Use of Omics Methods to Enhance Food Safety

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Characterizing the microbiome of food and processing environments

- Describing microbiota changes over long storage times
- Quantifying the impact of processing activities to predict likelihood of food safety incidents
- Microbiome mapping of processing environments

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Photo credits: Dr. Alexis Hamilton, Alex Hood, Max Esterhuizen (Virginia Tech)

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  - Providing supplemental slides with additional resources
- Only discussing content from partnerships or projects that are publicly available
  - Published
  - Open access

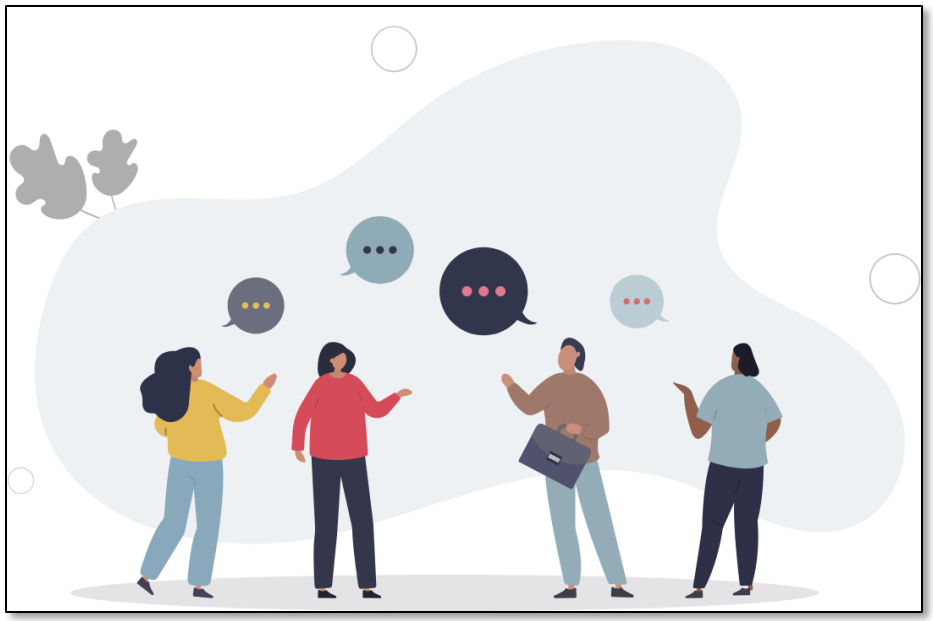
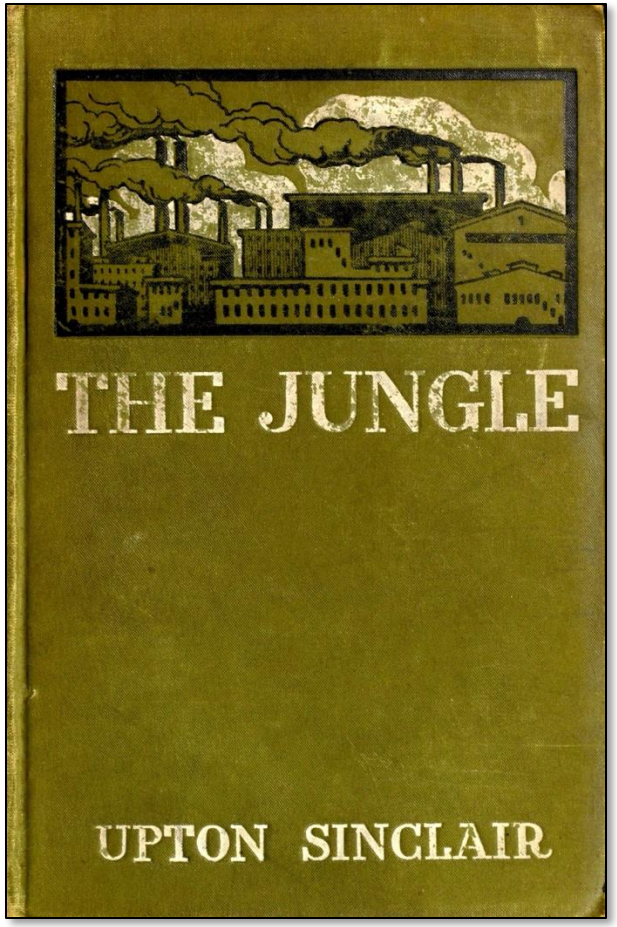


Photo credit: Canva

Before the age of food safety

- Foods and drugs were largely unregulated in the 1900s
- Upton Sinclair brought to light unsafe and insanitary practices used in the Chicago meat packing industry
  - Selling rotten or diseased meat
  - Contained remains of rats
- The Pure Food and Drug Act of 1906 and other regulations that set the stage for the regulatory landscape of the food industry today



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The food industry had a problem

Testing 100% of your food product

Testing some of your food product (based on probability)

No testing of your food product or the process

History of HACCP

1960's

It all begins: NASA and the US army implement food safety requirements for the United States space program in the form of a HACCP system

1970's

1971 - HACCP was presented to the food industry through the National Conference on Food Protection

1980's

1983 - WHO Europe endorsed the use of HACCP

1985 - NACMF was established and formed several publications on HACCP

1990's

1990 - EU makes having a HACCP plan a legal requirement for food businesses

1992 - NACMF presented the 7 core principles of HACCP

1993 - Major high-risk profile outbreaks that led to the mandatory implementation of HACCP

1994 - The International HACCP Alliance was established

2000's

First Windows HACCP solution sold to online customers

Began as a partnership between Pillsbury, the Natick Army Laboratory, and NASA to ensure foods would be safe to consume by astronauts in space

FoodDocs Food safety made easy

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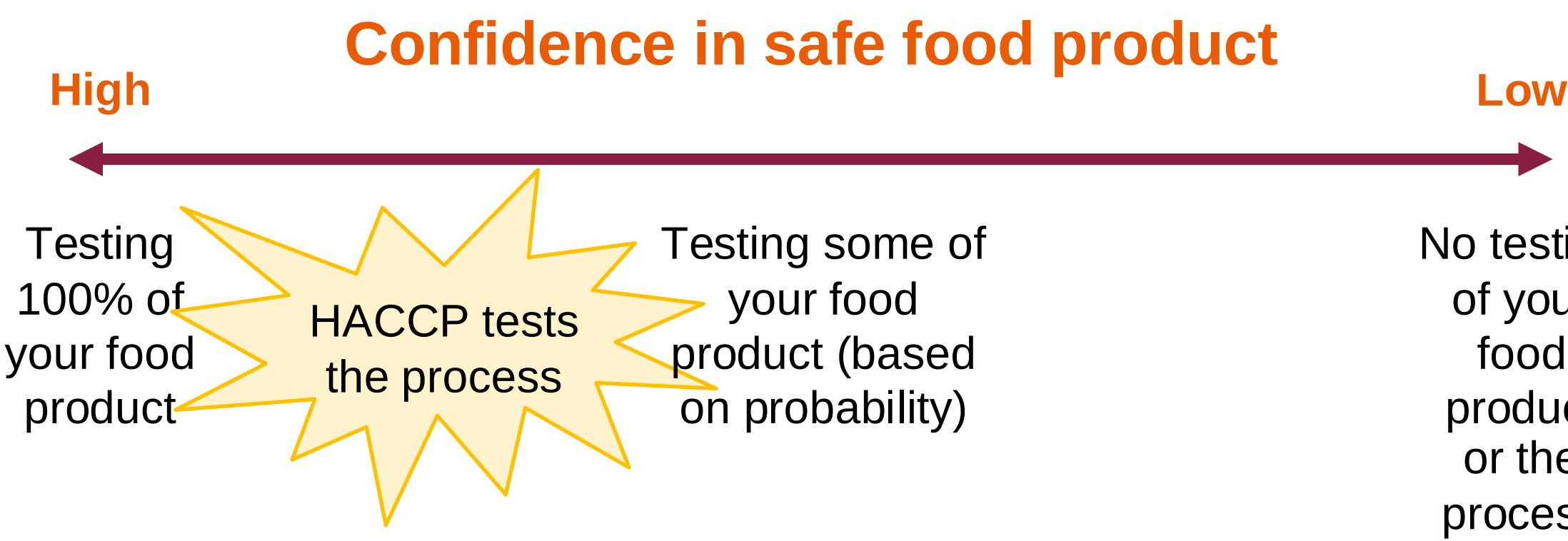
Photo credit: FoodDocs, U.S. Army, Earth.com, ebay

Does anyone know what we credit as being the first food in space?


Delicious with Breakfast
Delicioso con el desayuno
TANG
ORANGE NARANJA
Vitamin C
Calcium
MAKES 22 QUARTS
RINDE CUARTOS

What makes HACCP so innovative?



If you know the process is safe and you can prove that you follow the process, it is very likely that your food is also sa

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That's still not good enough

- Food Safety Modernization Act (FSMA) of 2011 now requires the food industry to be **proactive** and make **risk-based decisions about safety** before a safety issue occurs
  - "Safety critical decision making"
- Omics methods are one way the food industry has evolved to meet this charge

Photo credit: Obama White House Archives

FDA and CDC partnerships to conduct outbreak investigations

Key question: Can we establish relatedness between food products, environments, and clinical outbreaks to improve outbreak detection?

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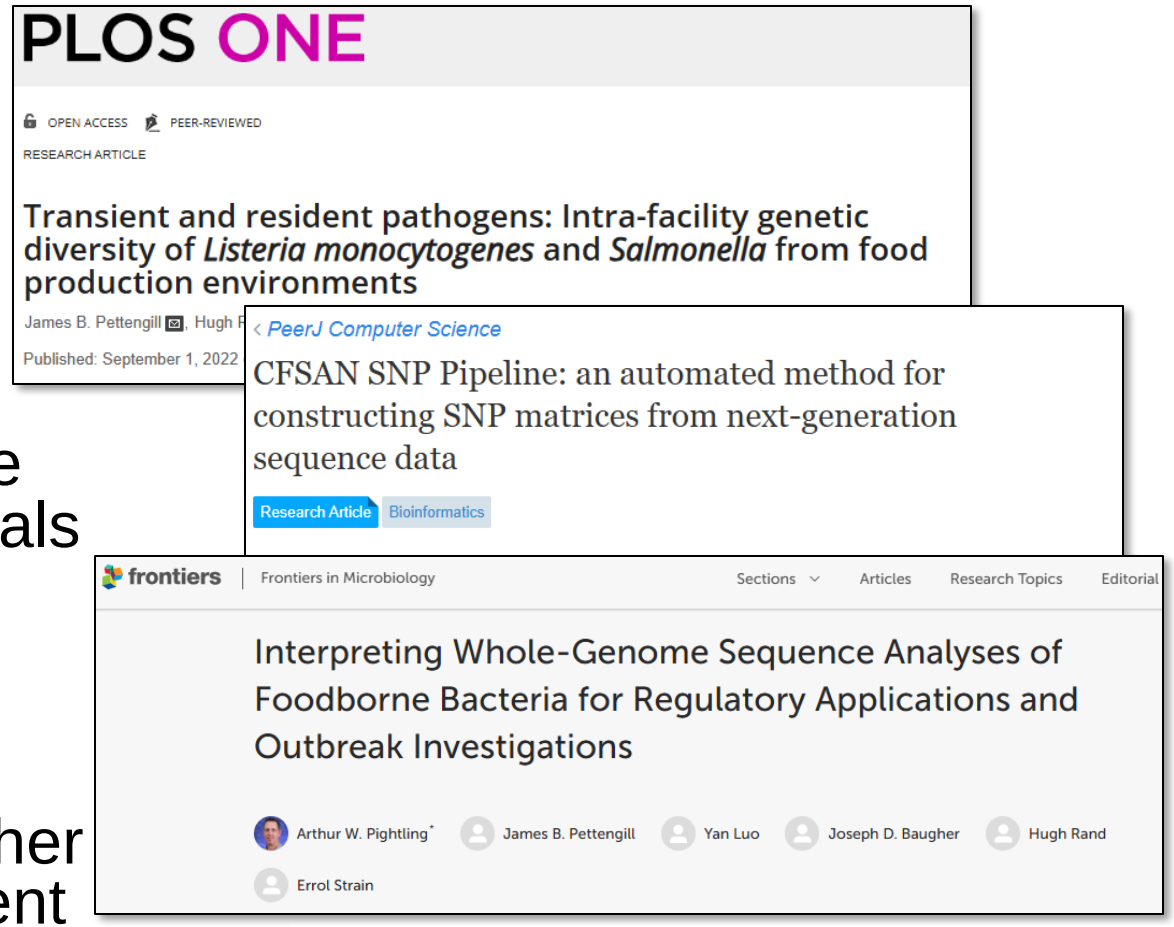
Whole genome sequencing (WGS) for surveillance

- Daily surveillance of public database to identify FDA regulated product genomic matches
  - Notifies the Office of Compliance and CORE about emerging signals
- Assist in calls with firms to educate on the use of and results of WGS
  - WGS is used to determine whether an isolate is a transient or resident strain



Slide credit: FDA

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Quasi-metagenomics and outbreak investigations

- 2010-2015 listeriosis outbreak that infected 10 people
- Quasi-metagenomics approach to identify pathogen-commodity-facility relationships in outbreak investigations
  - Enriched to improve detection
  - Intended to be culture independent

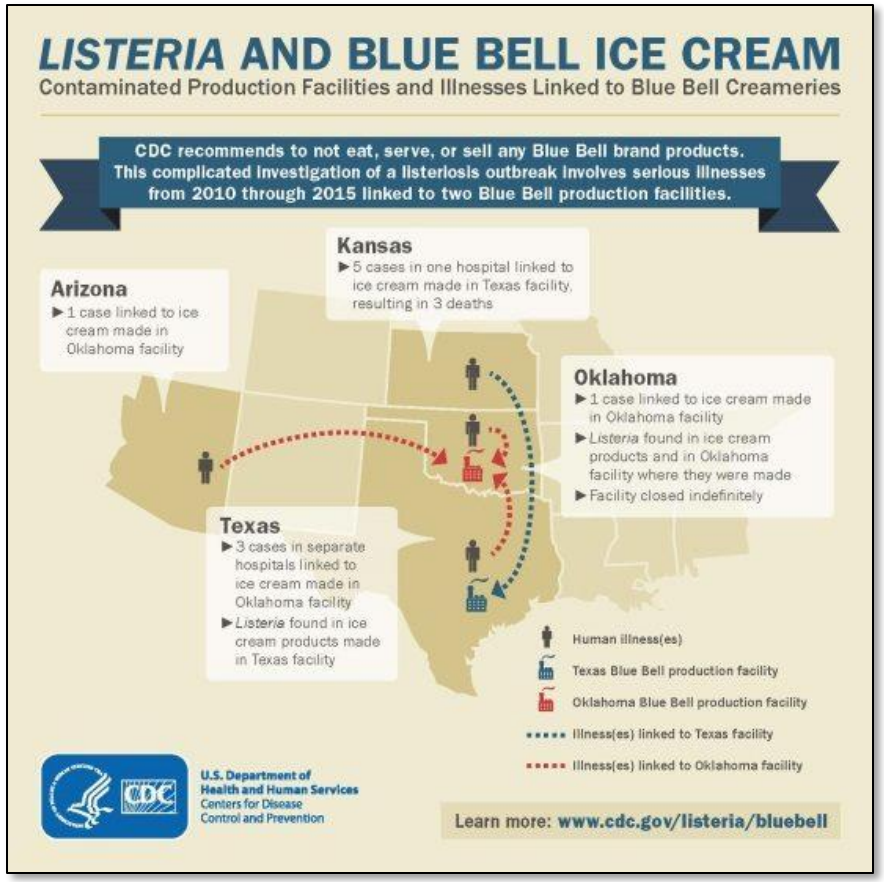

Photo credit: CDC

Screening the pet food microbiome to detect population shifts indicative of safety concerns

Key question: can we identify differences in composition that correlate to safety concerns?

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What did they set out to do?

- 2015: partnership between IBM Research and Mars, Inc.

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Photo credit: NASA, Emojis.wiki

What did they set out to do?

- 2015: partnership between IBM Research and Mars, Inc.
- Sequencing samples from pet food ingredients
  - Traditional methods require sampling for one pathogen at a time
  - Endeavored to sample for multiple pathogens at once (metagenomics)

"We wanted something more predictive, a preventative approach rather than reactive."
-Bob Baker

Photo credit: Mars, Inc.

What did they find?

- Shifts in the microbial community corresponding to ingredient composition differences
- *Salmonella* growth didn't correlate with multiple sequence analysis
- Microbiome sequencing is useful to characterize complex food microbial communities

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Monitoring the microbiome for food safety and quality using deep shotgun sequencing

Kristen L. Beck ✉, Niina Haiminen, David Chambliss, Stefan Edlund, Mark Kunitomi, B. Carol Huang, Nguyet Kong, Balasubramanian Ganesan, Robert Baker, Peter Markwell, Ban Kawas, Matthew Davis, Robert J. Prill, Harsha Krishnareddy, Ed Seabolt, Carl H. Marlowe, Sophie Pierre, André Quintanar, Laxmi Parida, Geraud Dubois, James Kaufman & Bart C. Weimer ✉

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Photo credit: Nature Partner Journals *Science of Food*

How have they used these data?

- Partnerships to create omics analysis platform
- Developed a contamination filtering step to improve microbial classification by greater that 99.9%
- Sequencing of 35,000 genomes
- Mining these data to identify, interpret, and create microbial risk management systems

Photo credit: PIPA

Efforts to map the microbiome in food processing environments

Key question: can we identify core built environment compositions that can be manipulated to ensure safety?

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What did they set out to do?

- Core vs. accessory microbiomes
  - Core: same genes in all samples evaluated
  - Accessory: target genes only present in some strains
- Environment vs. food microbiomes
  - Products: apples, cheese, meats, produce, seafood, etc.

What did they find?

- Most taxa found in processing environments are found in food products produced in the same facility
- Amplicon-based sequencing may be more appropriate for establishing routine control
  - Shotgun sequencing may be more appropriate when deeper level of information is needed
- Activities in these environments impact the structure and resilience of the microbiome

Summary

- The food industry has adapted extremely quickly to develop and use omics methods to improve preventive, risk-based decision-making
- Omics methods have successfully been used to enhance food safety outcomes
- The ability to reliably predict safety incidents will likely require continued augmentation of existing methodologies

Thank you!

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