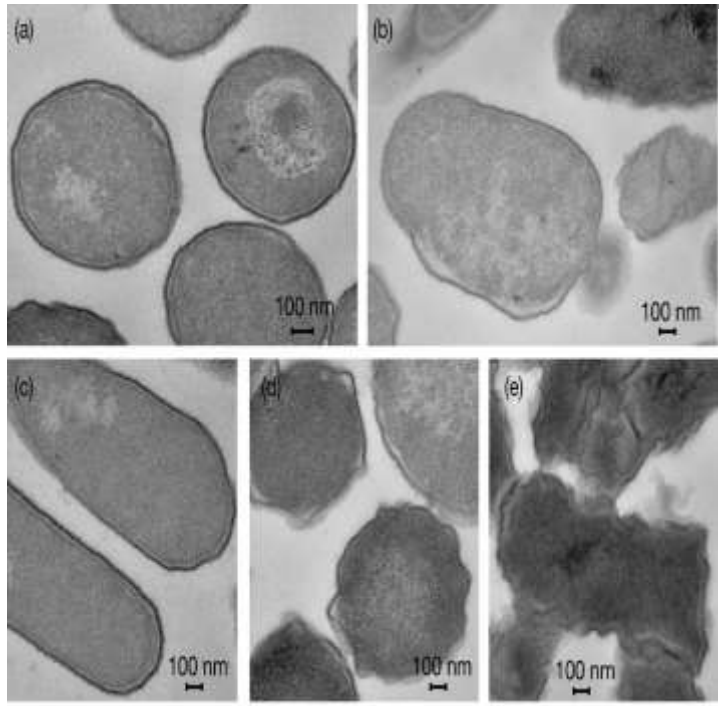


Hang Xiao, University of Massachusetts, Amherst

Engineered Water Nanostructures for Food Safety Intervention

...Making water nanostructures out of "thin air"…..





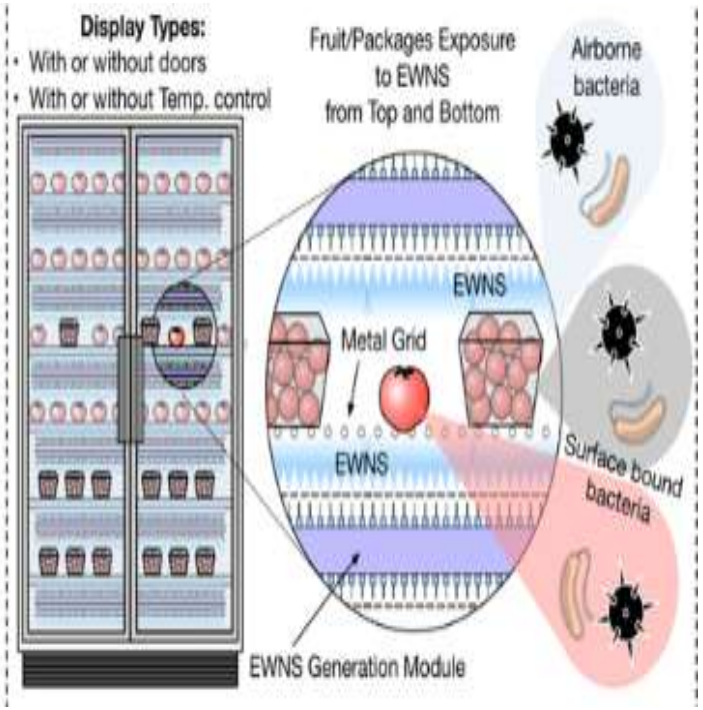
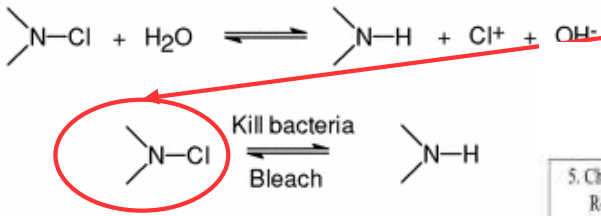
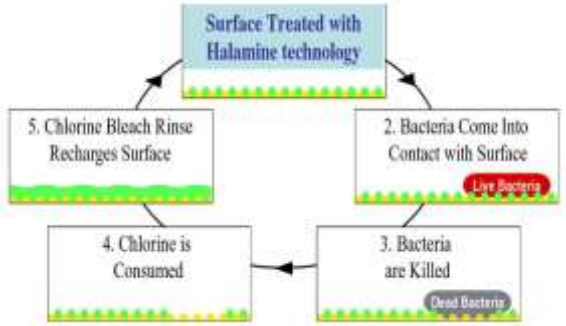


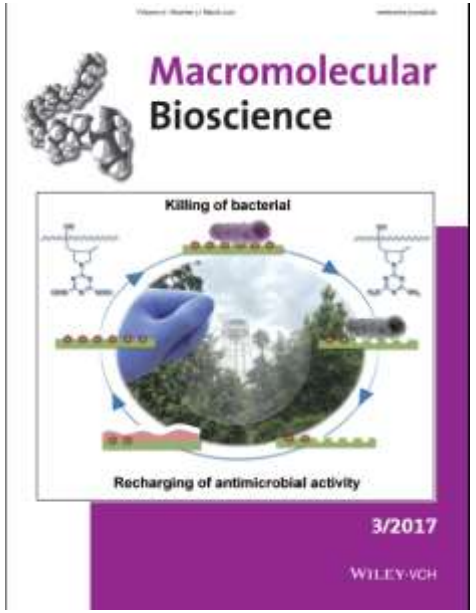
Image credit: Philip Demokritou and team, Harvard T.H. Chan School of Public Health

Research supported by USDA/NIFA and NIH

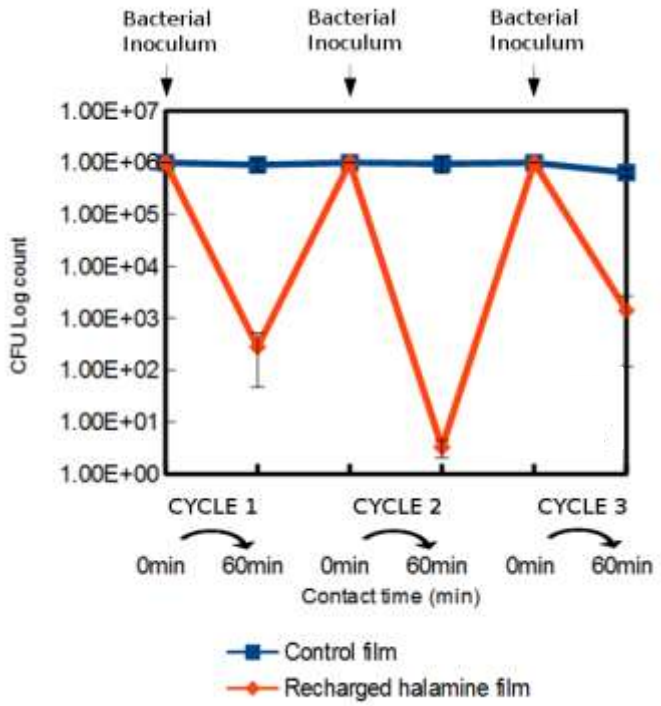
Antimicrobial efficacy of new films containing *halamine* groups







Nitin and Sun, University of California, Davis

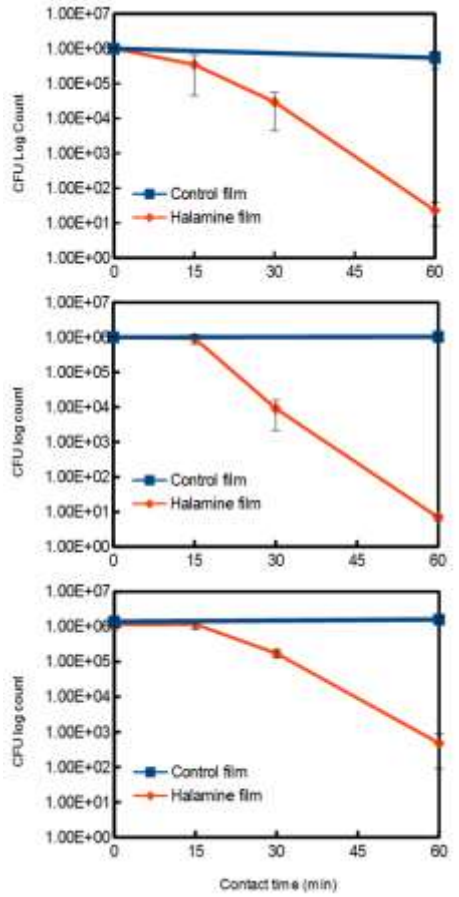


Multiple Charging Ability

↓

Multiple Antimicrobial cycles

Bacterial Reduction by contact (E. coli O157:H7)



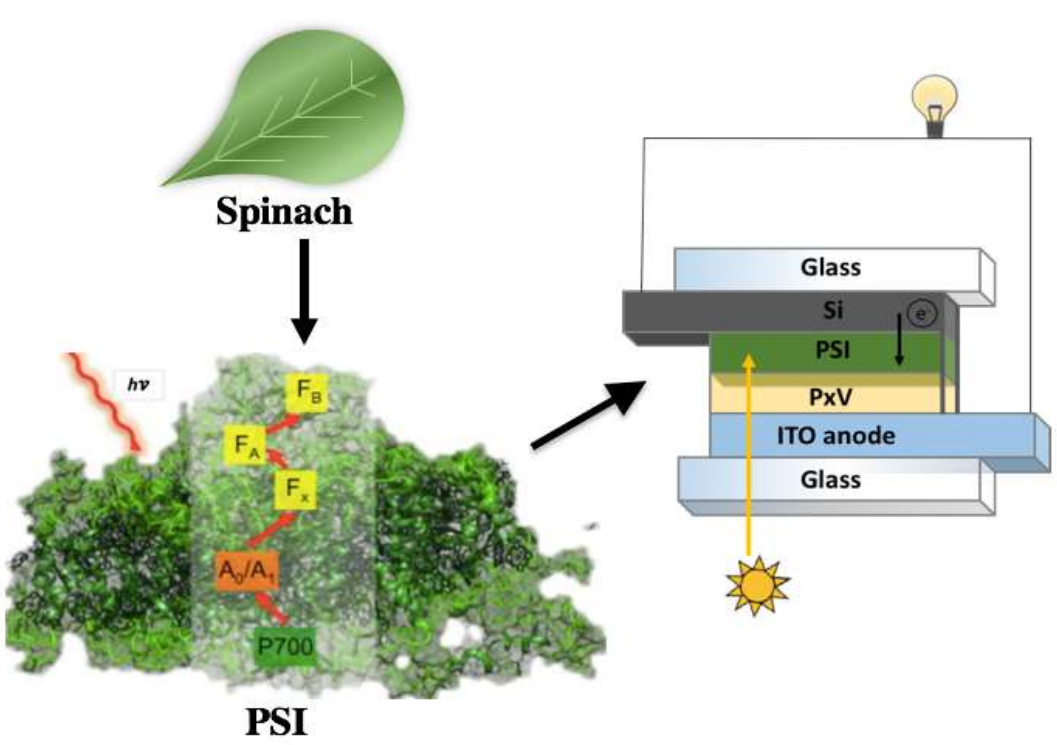
COD 0

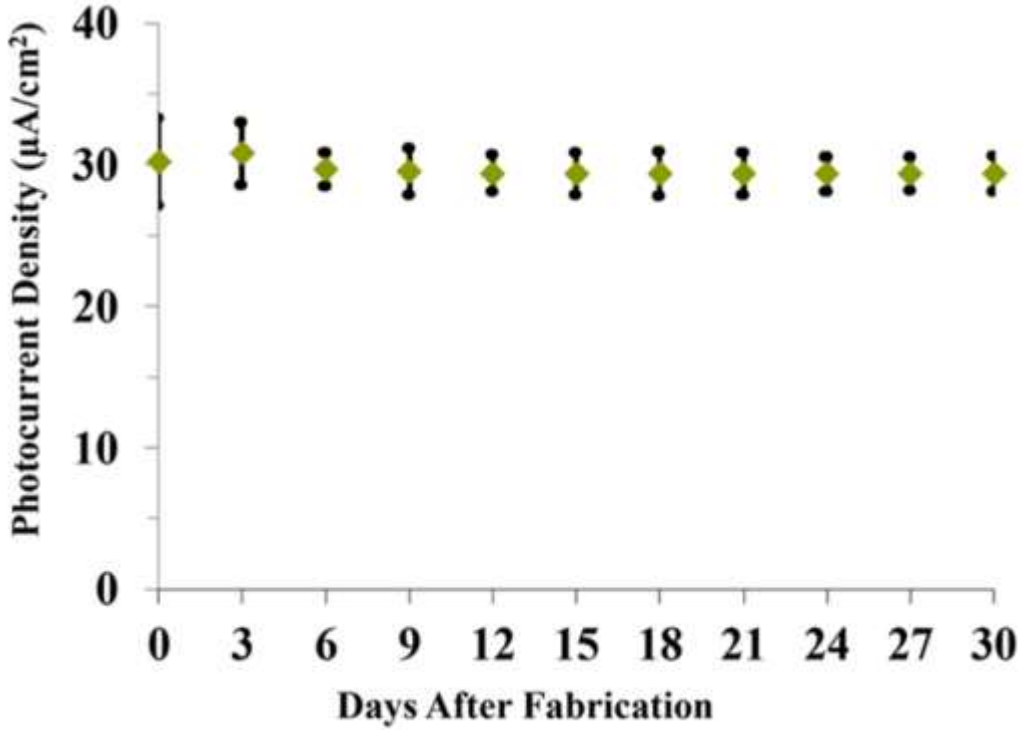
COD500

COD 2000

Up to **3 to 5 Log** reduction of 1x10^6 CFU spotted on 1x1 cm2 after 30-60 min contact with Halamine film

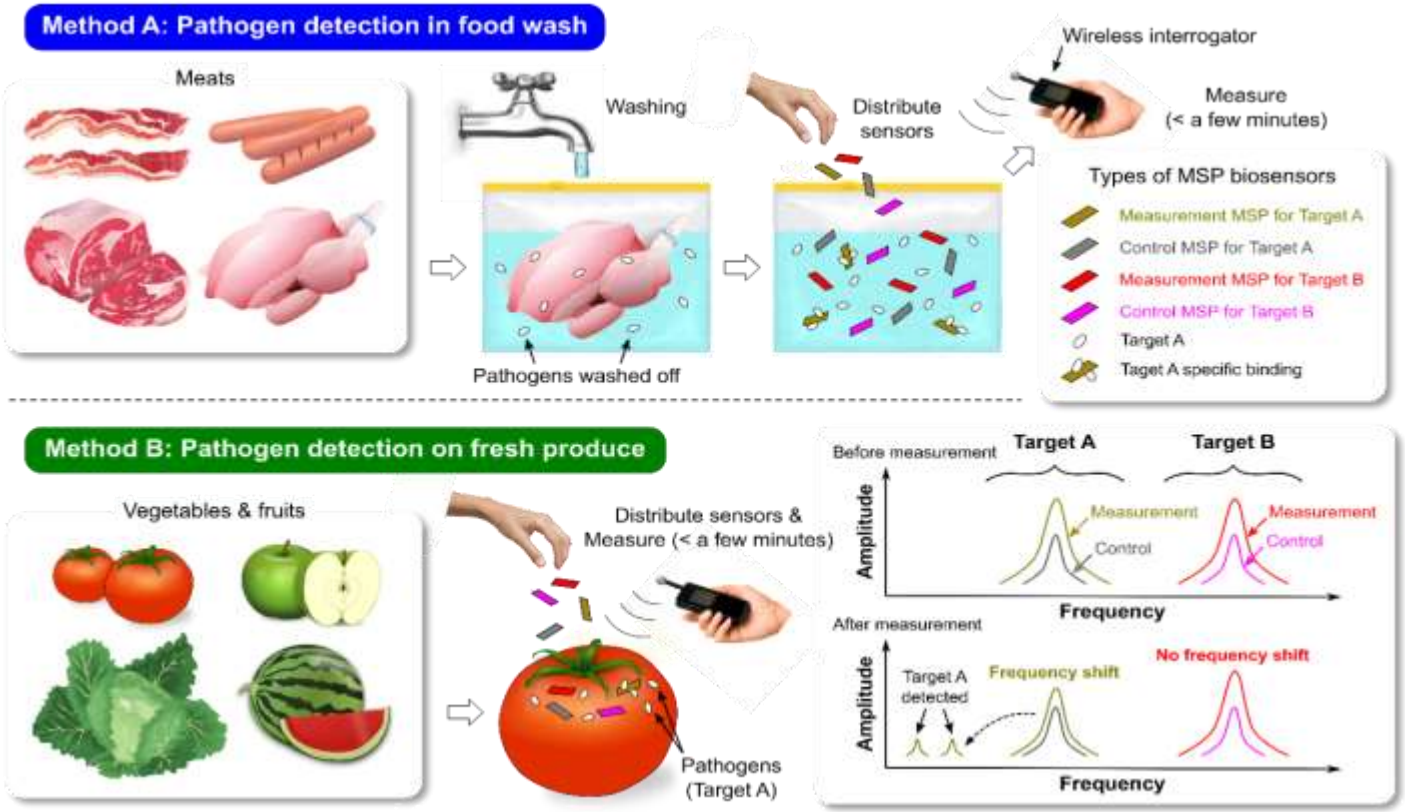
Polyviologens as Electron-Transport Material in Photosystem I-Based Photovoltaic Cells





- Jennings, Vanderbilt University

Development of a multiplex biosensor system for real time detection of foodborne pathogens



Proposed real-time detection of foodborne pathogens with multiplex MEP biosensors. In this figure, a multiplex detection system is used to detect the presence of multiple pathogens in food wash (Method A) or directly on food (Method B) and food preparation surfaces.

- Addresses the need for real time detection of common foodborne pathogens to minimize outbreaks
- Based on magnetoelastic particles complexed with molecular probes (phage-displayed oligopeptides) to detect resonant frequency change upon ligand (pathogen) binding
- Easy to use, cost-effective, and can be expanded to include more pathogens
- Versatile and can be used for indirect or direct measurements on-site (farms, processing plants, stores, etc.)

Sang-Jin Suh, Auburn University

Nanotechnology Enabled Biosensor Systems

- **Detection of abiotic and biological analytes in food and its environment**
  - Recognition surface molecule: antibody, synthetic peptides, aptamers
- **Transduction of signals**
  - optical, photonic, electromechanical, electromagnetic, electrochemical, electronic, others

- **Current status of biosensors (lessons from last 15 years)**
  - Very highly sensitive biosensors and many transduction mechanisms have been reported in research literature- single biomolecule to single pathogen.
  - Almost none of the new biosensors have made it to the commercial space, especially sensors with nanoscale features (**Reproducibility issues**)
    http://www.nature.com/nnano/journal/v9/n12/full/nnano.2014.287.html
  - *Monitoring* of biological entity is a challenge (**bio-interfaces degrade**)
  - New robust recognition chemistry is needed (aptamers have been disappointing)

Nanoparticle in Food is a broad topic

- Broad scope of applications of nanoscale science, engineering and technology to enhance food safety, quality, sensory attributes, and improve human health
  – Ex:
    - Sensing and detection
    - Processing technologies
    - Contact surface modifications
    - Food packaging
    - Nanoscale materials in food products
      - Naturally existed
      - Intentional vs unintentional addition/creation nanoscale materials in food

"Is Nano Safe to Eat or Not?" is not a right Question.

Low-fat diet
(Non-obese)
(10% of total kcal as fat)

- **Control without TiO_2**
- **0.1% wt TiO_2 (110 nm)**
- **0.1% wt TiO_2 (30 nm)**

6-week old
C57BL/6 mice

8 weeks

High-fat diet
(Obese)
(60% of total kcal as fat)

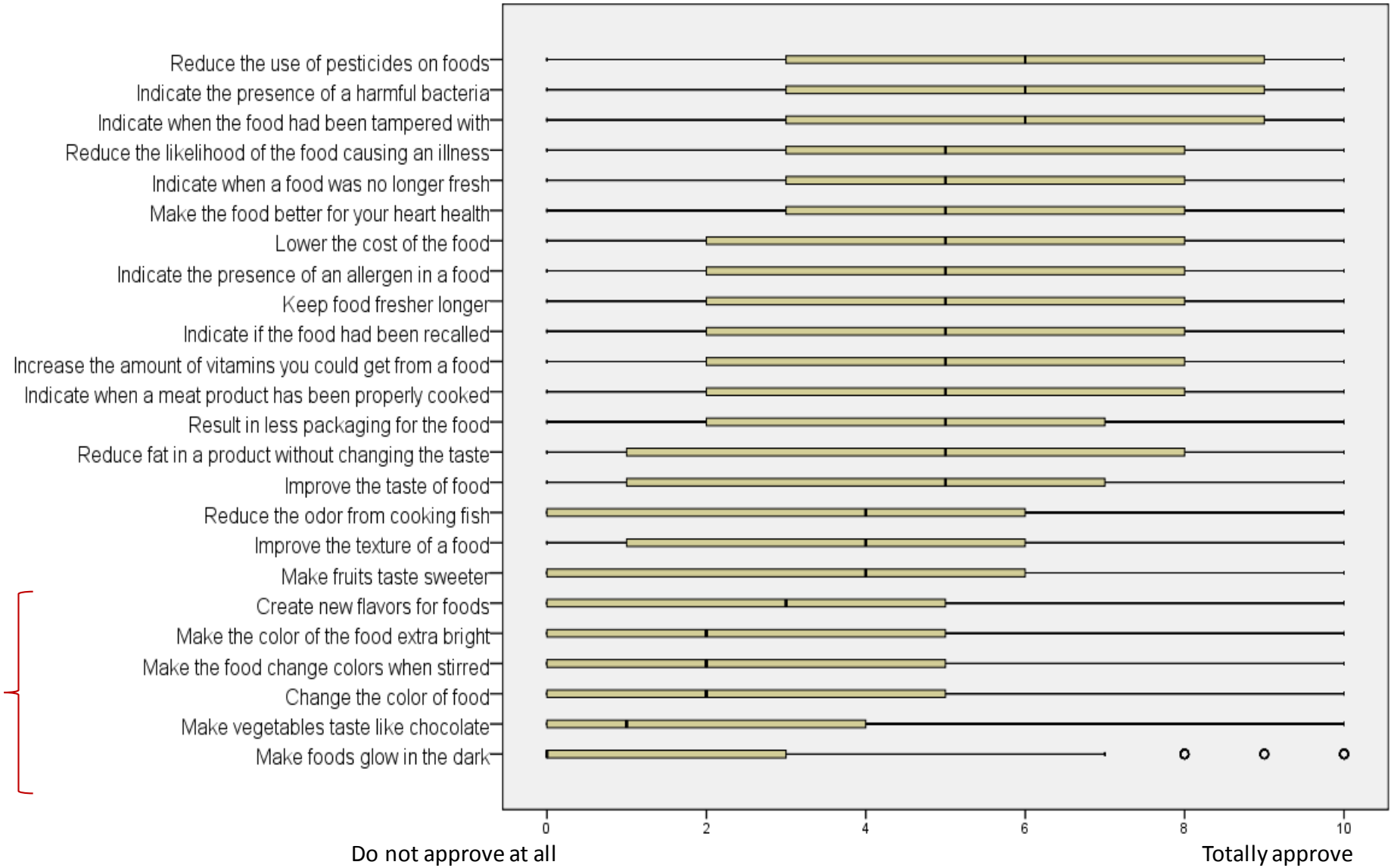
- **Control without TiO_2**
- **0.1% wt TiO_2 (110 nm)**
- **0.1% wt TiO_2 (30 nm)**

Understanding Public Acceptance of Nanotechnology In Food and Agriculture

- Fulfilling the promise of nanotechnology depends as much upon consumers' perceptions of nanotech products as it does on the ability to create them.
- The current controversies over GMOs demonstrates that failing to consider the perceptions of consumers is a poor strategy
- People's starting conception of nanotechnology may make it more difficult for them to extend their mental model of the technology to applications in food and agriculture
- Approval may depend on what benefits are achieved using nanotechnology

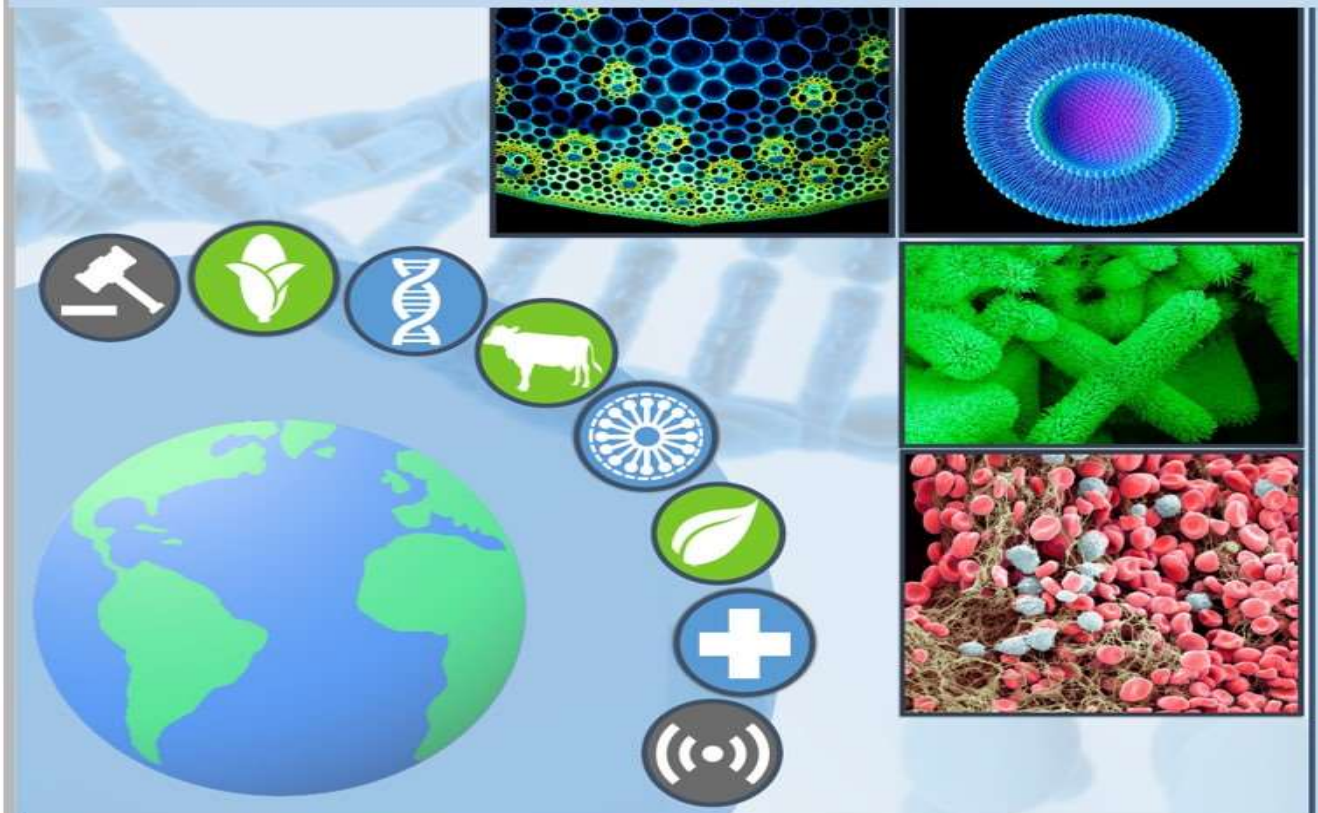
William K. Hallman, and Mary L. Nucci, Rutgers University

Approval based on Benefits



Nanoscale Science and Engineering
for Agriculture and Food Systems

Convergence of nanotechnology with food & agriculture



Discussion Topics

1. *Convergence of nanotechnology with food & agriculture*
2. *Advances in Nanomaterials*
3. *Environmental Nanotechnology*
4. *Nano-enabled approaches to improving human and animal health*
5. *Translation of nano-based science for application in food & agriculture*
6. *Internet of Food & Ag Nano-things: Big Data, Machine Learning, AI, Modelling*
7. *Emerging Investigators Session*
8. *Nanotechnology's impact on food safety*
9. *Nanotechnology's role in agriculture*

Gordon Research Conference
Frontiers of Science

Gordon Research Seminars
Graduate Research

Chair: Antje Baeumner, University of Regensburg
Co-Chair: Julie Goddard, Cornell University
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Co-Vice Chair: Melanie Kah, University of Vienna, Austria
GRS Chair: Ying Wang, UC Santa Barbara
GRS co-Vice Chair: Daniel White, UC Riverside
https://www.grc.org/programs.aspx?id=1688

Summary

- USDA pursuits in advancing nanoscale science and technology has greatly benefited from and contributed to the NNI and its goals.
- Nanoscale Science and Nanotechnology for agriculture and food applications has been steadily progressing to make impact for addressing societal challenges of sustainability, vulnerability, human health and joy of living.
- Nanotechnology will be a part of system approach of convergence of sciences for the future agricultural and food systems, and the economic prosperity and national security.

Thank you!

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