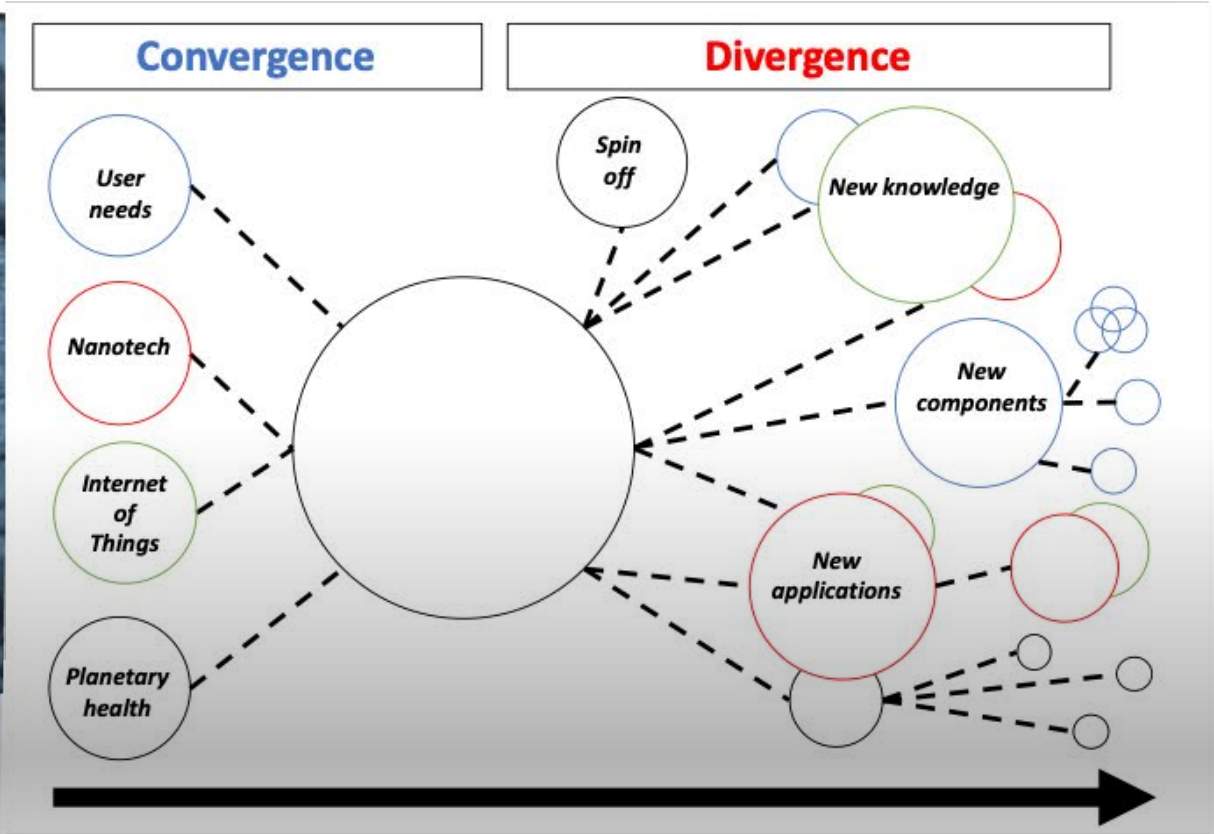

Future of food and agriculture from macro to nano: opportunities and challenges

Carmen L. Gomes

Mechanical Engineering, Iowa State University

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This webinar is hosted by:

NACK CENTER
Building College-University Partnerships for Nanotechnology Workforce Development

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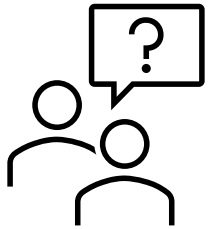

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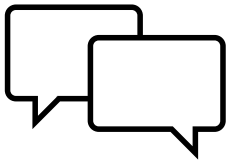

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Ozgur Cakmak
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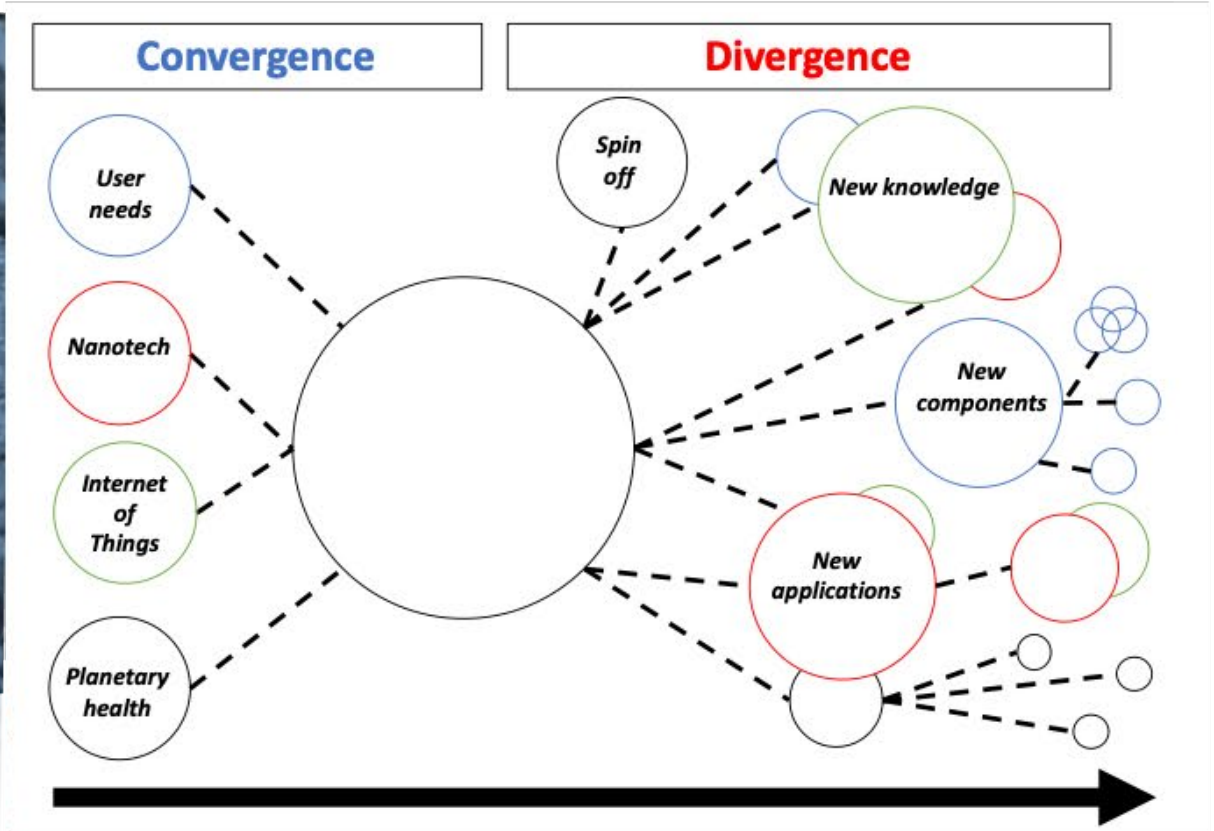
Penn State

Carmen Gomes
Associate Professor
Iowa State University

PennState



Future of food and agriculture from macro to nano: opportunities and challenges

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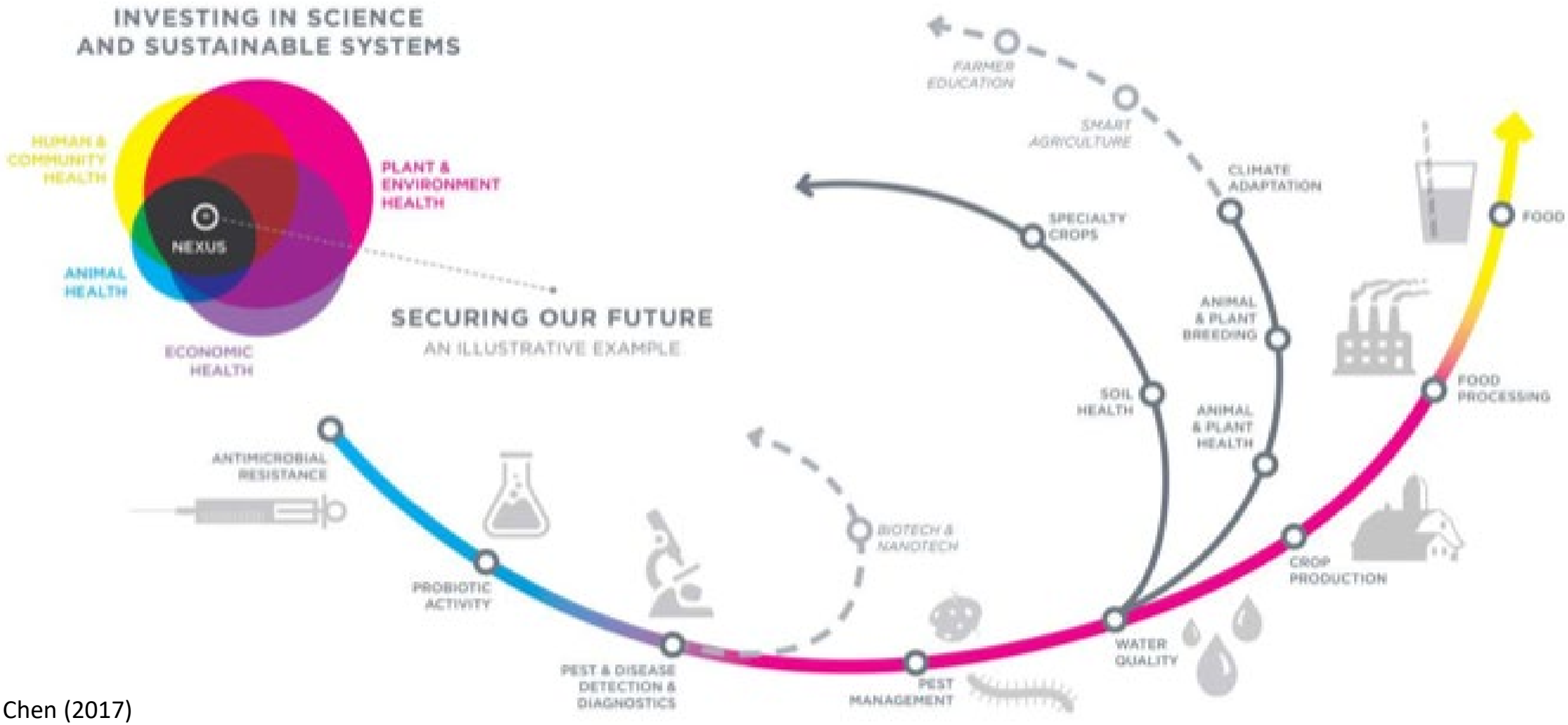
A Shared Vision of the Future

SUSTAINABLE DEVELOPMENT GOALS

- End hunger
- Achieve food security and improved nutrition
- Promote sustainable agriculture

THE NEXUS OF AGRICULTURE AND HEALTH



Courtesy of Chen (2017)

MINDSET FOR the 4TH INDUSTRIAL REVOLUTION

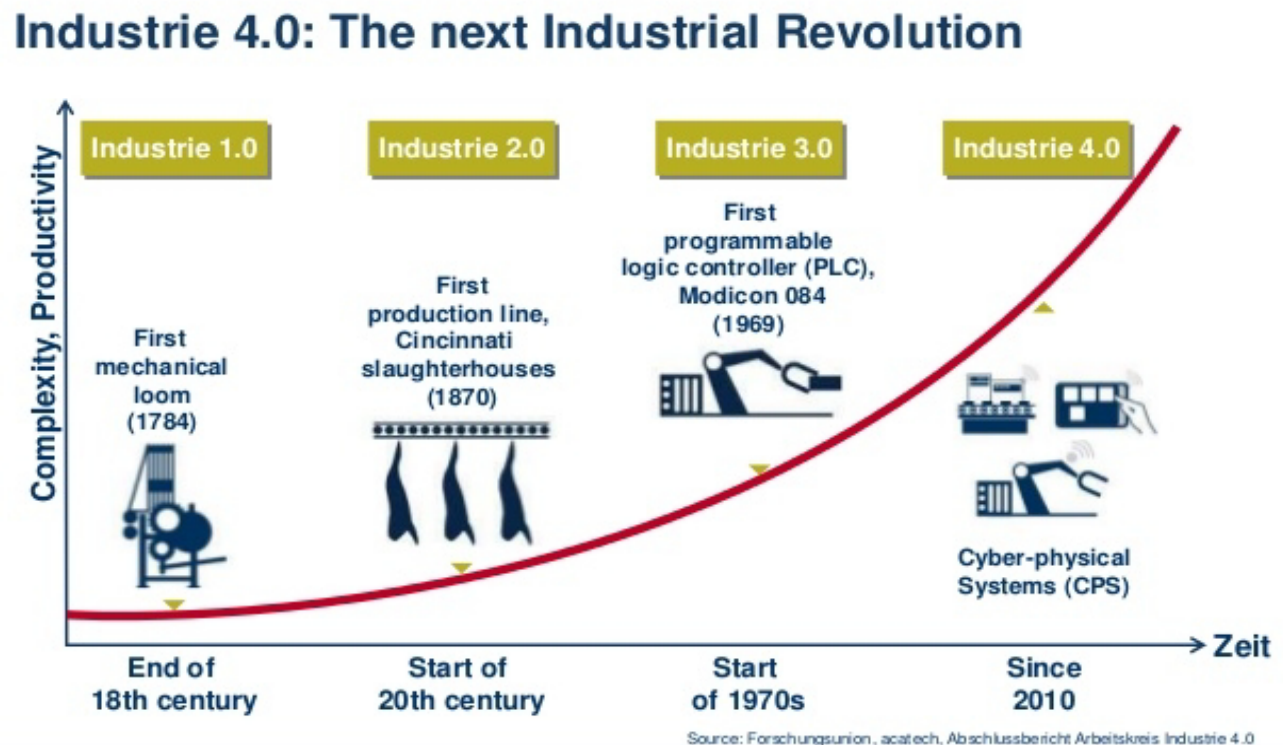
Think Systems, not Technologies

Empowering, not Determining

By Design, not by Default

Values as a feature, not a Bug

Connecting the dots



Source: Klaus Schwab & Nicholas Davis, *Shaping the Fourth Industrial Revolution*, World Economic Forum (2018)

Hierarchy of Needs as A Connected Playbook

Pleasure

Healthy
Aging

Disease
Prevention

Food
Distribution

Instant
Gratification

Minimally
Processed

Low Carbon
Food Source

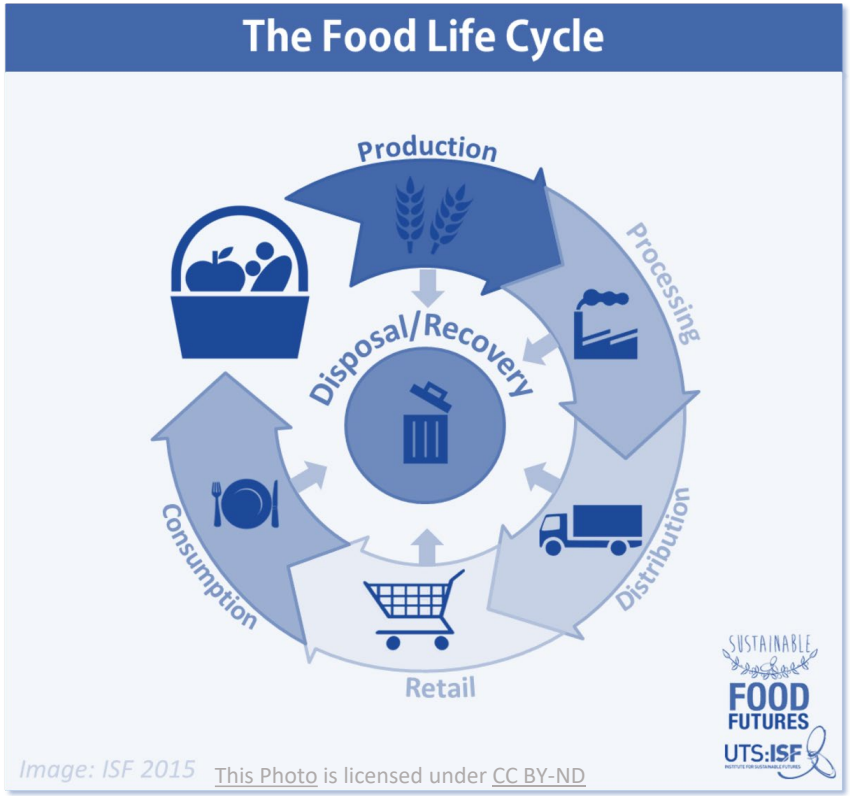
Food Waste

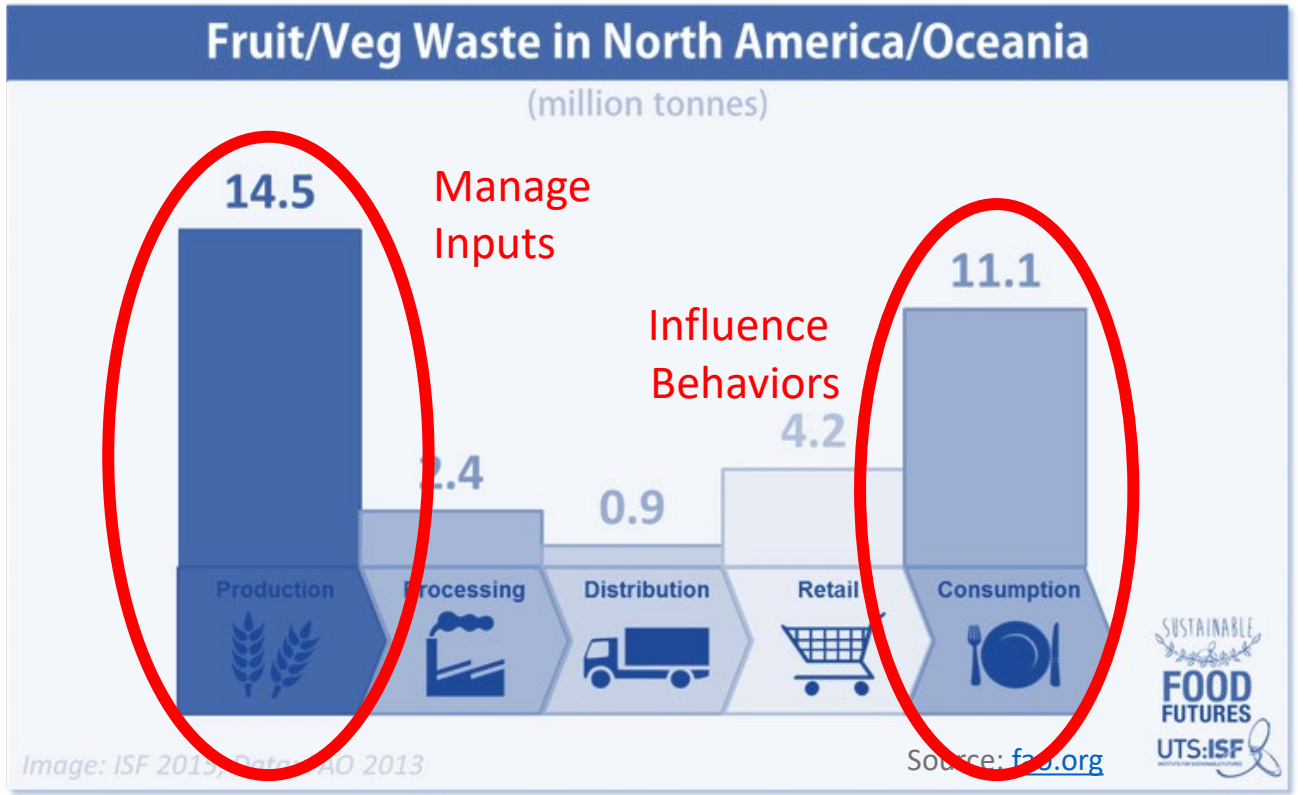
Sustainable
Farming

FOOD WASTE

Reduce Food Waste

Focus on the Biggest





Source: www.fao.org

Ways To Reduce Fruit & Veg Losses

45%

FRUIT & VEGETABLES
FOOD LOSSES

Along with roots and tubers, fruit and vegetables have the highest wastage rates of any food products; almost half of all the fruit and vegetables produced are wasted. Source: www.fao.org

In North America, Over 2/3 of the Losses occur in Agriculture & Consumption Levels

Recall & Food Safety
- WGS
- Traceability
- Blockchain

Self-Protection Post-Harvest
- Antioxidant
- Enzymes
- Hormones
- Respiration

Disrupt Distribution
- Closer to consumption
- Storage
- Packaging
- Send surplus to needy & deserts
- Disrupt restaurant and retail models

Fresh + Beyond Fresh
- Low carbon footprint & high quality food preservation
- Packaging
- Kitchen Technologies

Farm to Table Distribution

Extend Natural Shelf-Life

Expanded Ways to Consume

Change the Bar

Waste to Value

Use More Ugly

Make them Perfect
- Perfect shape
- Perfect taste

Use all parts
- Cellulosic conversion
- Field waste to sustainable food products
- Mine nutraceuticals or functional ingredients

Beyond Food
- Fuel
- Packaging
- Cosmetics
- Supplements
- Other products

Ways To Reduce Cereal Food Losses

30%
CEREALS
FOOD LOSSES

In industrialized countries, consumers throw away 286 million tonnes of cereal products.

Source: www.fao.org

In North America,
Over 2/3 of the Losses occur at the Household Consumption Level

Healthy Food Should Taste Good

Eat all parts
- Whole Grains

Find more use!
Plant-based Beyond Protein
- Promote plant-based cereal diet

Make them even Healthier
- Complex carb is sustainable and healthy
- Optimize processing to retain nutrition

Preservation
- Extend shelf-life using natural and consumer friendly methods
- Packaging technologies

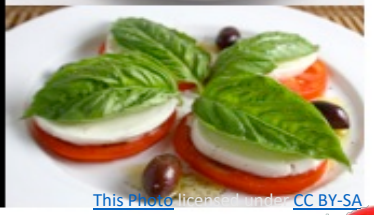
PLEASURE

Healthy Food Should Taste Good

2 **Sight**

1

What Influences food choices?



3 **Taste & Flavor**

THE IMPOSSIBLE CHEESEBURGER

4 **Mouthfeel & Sound**

Satisfaction beyond Taste 5

Healthy Food Should Taste Good

2 Sight

- Color & Luminescence
- Processing without destruction
- Preservation & Packaging

Taste & Flavor 3

- Flavor sciences
- Human Receptors
- Ingredient Innovations

1

What Influences food choices?

- Human Psychology
- Marketing
- Food Accessibility (retail, vending, restaurants and e-commerce models)

- Food Oral Processing
- Processing technologies
- Barrier technologies

4 Mouthfeel & Sound

- Food & Health Relationships
- Biomarkers
- Biosensors

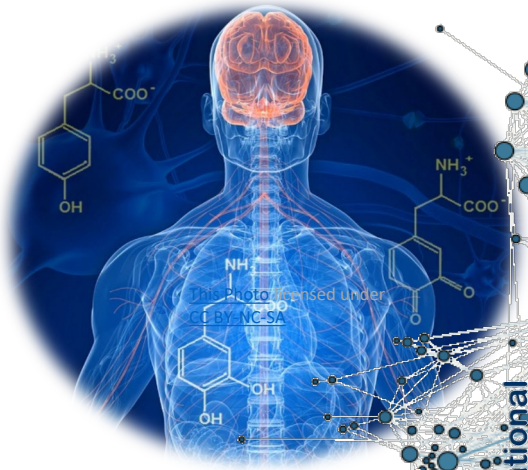
Next Topic

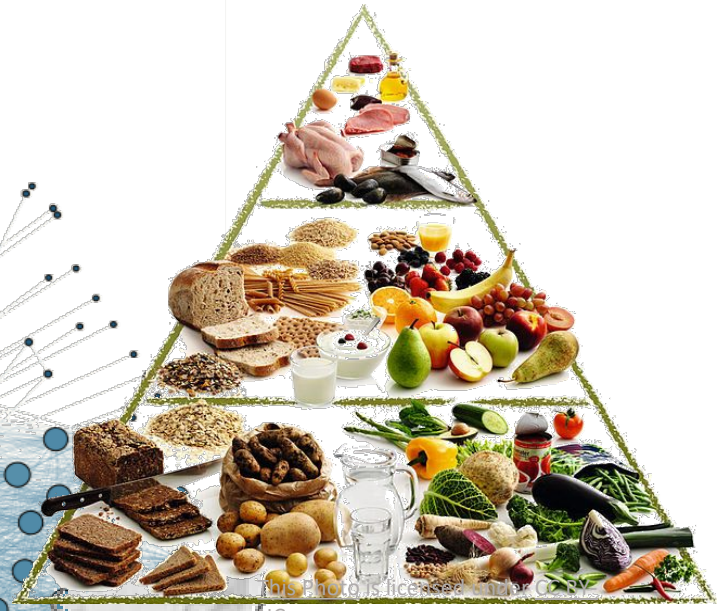
Satisfaction beyond Taste 5

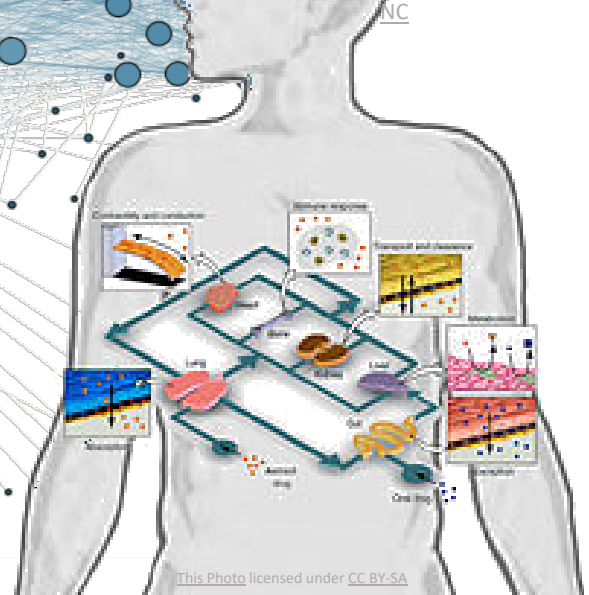
HEALTHY AGING

Similar to retirement savings,
one must begin when they are still young.

Food-Health: Connecting the Dots







REFRAME

break the bottlenecks ... shift the paradigms

Macro System Thinking: Problems to Solve

Detect, Control & Connect

- Spoilage detection
- Pathogen detection
- Biomarkers for Health
- Supply-chain traceability
- Food Distribution Disruptions

Preserve & Expand Use

- Safe and effective preservation
- Sustainable packaging and preservation
- Reduce packaging use while preserving food
- New use for food waste
- Waste less
- Use all parts of plant
- More plant-based

Understand

- Food degradation mechanisms
- The psychological aspect of eating
- Oral Processing of Food
- Food-Health interaction
- Distresses due to food (allergens and intolerance)

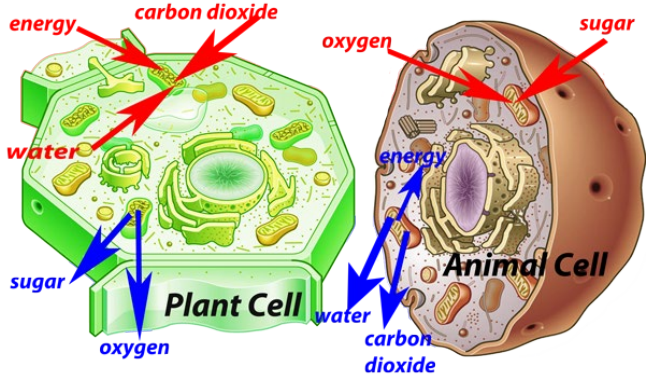
Safe & Consumer Accepted

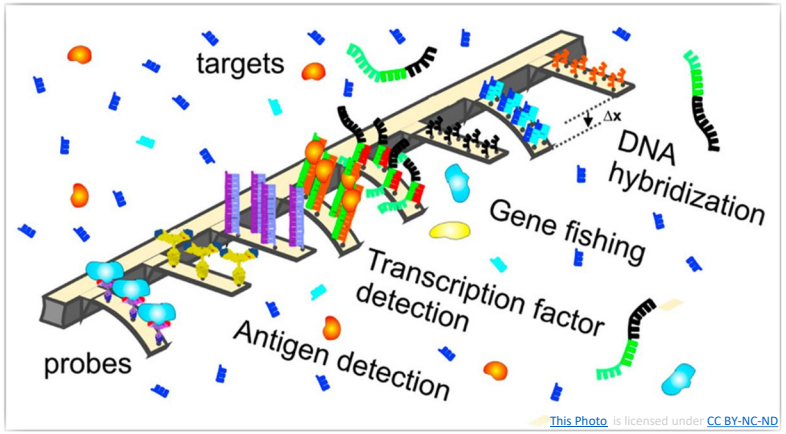
- Education for Safety
- Education for Biology and Biotech
- Safety of new materials
- Safety of new technologies
- Ecosystem view of technologies & interactions

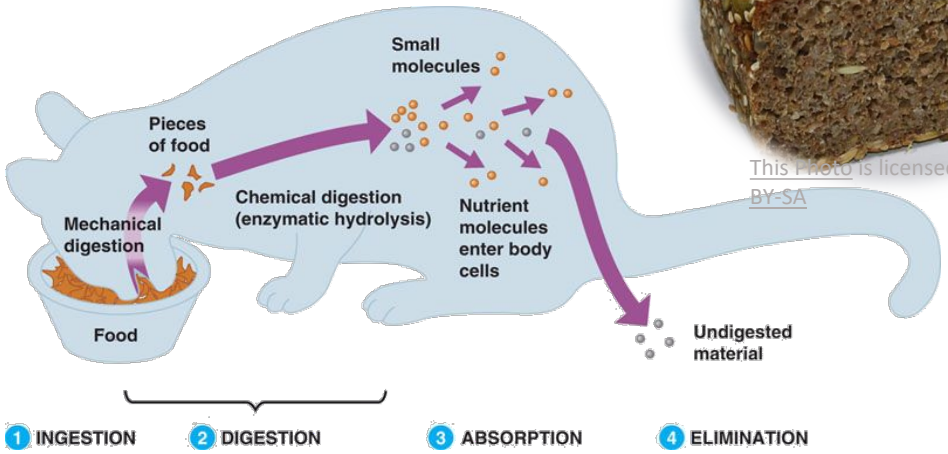
Deliver Health & Joy

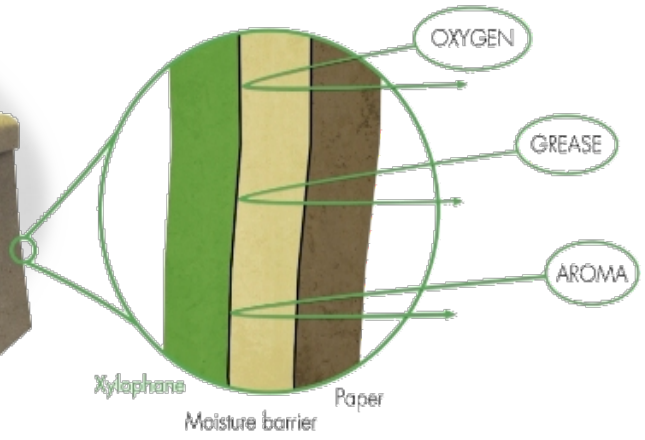
- Food structure manipulation
- Food structure preservation
- Macromolecular interaction
- Encapsulation and release of bioactives
- Tailored release kinetics
- Minimally processed safe food

Shift to Nano: To Find and Change Bottlenecks









Food, Environmental, and Agricultural Sensing Technologies innovations needed

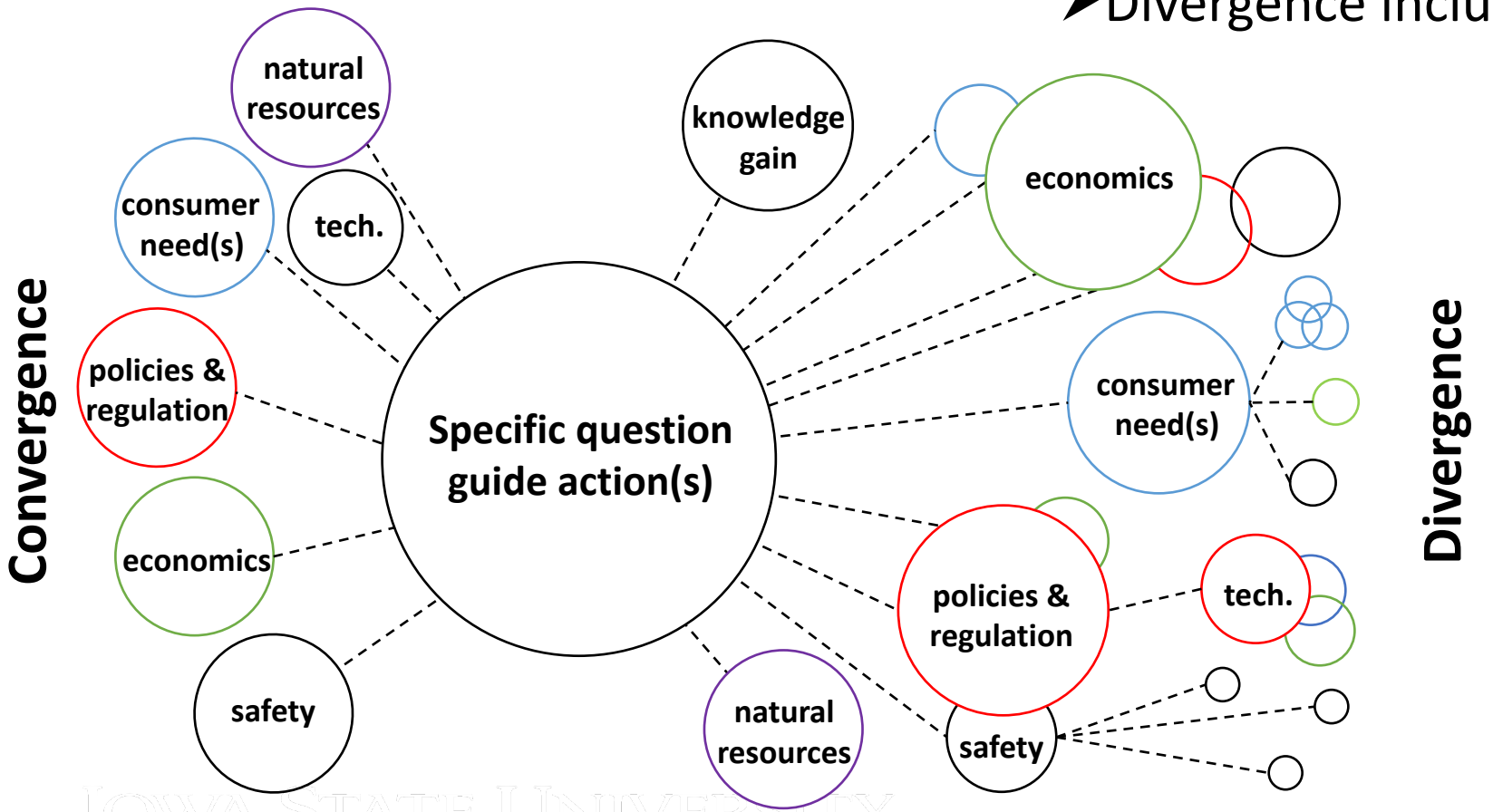
- integrated sample preparation
- label-free or direct detection in complex matrices
- long-term sensor stability
- development of low-cost and user-friendly devices
- integrate new mobile robotic sensing platforms (e.g., UAV)
- detailed analysis of complex matrices

- biosensors that have viable pathways for commercialization
- **use-inspired sensor design**
- **consider the triple bottom line:** economic, environmental and social values
- **tools that can support interoperability**
- New material arrangement and architecture
- **biodegradable** materials


Questions ??

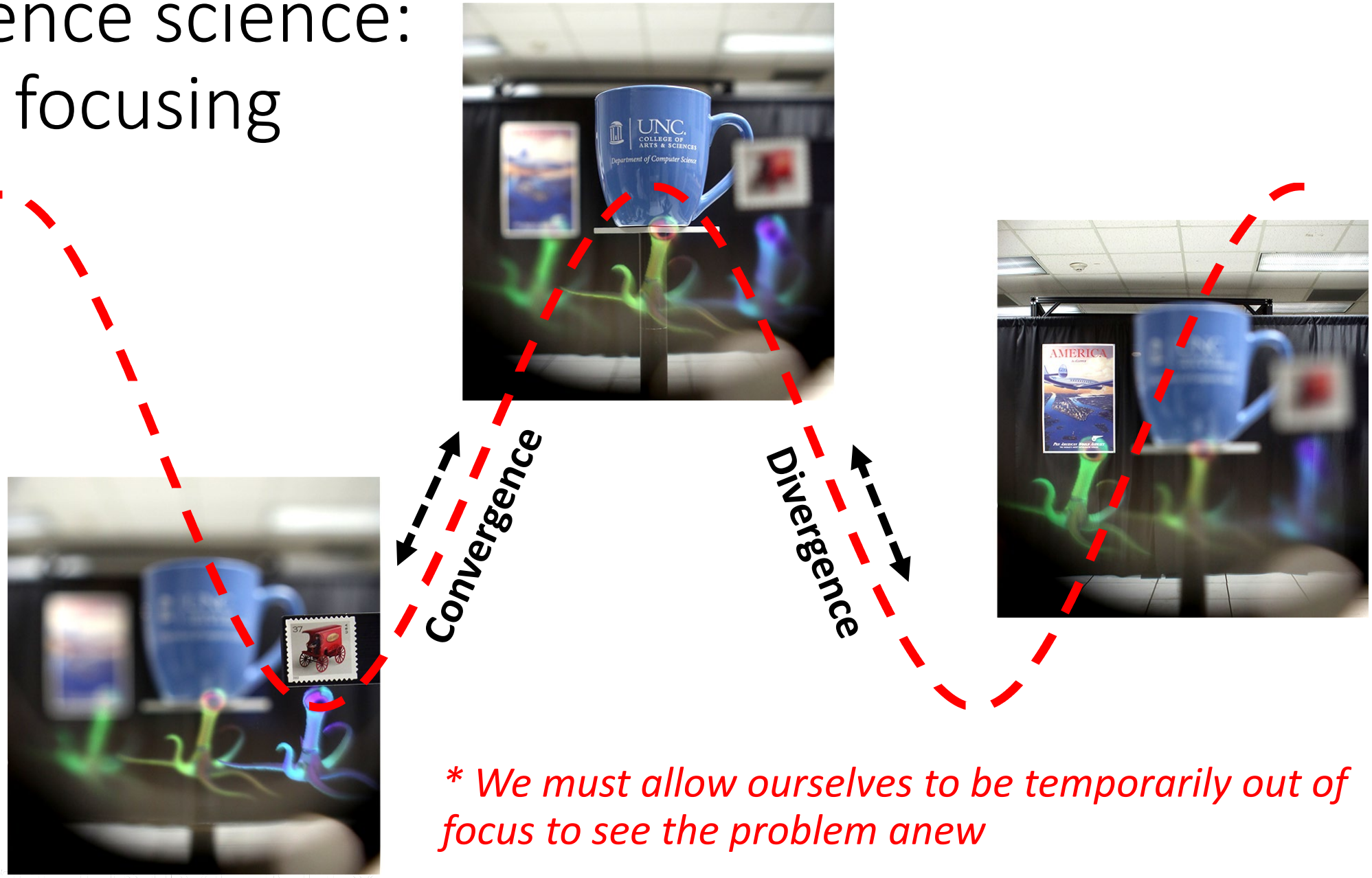
Convergence science is our roadmap

- Trans-disciplinary questions drive ideation
- Key players converge to address individual challenges
- Divergence includes spin-off products and ideas



** We may not need to understand <u>all</u> the connections amongst the pieces of the puzzle*

Convergence science: Dynamic focusing



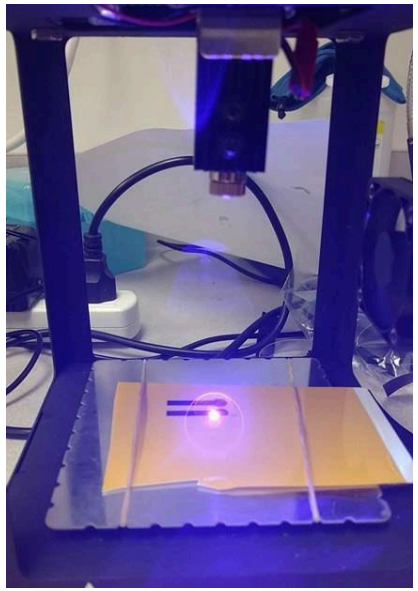
** We must allow ourselves to be temporarily out of focus to see the problem anew*

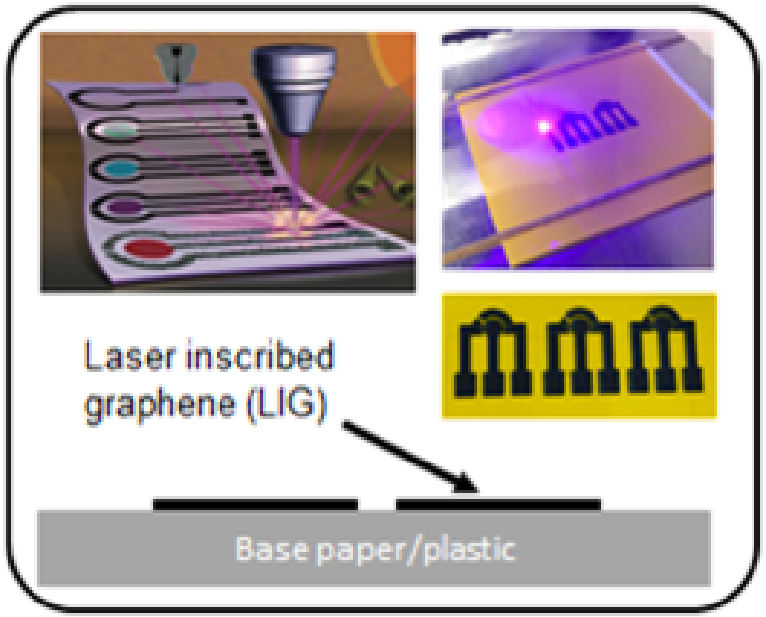
How Can we Meet the Food Security, Safety, and Sovereignty Needs of Low-Income Communities?

Stories of convergence in Colombia by Prof. Diana Vanegas at Clemson

Hackers space for nanotech tools in low-income settings

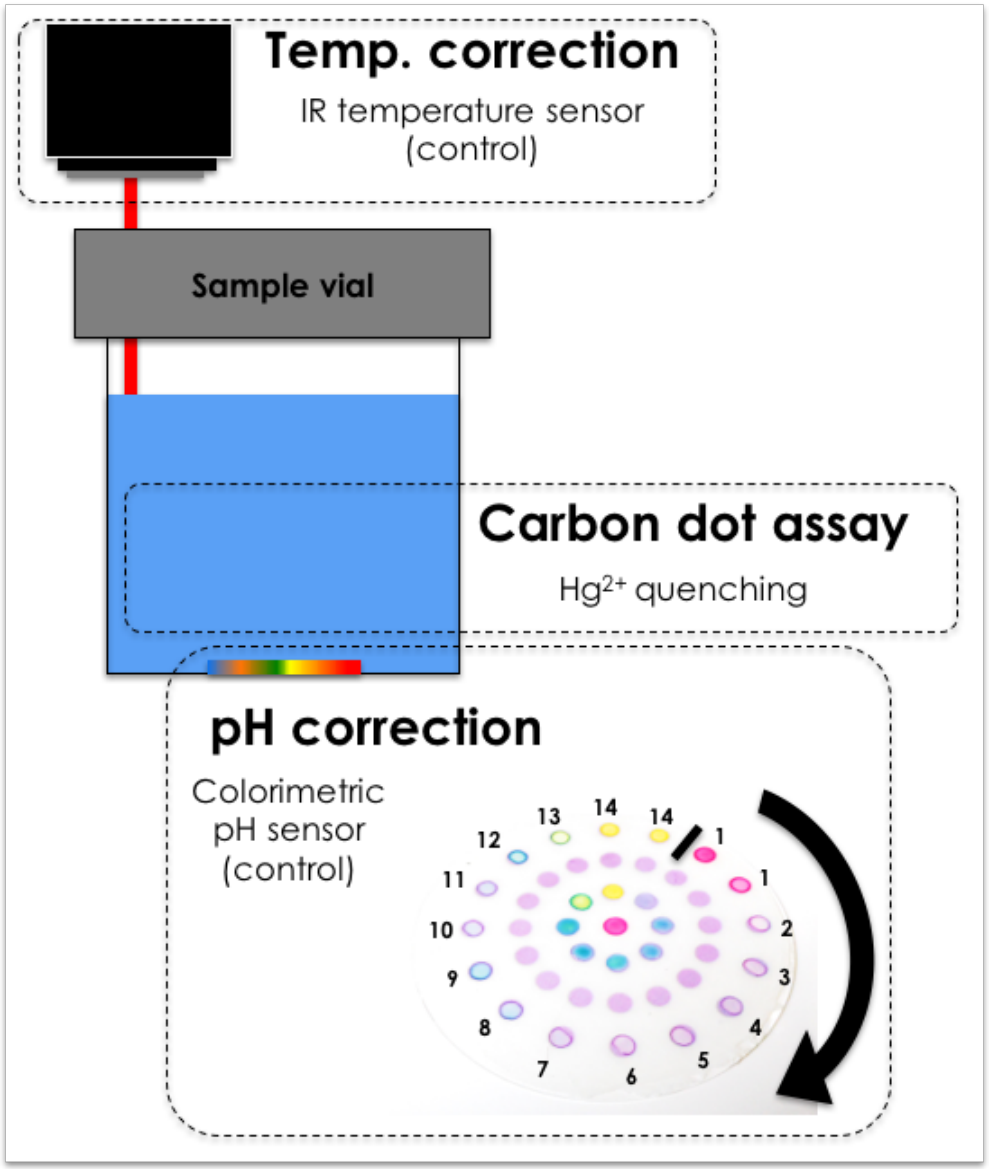
- Using a low cost ($60) millisecond pulsed laser, we have tuned the method for rapid fabrication of low cost conductive plastics.





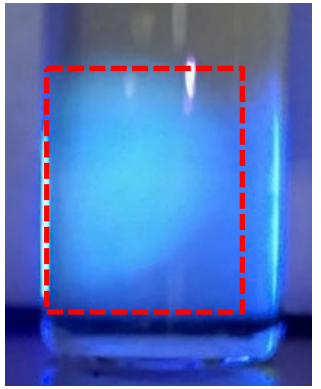
Vanegas, D. G. Clemson University.

Correcting for pH and temperature



Hg^{2+} = 0 ppb

T=25 C

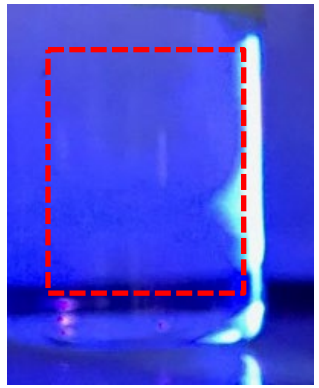


Blank

pH=7

Hg^{2+} = 50 ppb

T=25 C



+ sample

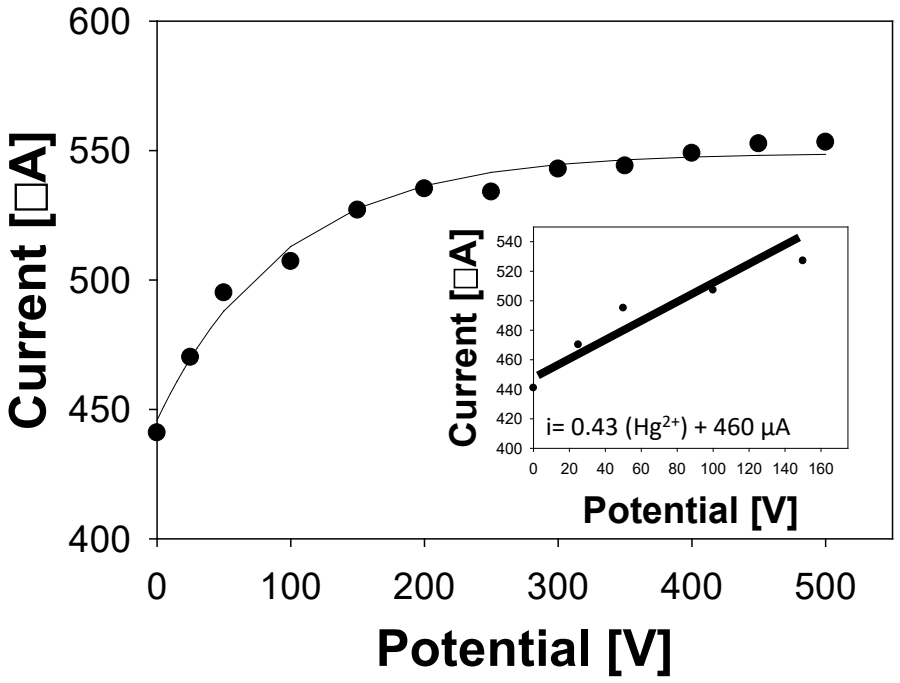
pH=6

** Currently working on a post hoc algorithm that will process images and temp data*

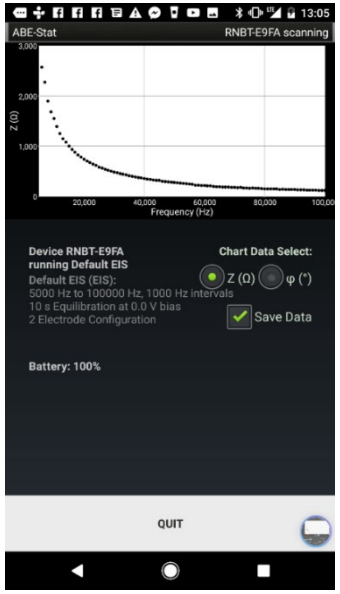
Vanegas, D. G. Clemson University.

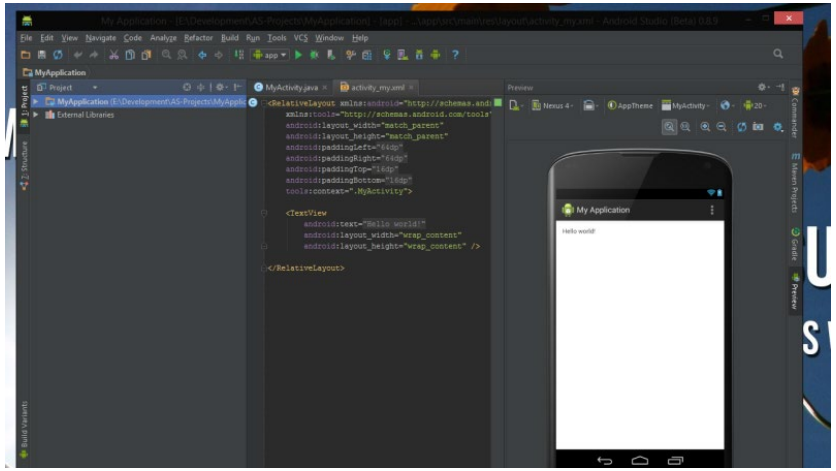
Handheld signal acquisition and mobile phone app

- Nanosensor performance
  - LOD = 1.2 µg/L (ppb)
  - Sens. = 0.43 µA/[Hg^{2+}]
  - Linear range = 1-200 µg/L (ppb)



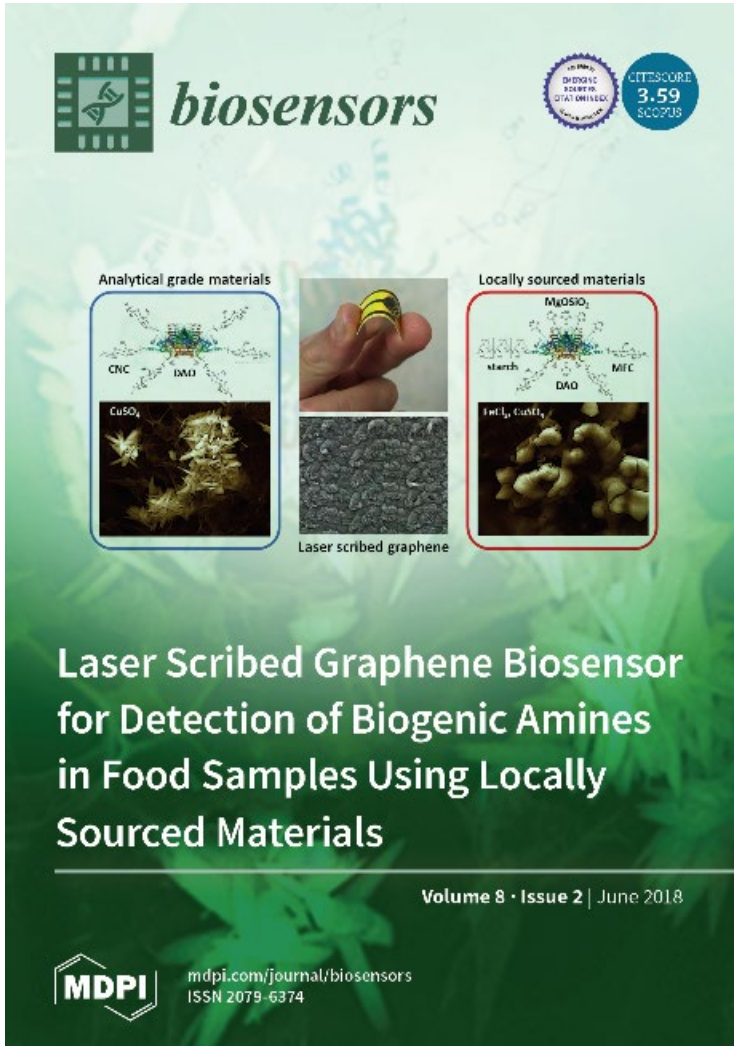
- Currently testing electrodes with smartphone potentiostat
  - Creating mobile apps, cybersecurity infrastructure

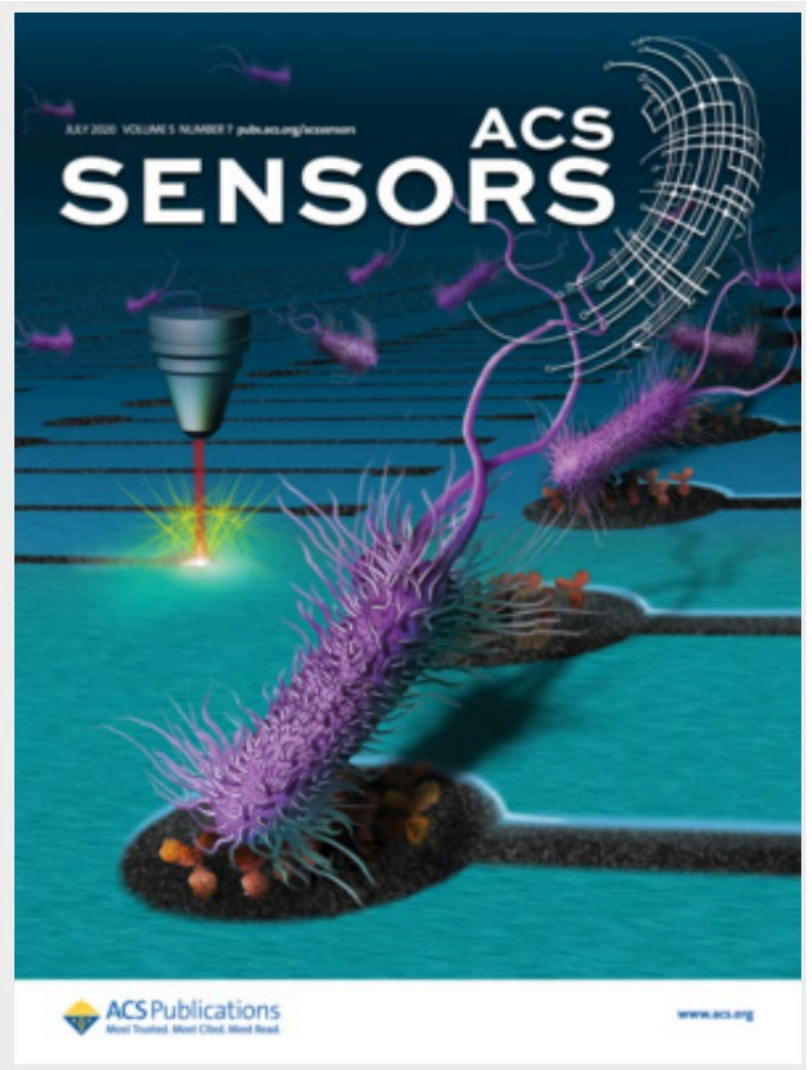




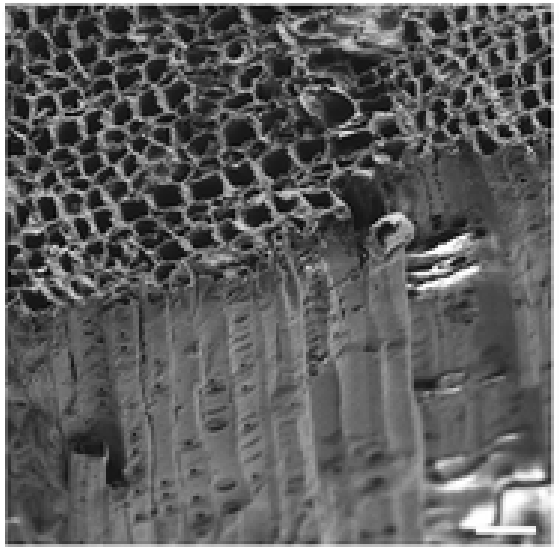
Vanegas, D. G. Clemson University.

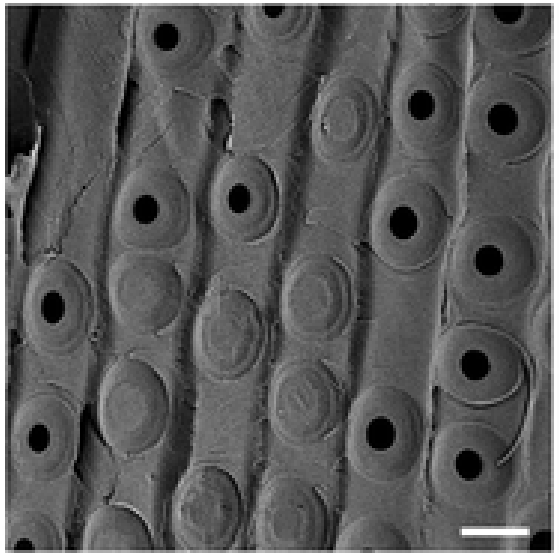
Nanotechnology-based tools for food and water safety in low-income communities… Definitely possible!





Water Filtration Using Plant Xylem from Karnik lab at MIT





Filter construction (Eastern White Pine)

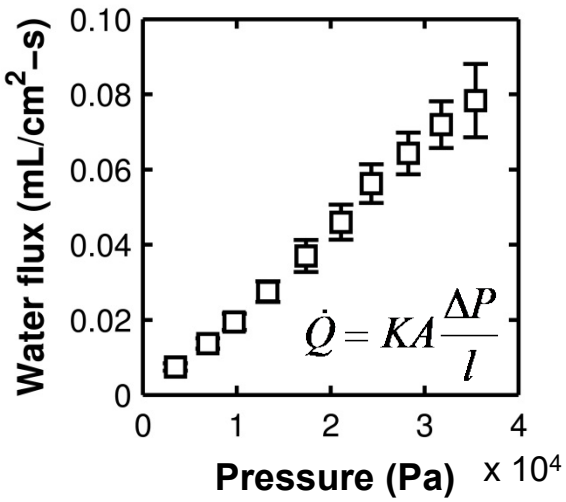
cut branch

peel off bark

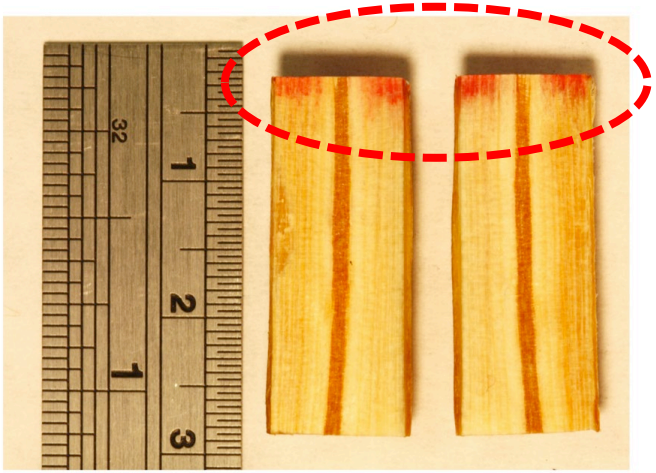
fasten into tube

xylem filter

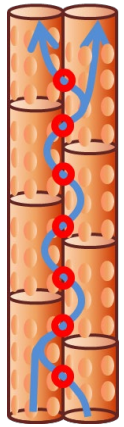
Water permeation



Cross-section after filtration



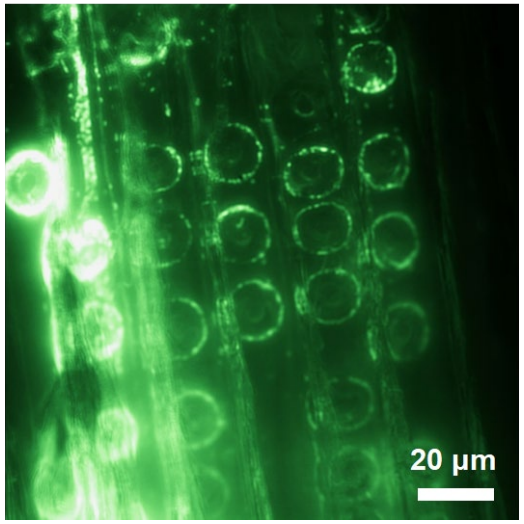
Ink filtered by top 2-3 mm, consistent with conduit length

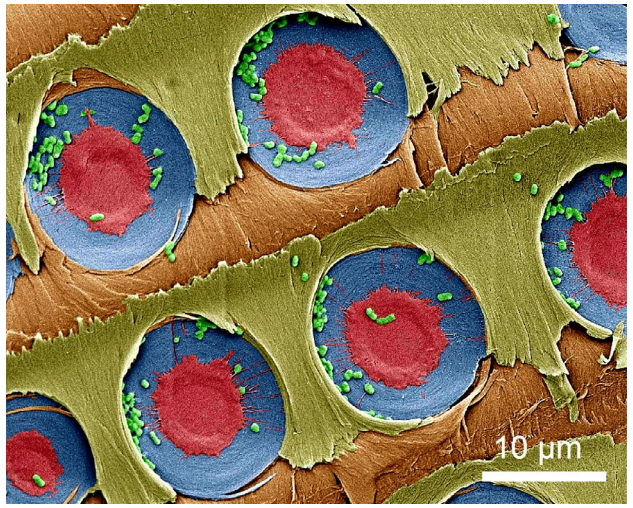


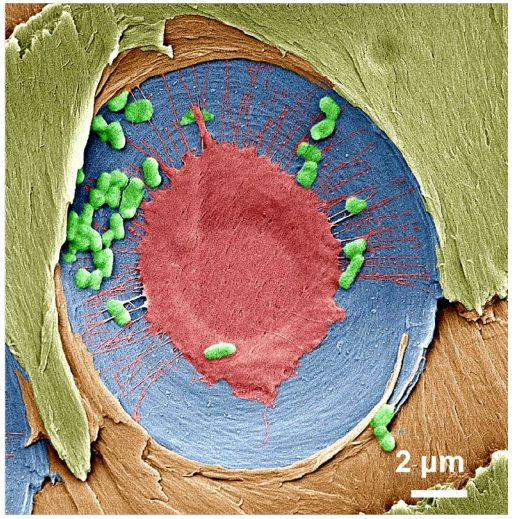
Boutilier, Lee et al *PLoS One* (2014)

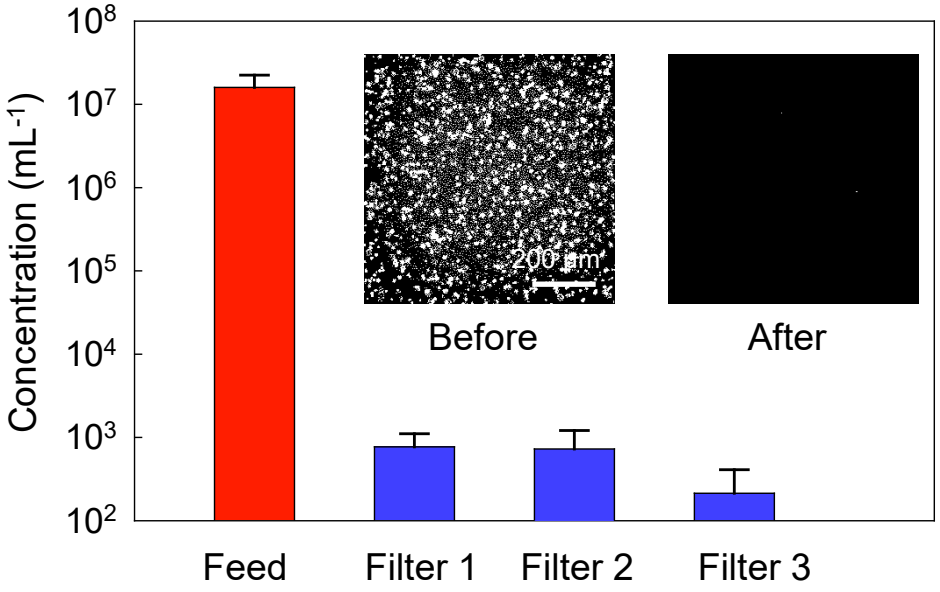
Filtration of bacteria from Karnik lab at MIT

- Fluorescently labeled inactivated *E. coli* (~1 μm)







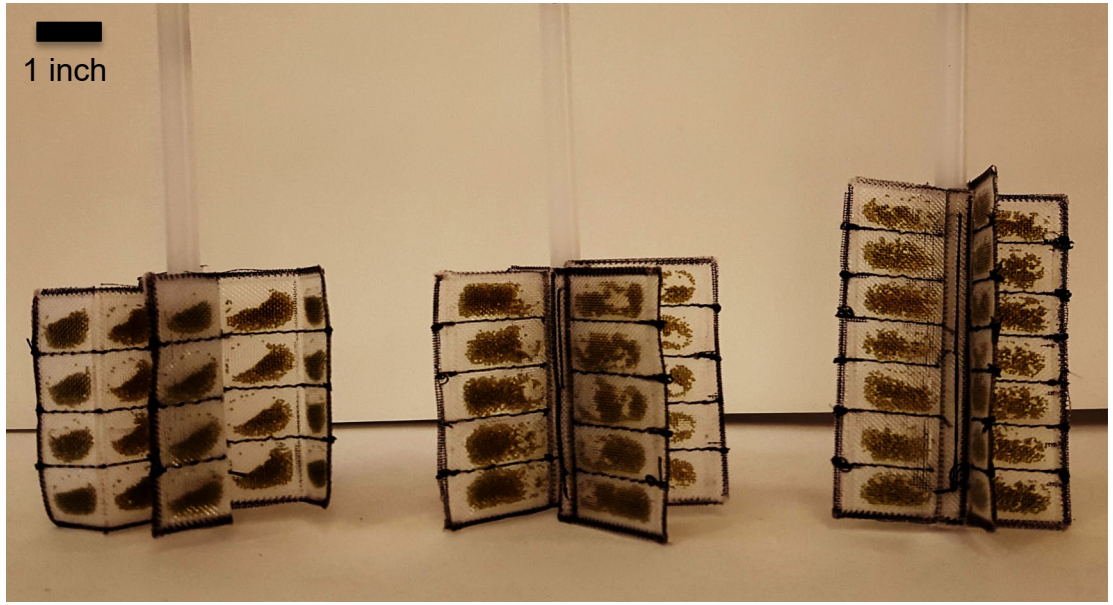


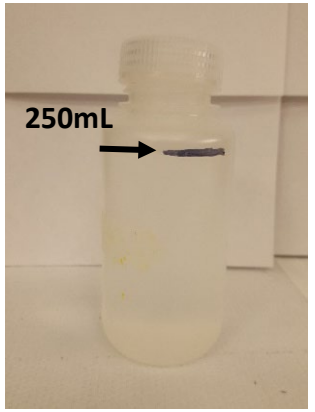
- *E. coli* were filtered within the top 2 – 3 mm of filter
- Hemacytometry showed > 99.99% rejection of *E. coli*
- 6 mm-long filter shows perfect rejection of 1 μm particles

Boutilier, Lee et al *PLoS One* (2014)

Point-of-use water sensors from Karnik lab at MIT

- Findings from fieldwork in India
- Current infrastructure is <u>unable to test</u> many trace pollutants of concern
  - Limited instrumentation at local labs
  - Inaccurate or nonexistent field test kits[1]
  - Difficulty sending samples to central labs





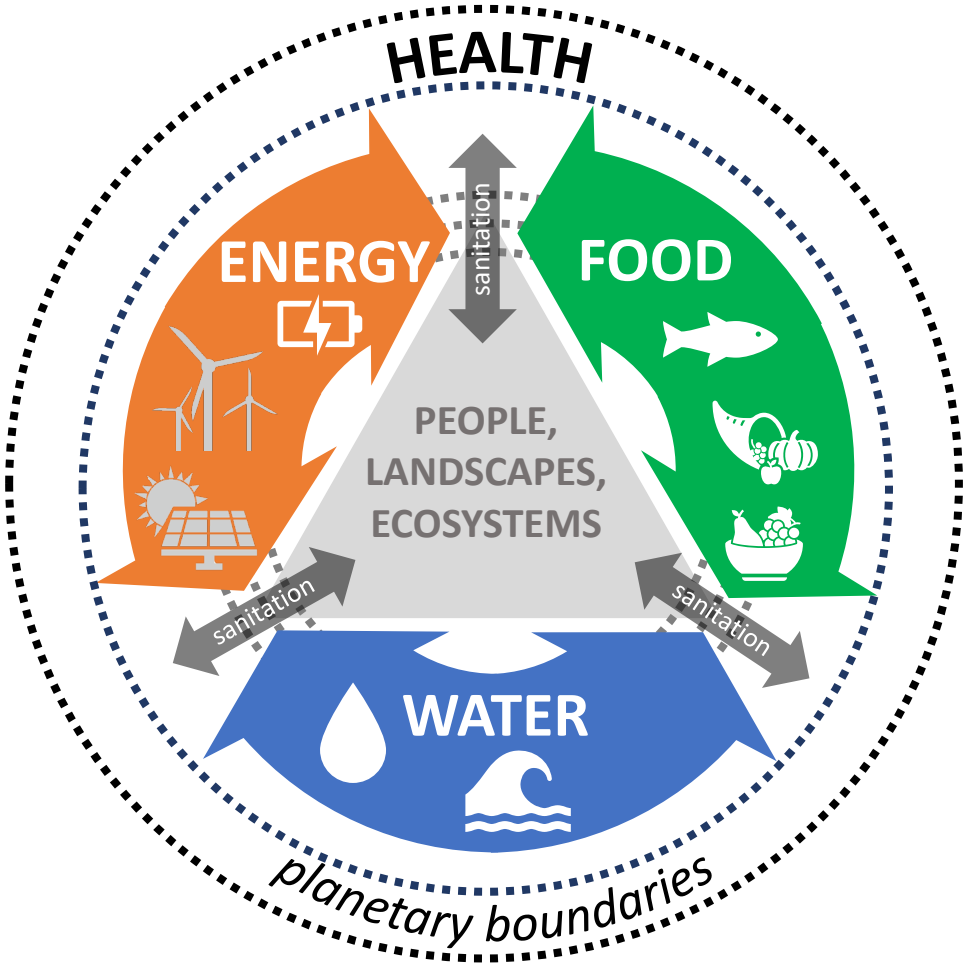
<u>Opportunity</u>: Preserve and forward bio/chemical information from local lab/source to state lab, where local analytical capability does not exist (heavy metals, arsenic, organics)

SUCCESS BEGINS WITH THE END IN MIND

- Are we asking good questions?
- Does this address the bottleneck?
- Is there a consumer benefit?
- What is the environment & safety impact?
- Is the approach efficient & scalable?

Opportunities and challenges are evolving

- Recent advancements in nanotech.
  - CRISPR-Cas9 is commonplace
  - Materials informatics is making leaps and bounds
  - Sensors for water quality tracing (irrigation to packaging)
  - IoT in ag/food has major momentum
- Persistent Challenges
  - Pre pandemic inequity
    - Billions lack safely managed drinking water, sanitation services, food to eat
  - Post-pandemic supply chains
    - Food-Energy-Water-Sanitation-Health (FEWSH) systems



FEWSH: Food-Energy-Water-Sanitation-Health

Systems-level analysis

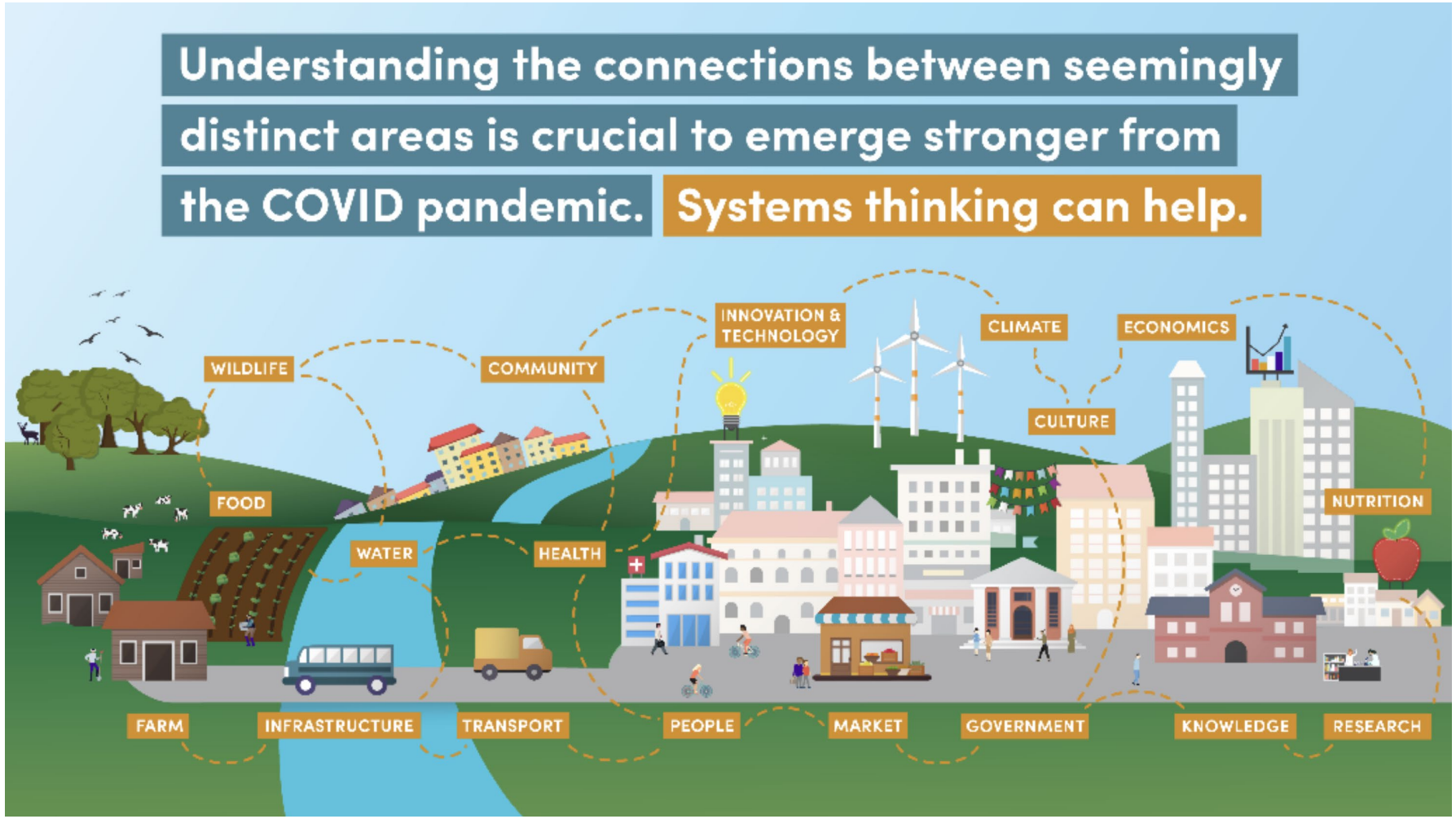
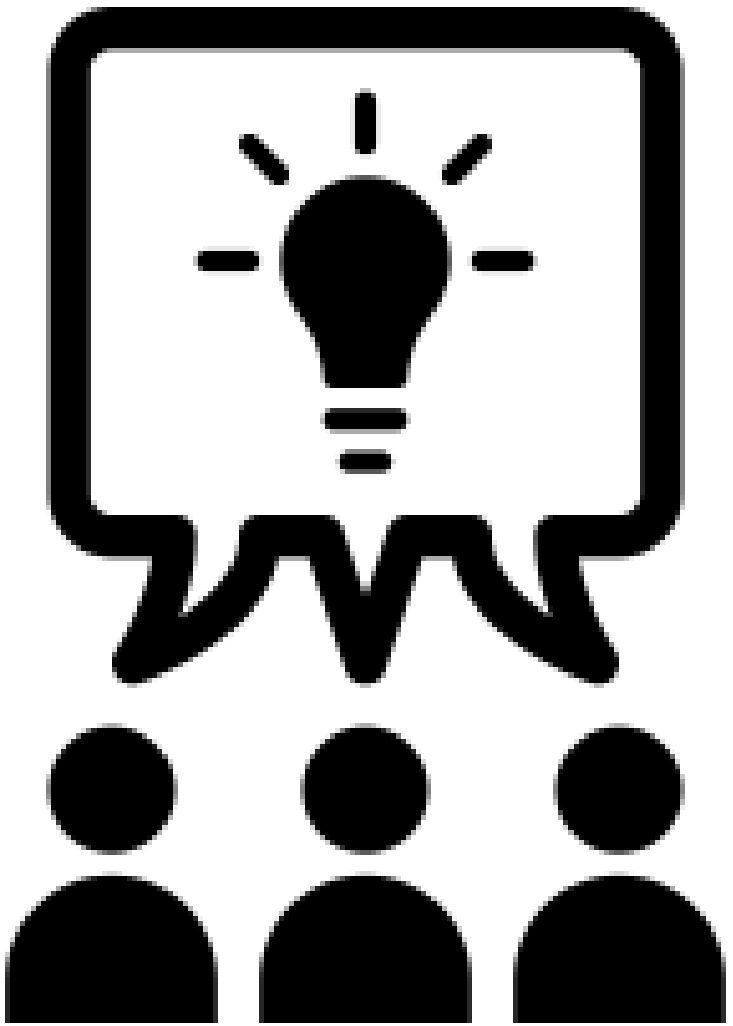


Image: Rockefeller Foundation and EcoAgriculture Partners

Concluding thoughts

- Trust the process
  - May not need to understand all the connections amongst the puzzle pieces
  - Must allow ourselves to be temporarily out of focus to see the problem anew
- Avoid biasing research question(s)
  - Ask questions at the most granular level possible
  - Utilize dynamic focus (multiple times)
- Systems thinking provides rich context
  - Loose connections amongst components reduces risk of catastrophic failure
  - Look for non-obvious relationships (threads)



Concluding/ongoing thoughts

- Different cultures have different values and that needs to be respected and embraced
- Working with nature instead of trying to outsmart it
- Food is more than fuel and indulgence to our bodies
- Nanotechnology portfolios are required to meet diverse stakeholder needs
  - Time is one of the most important factors in technology adoption/appropriation
  - Technologies come fast, but convergence usually don't
- Technology tradeoffs, *not tradeoffs of stakeholder needs*, necessary for adoption/appropriation
- Technology tools need to inform users about library of alternatives so that informed decisions can be made
- If a concerted, and *patient,* effort is made to initiate technology appropriation from the onset, libraries of technologies become available to the user based on mutual *trust*

Thank you for attending!

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