Microbial Threats to Food System in the Age of Big Data

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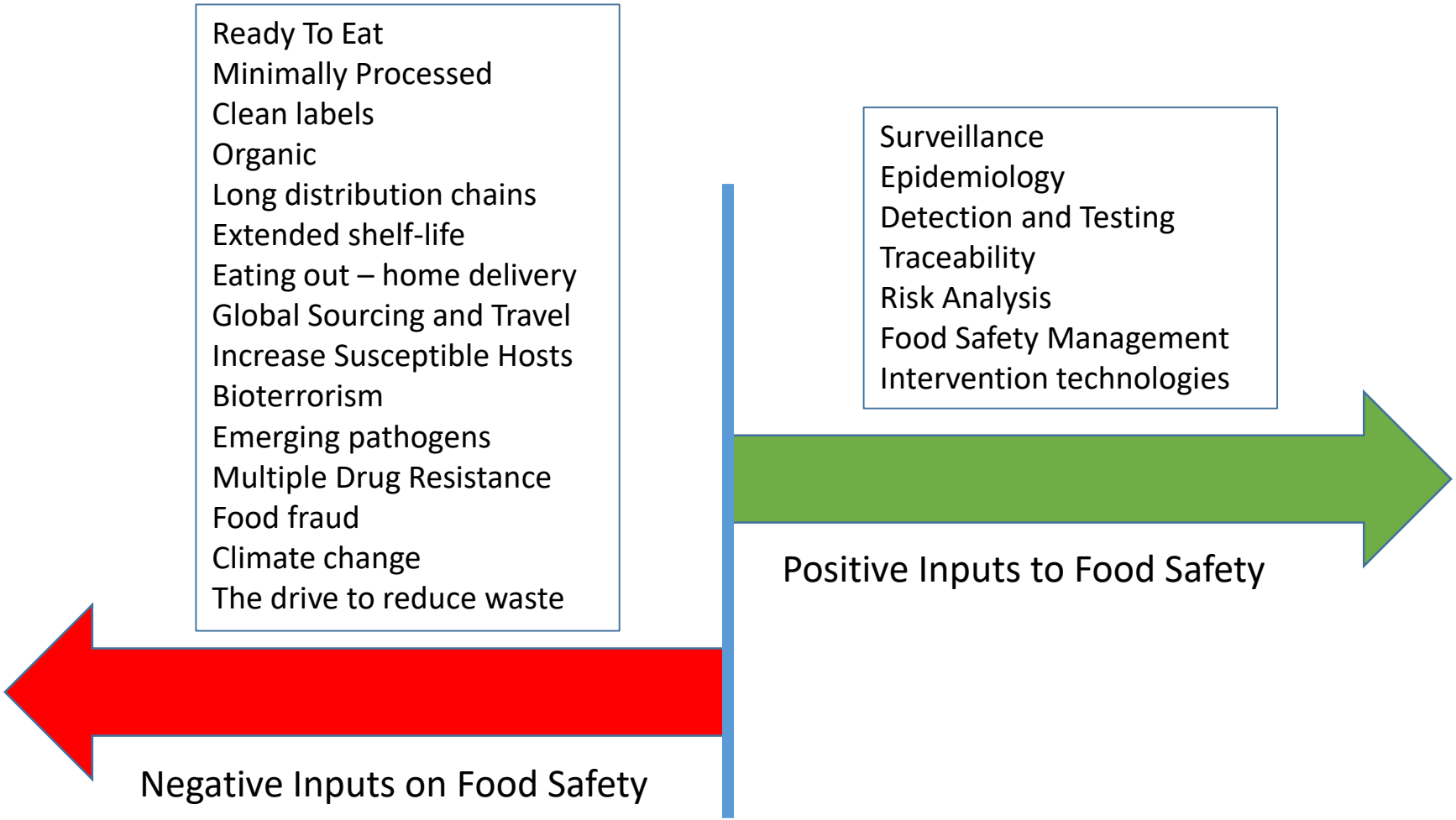
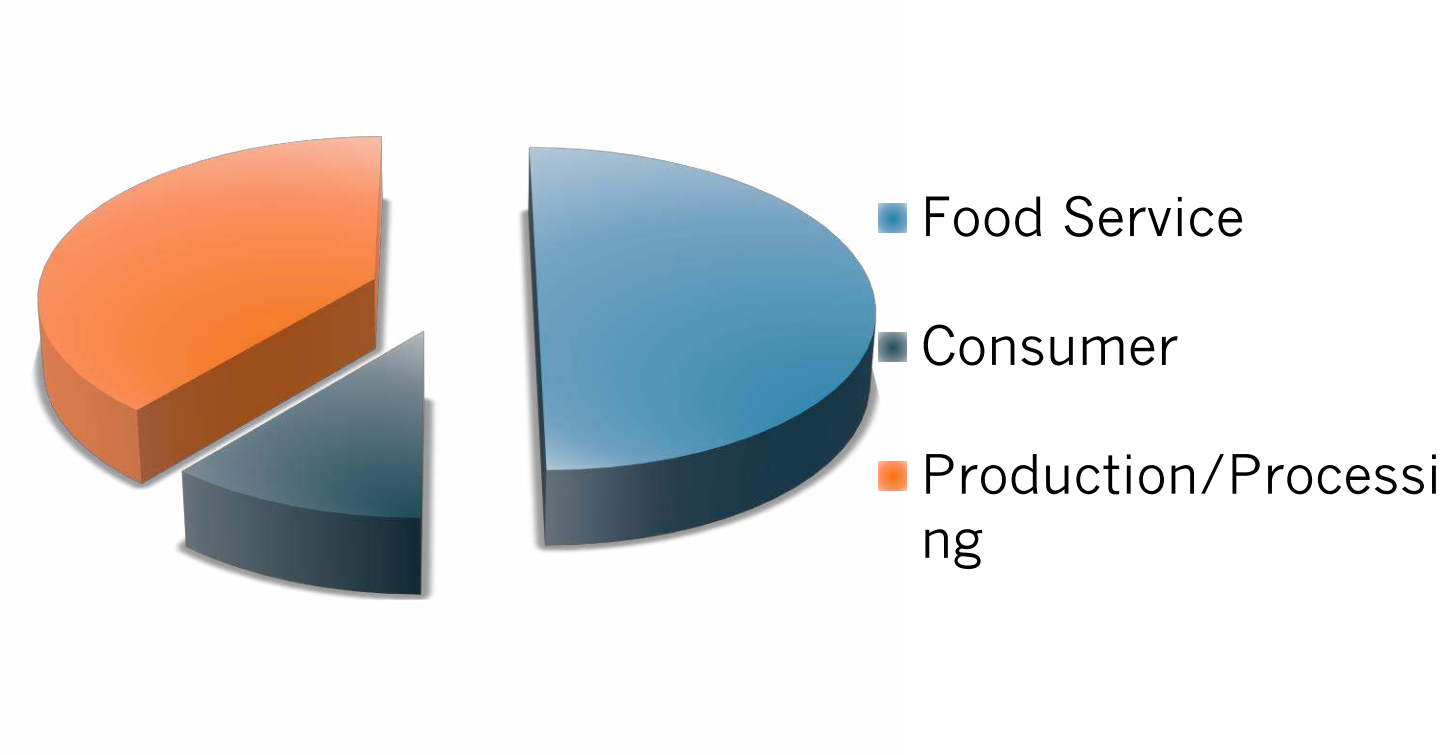
DEPARTMENT OF
FOOD SCIENCE


Ready To Eat
Minimally Processed
Clean labels
Organic
Long distribution chains
Extended shelf-life
Eating out – home delivery
Global Sourcing and Travel
Increase Susceptible Hosts
Bioterrorism
Emerging pathogens
Multiple Drug Resistance
Food fraud
Climate change
The drive to reduce waste
Negative Inputs on Food Safety
Surveillance
Epidemiology
Detection and Testing
Traceability
Risk Analysis
Food Safety Management
Intervention technologies
Positive Inputs to Food Safety

Source of Pathogens



Consumers

- Increase in susceptible “ageing” population
- Clean labels and “natural” products
- Antibiotic and GMO free
- Organic
- Food fads
- Eating outside the home
- All year round availability and diversification of products
- Social media and reporting
- Transition from Germophobia to Micromania

‘Raw water’ is the latest pseudo-scientific craze that could make you sick

Drinking 'raw water' could cause raw diarrhea

By Rachel Becker | @RA_Becks | Jan 1, 2018, 5:16pm EST

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Cooking With Your Mouth: Why using a knife for chopping your carrots is so last year

Tony Turnbull on the viral video that recommends chewing instead

Food Safety Culture Remains an Issue

Retailers

- Leading the narrative on food safety
- Mini-processing facilities (in store prepared)
- Increased food safety risks (*Listeria monocytogenes*)

FSIS Best Practices Guidance for Controlling Listeria monocytogenes (Lm) in Retail Delicatessens

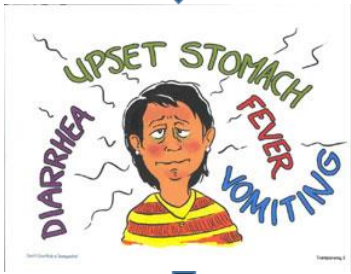
This guidance document provides specific recommendations for actions that retailers can take in the delicatessen (deli) area to control *Listeria monocytogenes* (*Lm*) contamination of ready-to-eat (RTE) meat and poultry products. This document is also available in PDF

Tracking the Source of Pathogens

- Food safety policy remained the same for 40 years
  - Prevent pathogens reaching the consumer

- Public Health: At best find the food vehicle but not original source

?



?

Rapid Spread

- Zoonotic pathogen
- Avian flu
- Blue tongue disease
- Swine influenza

Bacterial

*Arcobacter butzleri**
*Campylobacter jejuni**
*Campylobacter fetus**
Cronobacter sakazakii
E. coli O157:H7*
E. coli, non-O157 STEC*
E. coli, enteroaggregative/STEC
E. coli, other diarrheagenic
*Listeria monocytogenes**
Vibrio cholerae O139, toxigenic*
*Vibrio vulnificus**
*Vibrio parahaemolyticus**
*Yersinia enterocolitica**
*Yersinia pseudotuberculosis**

Algal

*Pseudo-nitzschia pungens** (domoic acid-producing)

Parasitic

*Cryptosporidium**
Cyclospora cayetanensis
*Sarcocystis**

*Trypanosoma cruzi**

Viral

Astrovirus
Caliciviridae (norovirus and sapovirus)
Hepatitis E*
Nipah virus*
Rotavirus

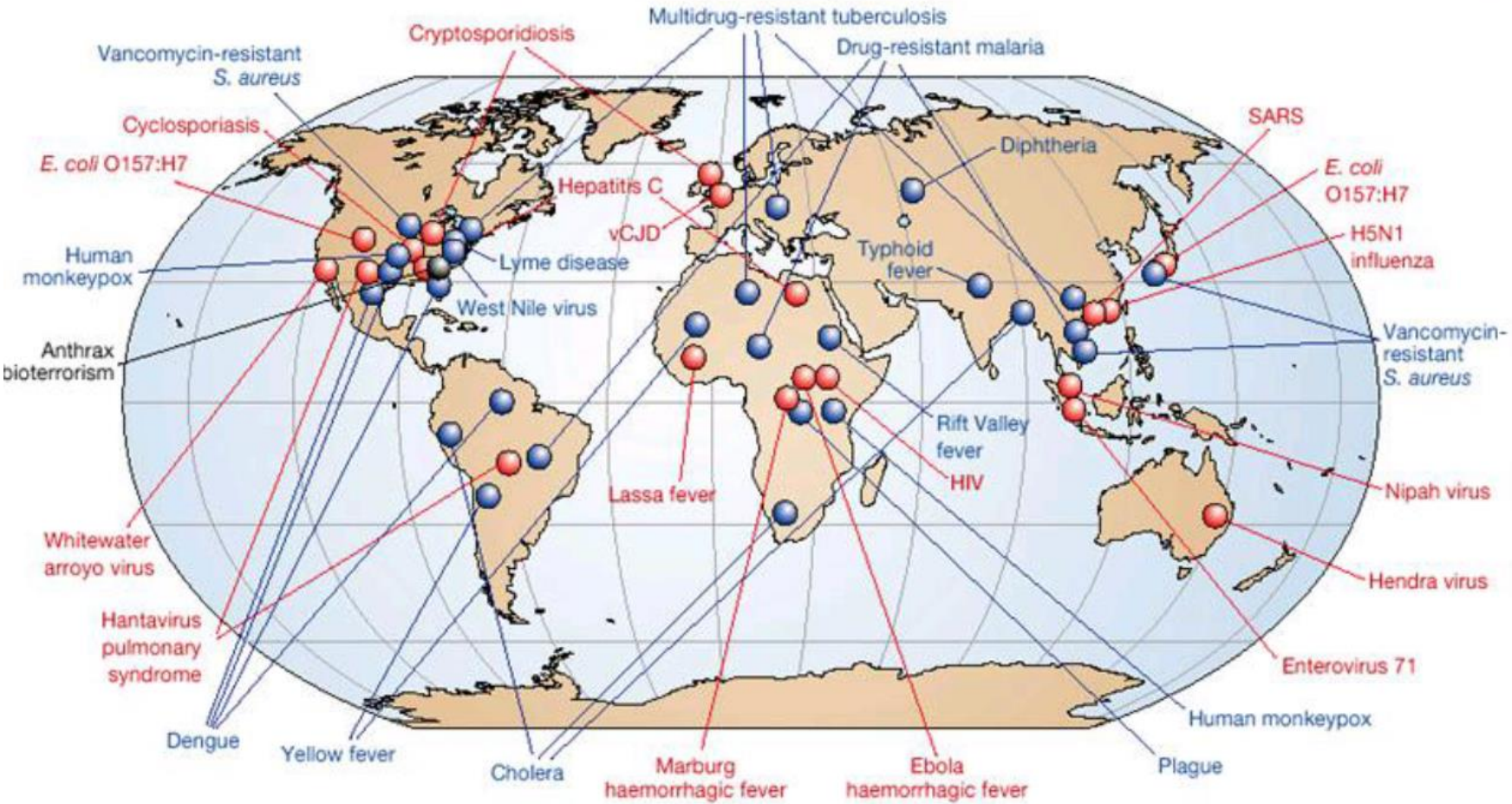
Fungal

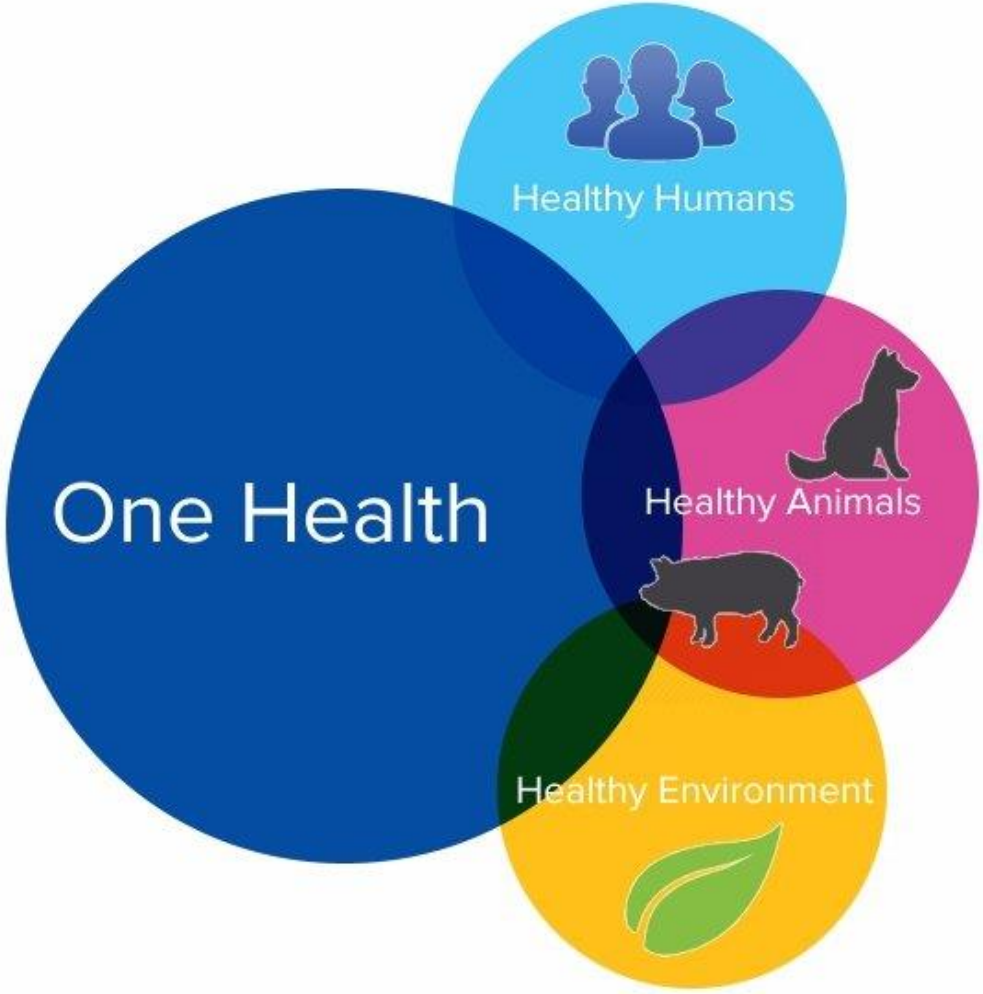
Aspergillus flavus aflatoxin

Prion Agent

new Variant Creutzfeld Jacob Disease prion*

Global examples of emerging and re-emerging infectious diseases.




Healthy Humans
One Health
Healthy Animals
Healthy Environment

Antibiotic growth promotors are being phased out

Positive

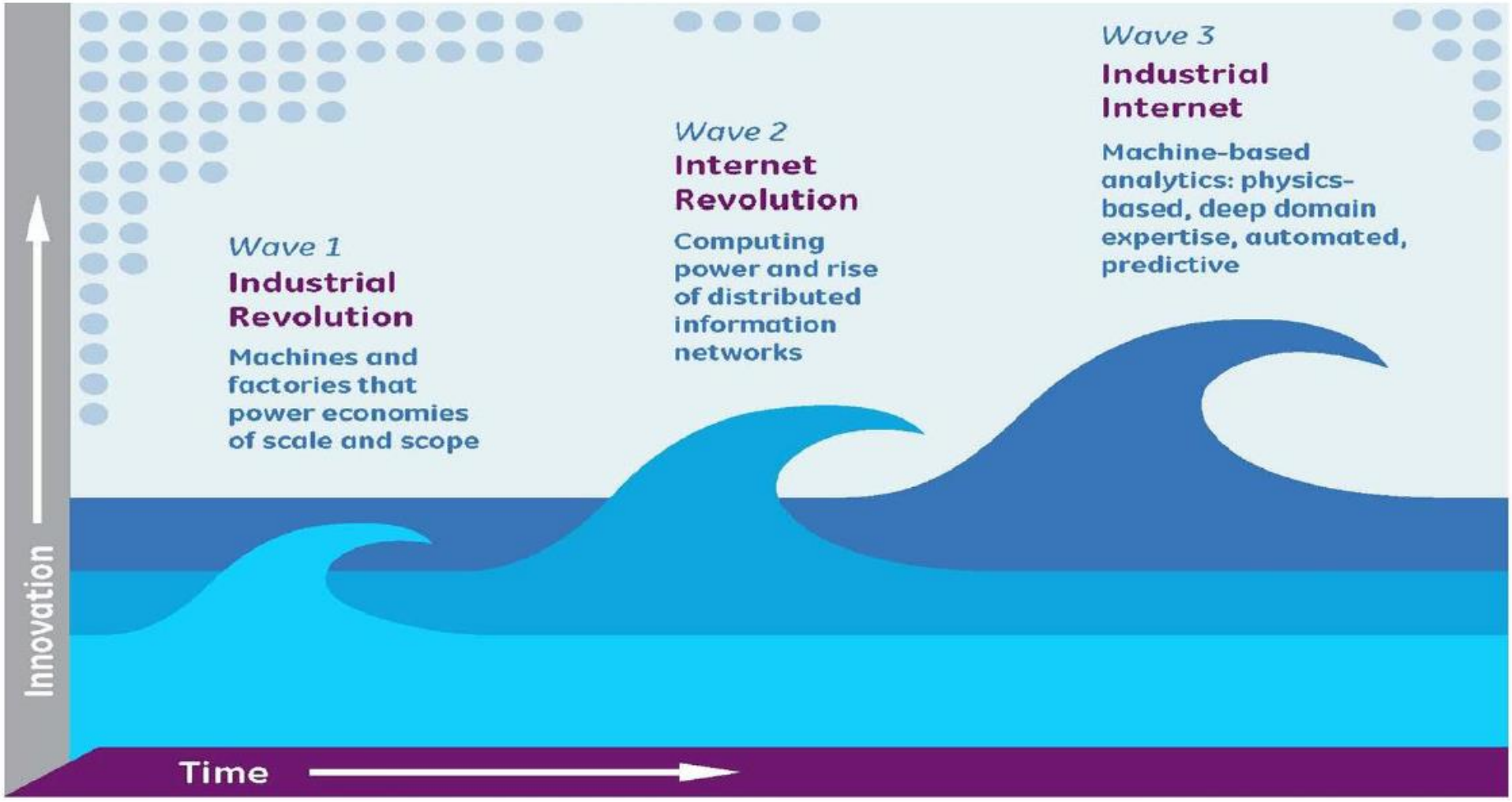
- Be in-line with consumer expectation
- Available antibiotics are becoming ineffective
- Reduce prevalence of multi-drug resistant pathogens

Negatives

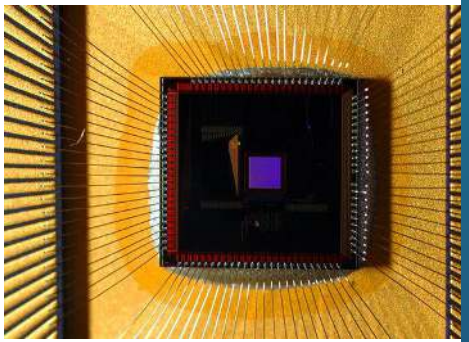
- Animal welfare
- Increased mortality
- Increase prevalence of pathogens
- Lower growth rates
- Lack of alternatives

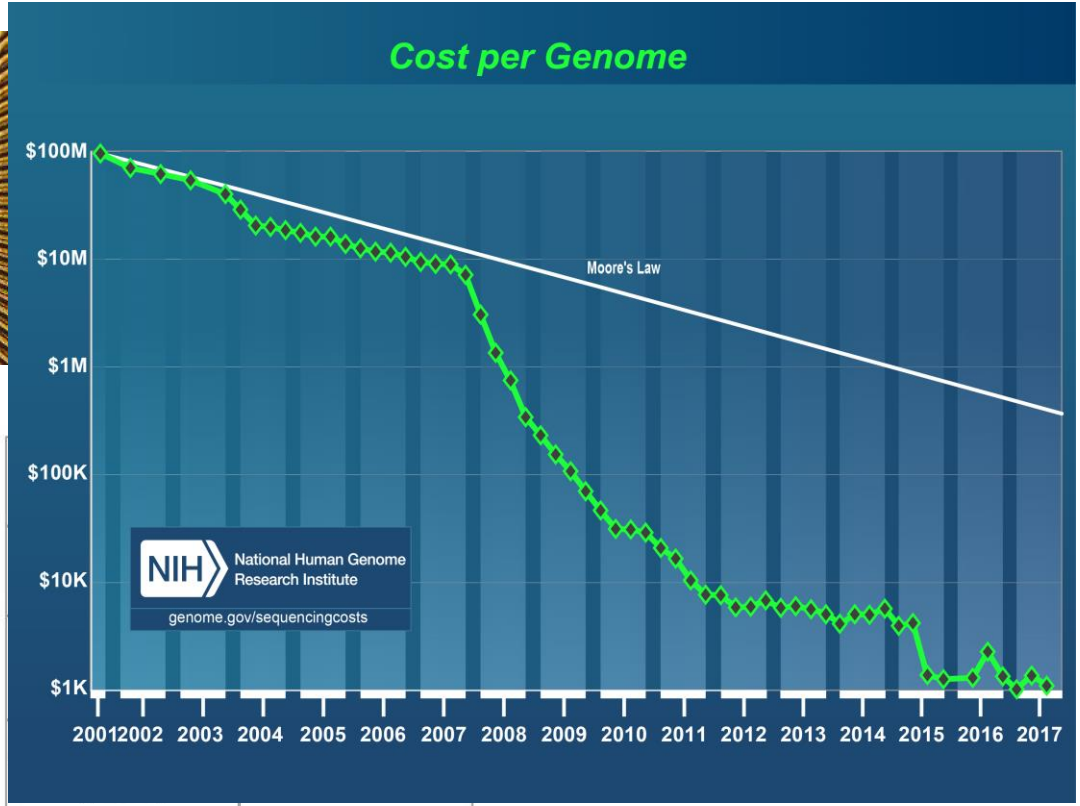
There is a better way

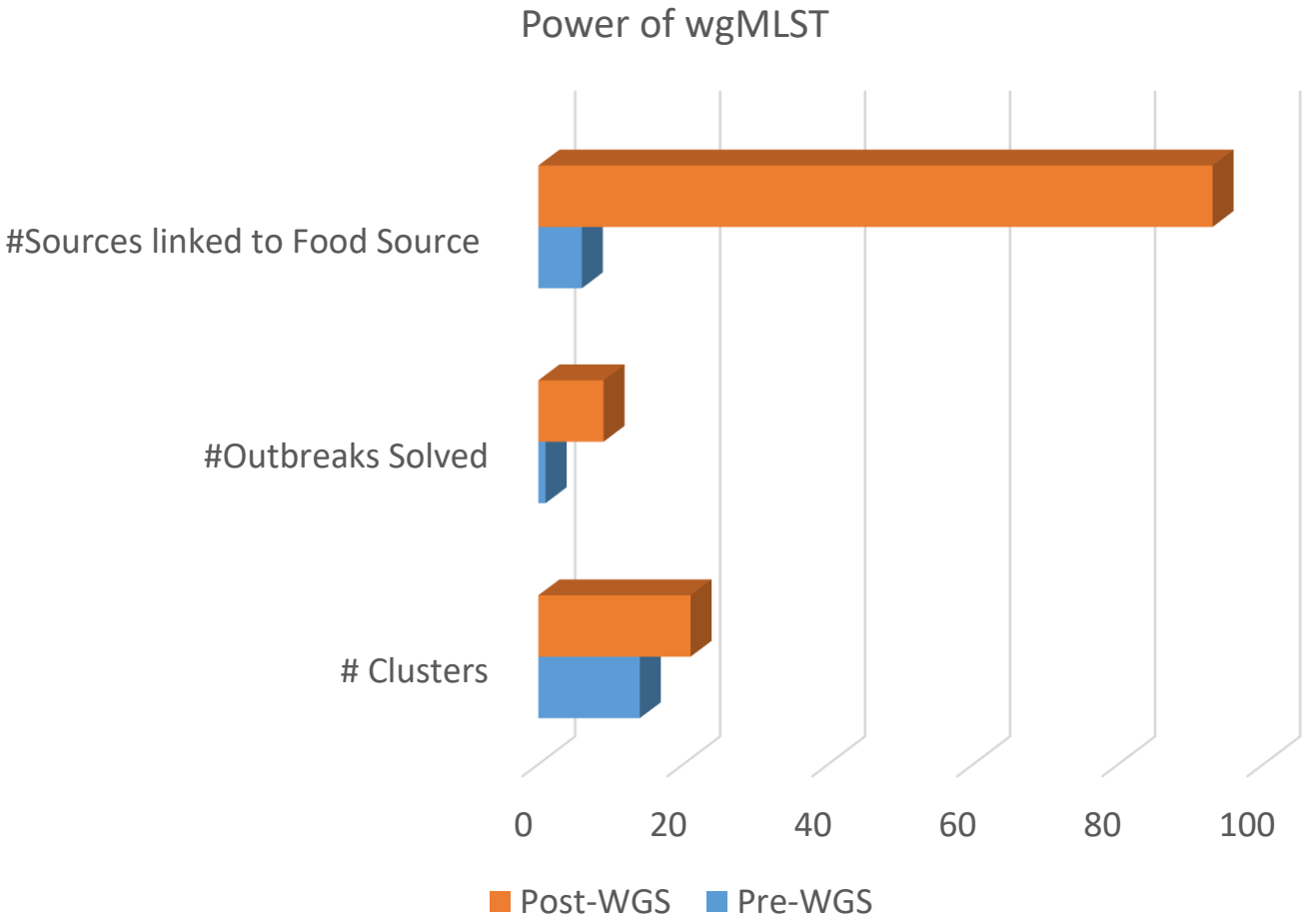
- Antibiotics used in combination with other antimicrobials: Bacteriophages
- Vaccination programs
- Reduced animal movement
- Management practices
- Waste management practices
- Biosecurity
- Biological/Probiotic solutions
- Change the way animals are produced


Wave 1
Industrial Revolution
Machines and factories that power economies of scale and scope
Wave 2
Internet Revolution
Computing power and rise of distributed information networks
Wave 3
Industrial Internet
Machine-based analytics: physics-based, deep domain expertise, automated, predictive
Innovation
Time

DNA Sequencing






Power of wgMLST
#Sources linked to Food Source
#Outbreaks Solved
Clusters
0
20
40
60
80
100
Post-WGS
Pre-WGS

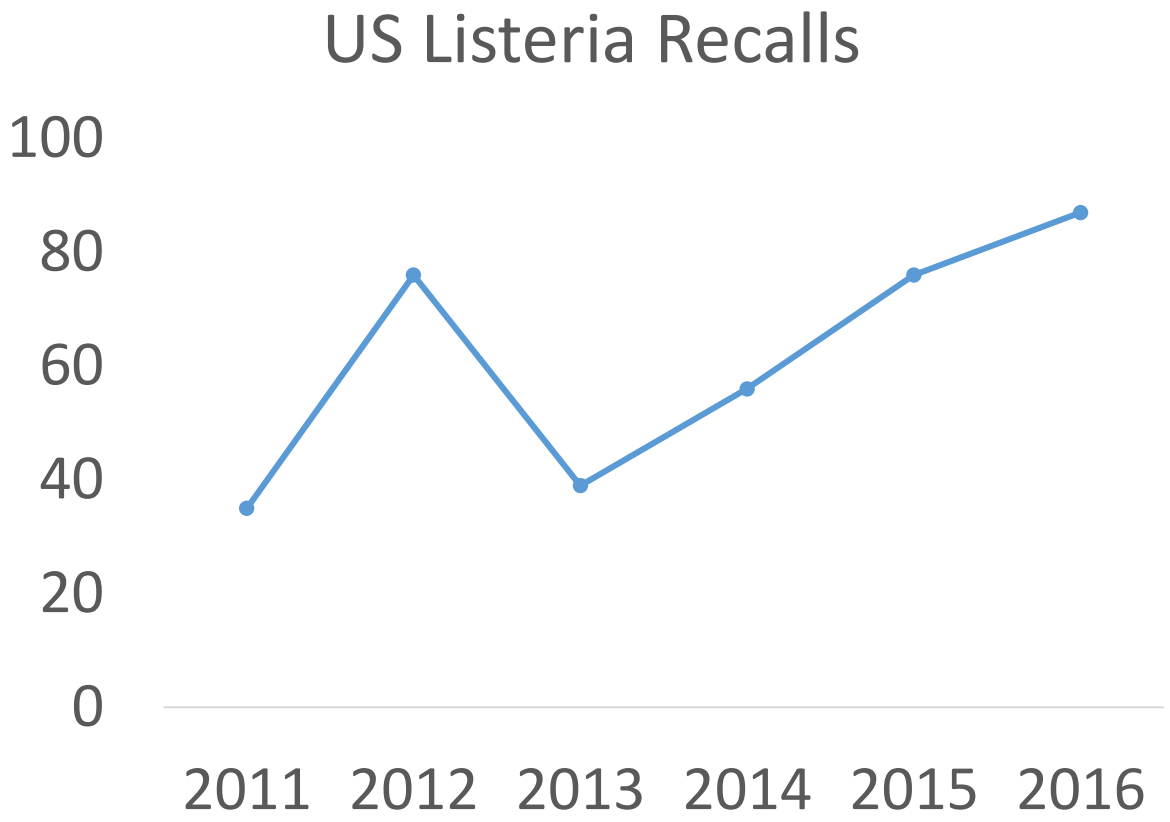
Outbreaks Rapidly Identified using WGS

- Blue Bell Ice cream

- Candy Apples

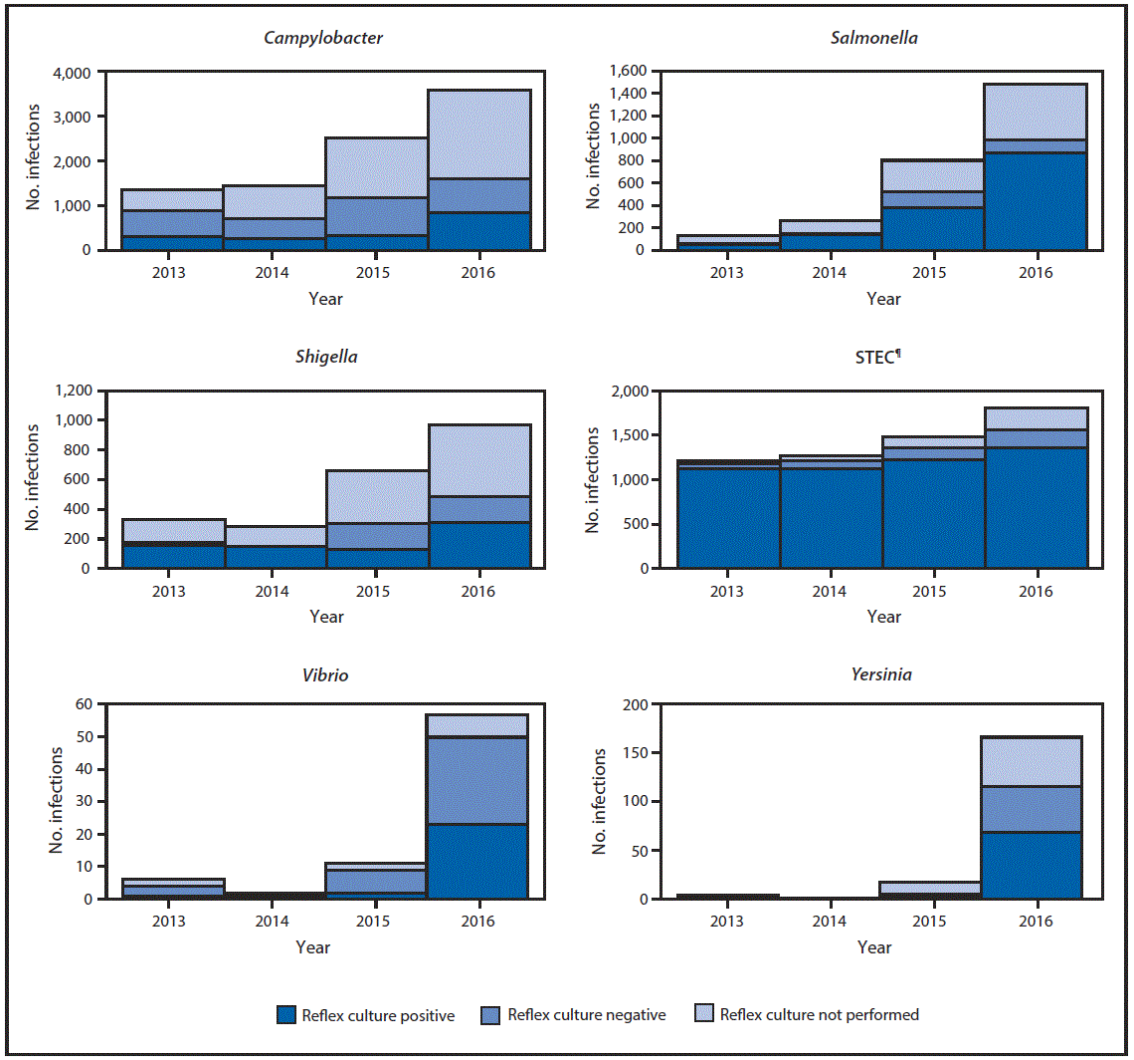
Identified unusual food vehicles

- Flour – *E. coli* O121 and *E. coli* O126
- Frozen pizza – *E. coli* O157:H7
- Coconut – *Salmonella*
- Fruit cream bars – *Listeria monocytogenes*
- Shredded coconut – *Salmonella*
- Biscuits – *Listeria monocytogenes*
- Apple slices – *Listeria monocytogenes*
- Pancake mix – *Listeria monocytogenes*


US Listeria Recalls
100
80
60
40
20
0
2011
2012
2013
2014
2015
2016

Implications of Improved Diagnostics

- Early detection of foodborne illness outbreaks
- Increased probability of source attribution
- Increase in product recalls
- Identification of unusual food vehicles
- Screening positive – culture negative


Campylobacter
No. infections
4,000
3,000
2,000
1,000
0
2013
2014
2015
2016
Year
Salmonella
No. infections
1,600
1,400
1,200
1,000
800
600
400
200
0
2013
2014
2015
2016
Year
Shigella
No. infections
1,200
1,000
800
600
400
200
0
2013
2014
2015
2016
Year
STEC¶
No. infections
2,000
1,500
1,000
500
0
2013
2014
2015
2016
Year
Vibrio
No. infections
60
50
40
30
20
10
0
2013
2014
2015
2016
Year
Yersinia
No. infections
200
150
100
50
0
2013
2014
2015
2016
Year
Reflex culture positive
Reflex culture negative
Reflex culture not performed

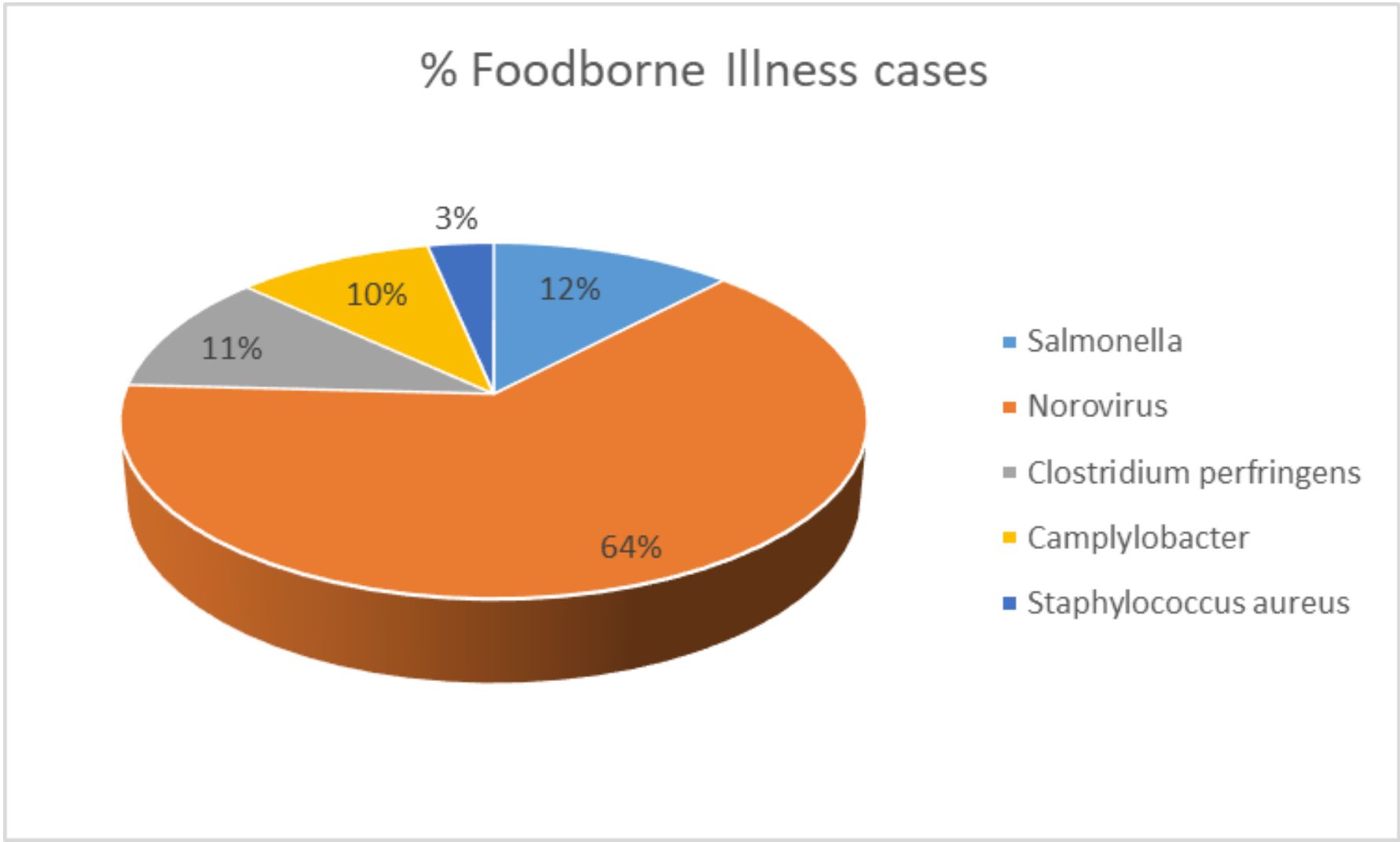
Dormant State

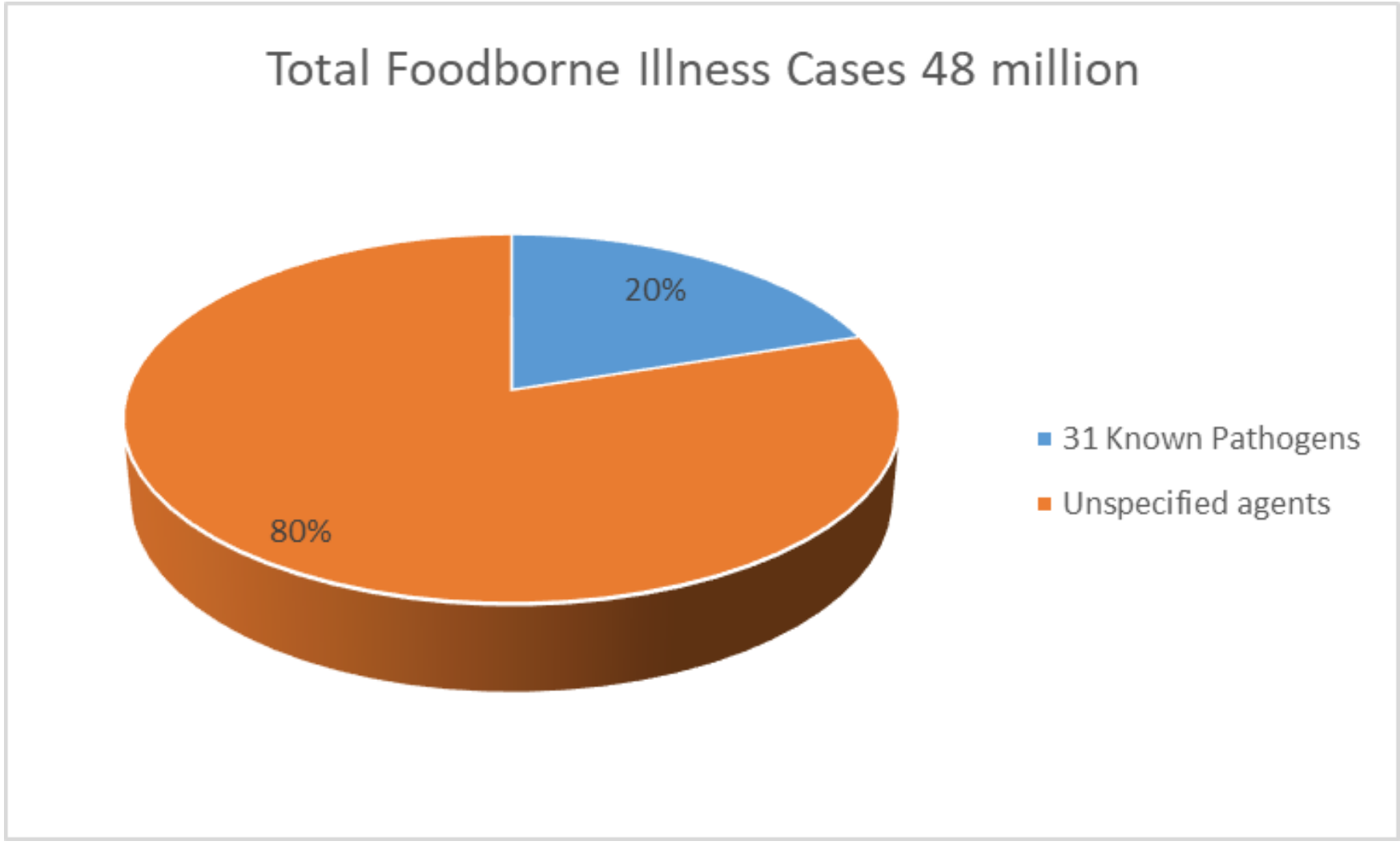
VBNC

- Retain viability but fail to grow
- Intermediate state between living and dead
- What triggers resuscitation from VBNC?

Persister

- Cells that downregulate metabolism in presence of nutrients
- Non-growing
- Residual survivors after antibiotic exposure
- What triggers induction and release of persister state?

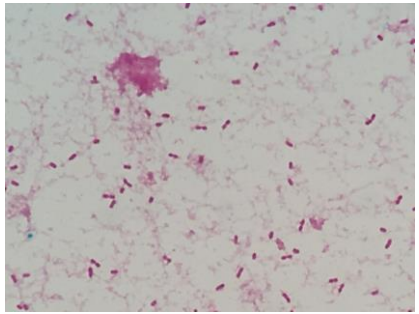

% Foodborne Illness cases
3%
12%
10%
11%
64%
Salmonella
Norovirus
Clostridium perfringens
Camplylobacter
Staphylococcus aureus


Total Foodborne Illness Cases 48 million
20%
80%
31 Known Pathogens
Unspecified agents

Unspecified Agents: Food Safety Concern?

Agents recovered in foods but unclear to the degree contribute to foodborne illness.

Food is one of several routes



Aeromonas

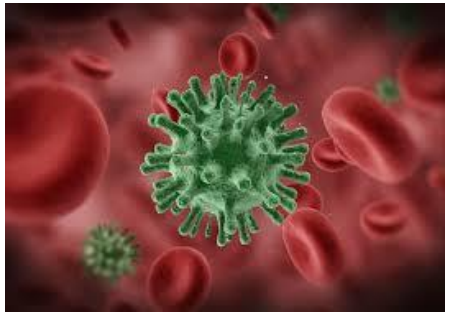
Clostridium difficile

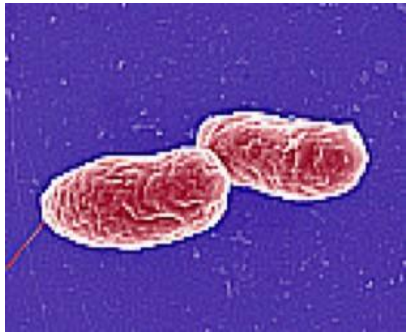
Edwardsiella

Escherichia allberti

E. coli ST131

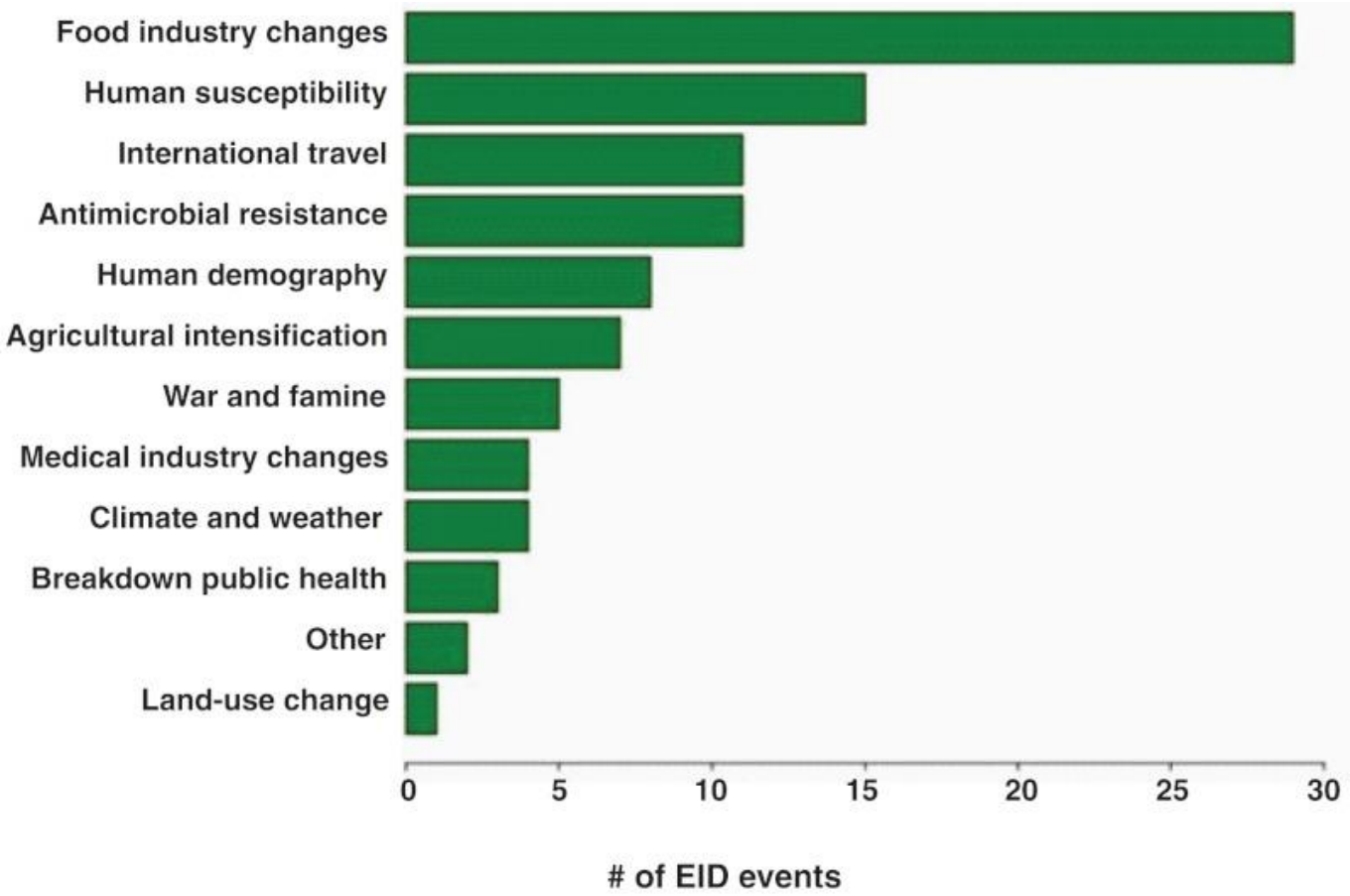
Plesiomonas





List likely to be extended

Emerging Infectious Diseases



Food Industry Changes

- Globalization
- Increased animal protein
- Growth promotors
- Animal movement
- Complex distribution networks
- Diversity of ingredients
- Minimally processed
- Removal/inclusion of preservatives
- Centralization - intensive
- Small-to-Medium size processors

Sugar additive linked to rise of killer superbug

January 10, 2018 15:34

A SUGAR additive found in cream cakes, fruit juices and jams has fuelled the rise of a killer superbug, new research has found.

As The Herald Scotland reports, the study shows the sugar – known as trehalose – is metabolised by the potentially deadly bacterium Clostridium difficile. It suggests the common

Black Death 'spread by humans not rats'

By Victoria Gill
Science correspondent, BBC News

56 minutes ago

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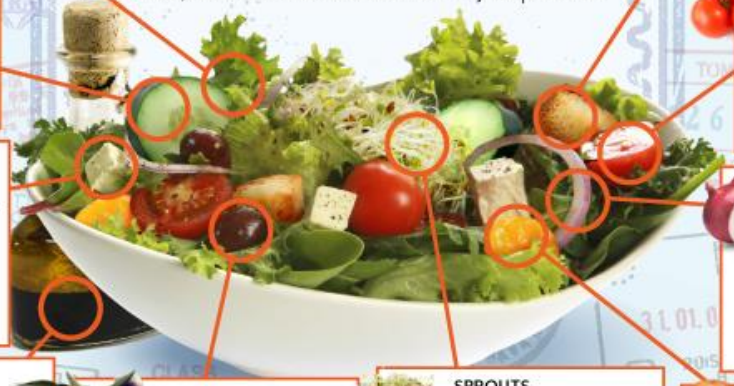
The Well-Traveled Salad.

Do You Know Where Your Food Has Been?

As consumers, many of us fail to recognize that even our domestic and local food supplies are part of a global network. The daily activity of consuming food directly links our health as humans to the health of crops and produce, food animals, and the environments in which they are produced.



LETTUCE
Canada, Chile, Dominican Republic, Mexico, Peru, USA

CUCUMBERS
Canada, Honduras, India, Mexico, Spain, USA

FETA CHEESE
Canada, Denmark, Egypt, Germany, Greece, Israel, Italy, Turkey, UK, USA

VINAIGRETTE
Argentina, Brazil, Canada, Chile, China, France, Germany, Greece, India, Indonesia, Italy, Mexico, Morocco, Peru, Portugal, Spain, Thailand, Tunisia, Turkey, USA, Vietnam

OLIVES
Greece, Israel, Mexico, Spain, USA

SPROUTS
Argentina, Australia, Bangladesh, Canada, China, Egypt, France, India, Morocco, Nepal, Pakistan, South Africa, Spain, Turkey, USA

MANDARIN ORANGES
Israel, Mexico, Morocco, South Africa, Spain

CROUTONS
Argentina, Australia, Brazil, Canada, China, France, India, Mexico, Netherlands, Poland, Russia, Switzerland, Uruguay, USA, Vietnam

TOMATOES
Canada, Dominican Republic, Holland, Israel, Italy, Mexico, USA

ONIONS
Canada, China, Germany, India, USA

A "One Health" approach to food safety—bringing together expertise and resources from the clinical, veterinary, wildlife health, and ecology communities—has the potential to reveal the sources, pathways, and factors driving the outbreaks of foodborne illness and possibly prevent them from occurring in the first place.

NOTE: *Countries are listed in alphabetical order and not by volume of export.*

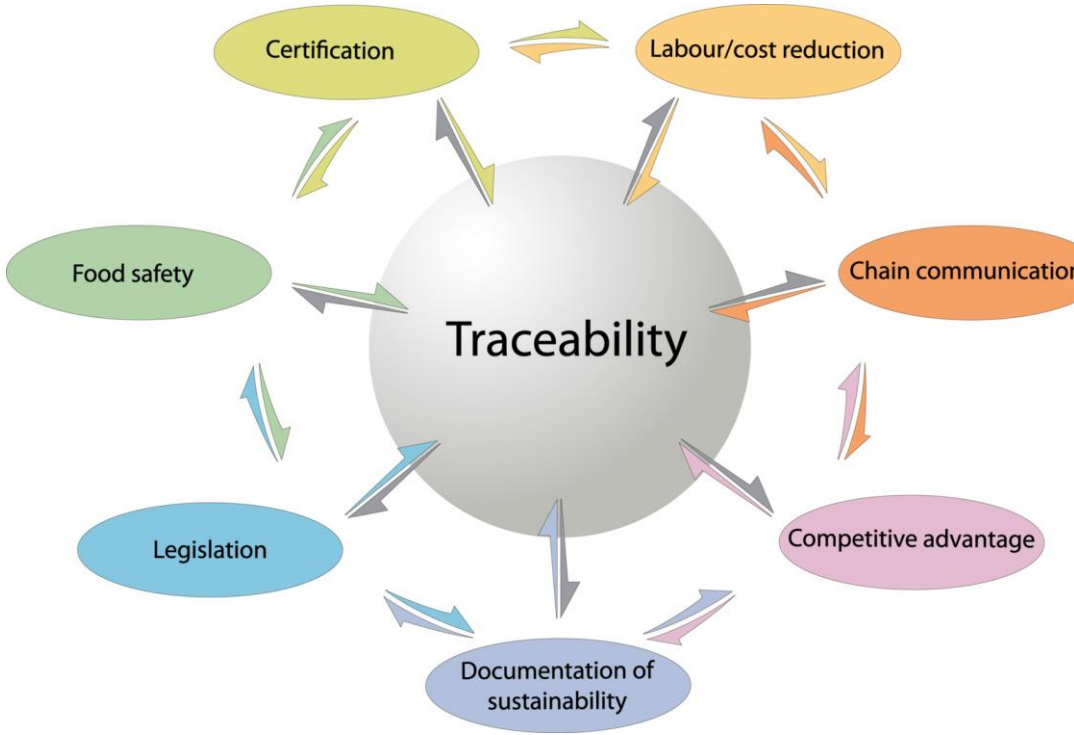
INSTITUTE OF MEDICINE
OF THE NATIONAL ACADEMIES
www.iom.edu

Traceability

- Preparedness
- Response
- Recovery
- Prevention

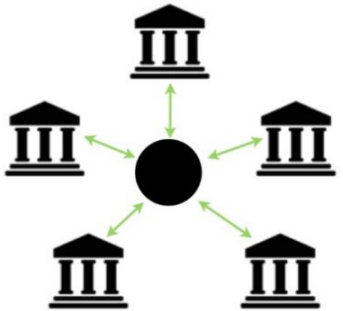
- Beyond one-step-forward-one-step back

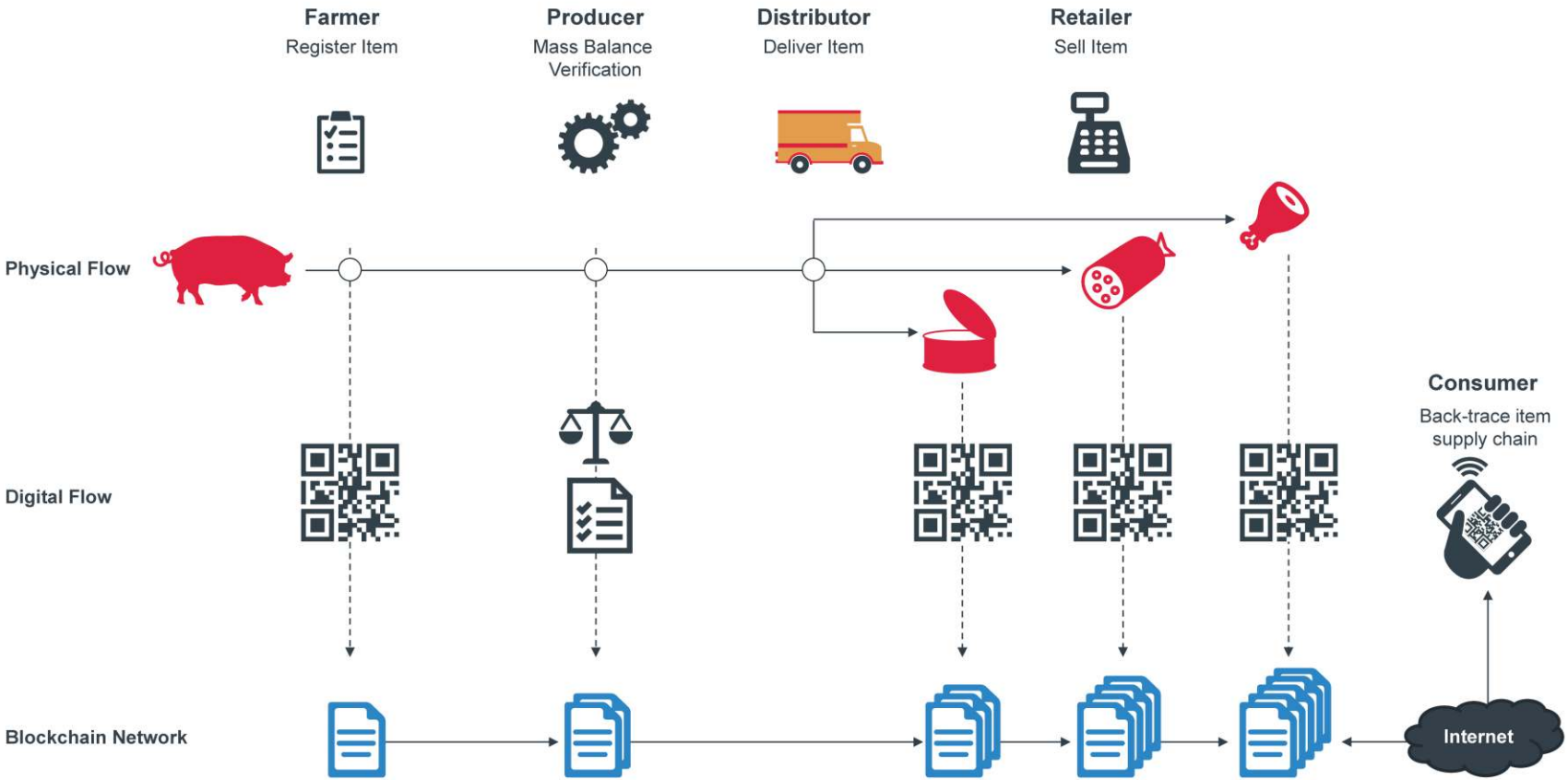
- Global Food Traceability Center
- Challenge: No standard information exchange protocol
- Integration of food safety systems
- $11nb Market



Blockchain (Distribution Ledger Technology; DLT)

- Capture and protect information in time
- Decentralized information network
- Secure
- Transparent
- Data management




Farmer
Register Item
Producer
Mass Balance Verification
Distributor
Deliver Item
Retailer
Sell Item
Physical Flow
Digital Flow
Blockchain Network
Consumer
Back-trace item supply chain
Internet

Blockchain: Hype or Hyped

Benefits to Food Safety

- Rapid tracing to source of contaminated product
- History of contaminated product
- Facilitate limited recalls
- Limit market impact
- Efficient distribution management

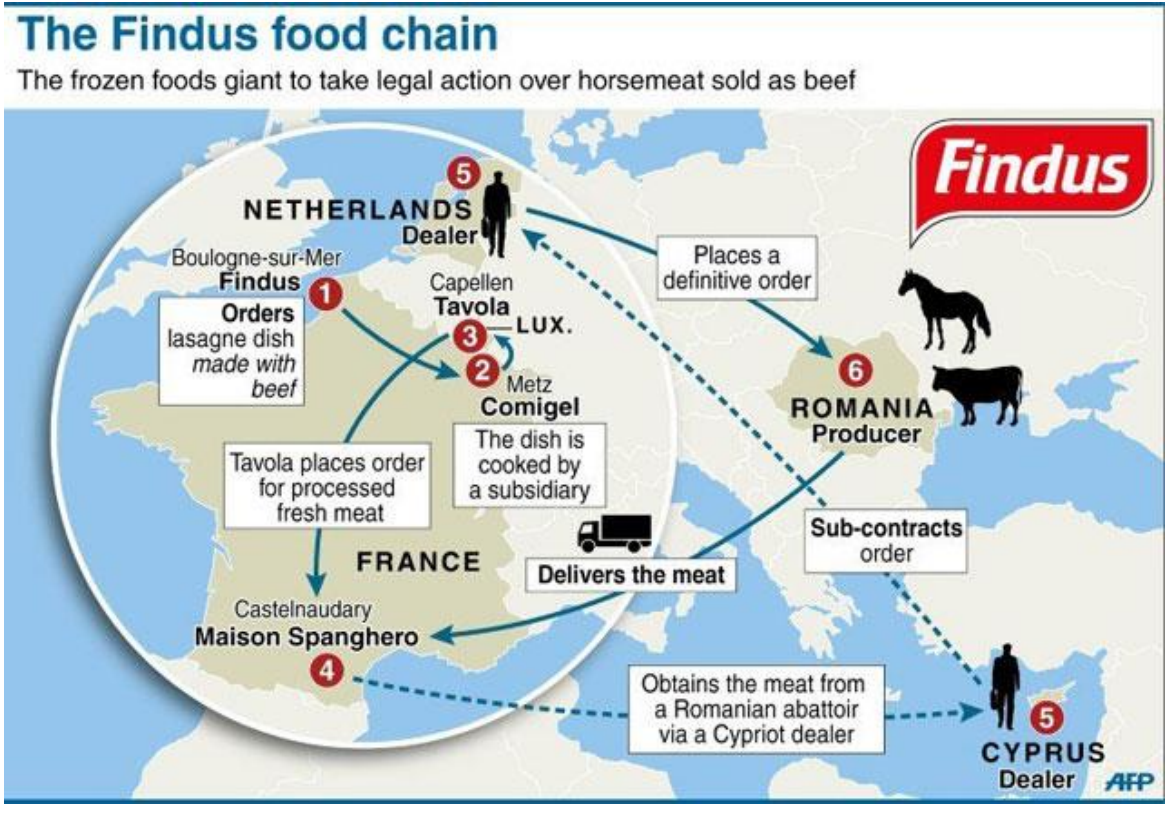
Limitations

- Accurate information – prone to human error
- Open to misinformation
- Commercially sensitive information
- Limited information uploaded
- Everyone needs to be on the same page
- Availability of information during investigations

Would Blockchian helped here?

- *E. coli* O157:H7 outbreak possibly linked to Romaine lettuce
- PHAC advisory to avoid Romaine
- Outbreak over before it was detected
- Unwillingness for Government to release information
- No advantage of using Blockchain

Blockchain Could have Prevented Horsemeat Scandal



French salmonella baby milk scandal 'affects 83 countries'

14 January 2018

Share

AFP

The recall was issued in December and French retailers have been threatened with legal action if they sell it

Beyond the Blockchain

- Restricted access to commercial sensitive information
- Input from sensors and monitoring records
- Real-time surveillance across the chain
- Internet of Things

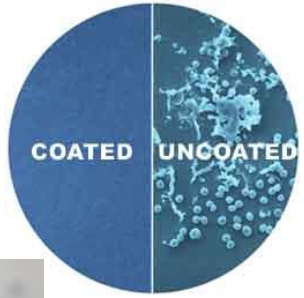
In China, You Can Track Your Chicken On–You Guessed It–The Blockchain

To guarantee customers that their chickens are actually free-range, Gogochicken is tracking them with an ankle bracelet and putting the information online.

[Photo: ZhongAn Technology]

Future Trends in Food Safety

- Antimicrobial coatings to enhance sanitation
- Microbiome to boost immune function
- Non-thermal interventions
- Diagnostics – virulence profiling
- Home diagnostics
- Dormancy – are you dead or sleeping?
- Risk profiling through food chains
- Intelligent packaging



Final Thoughts

- Preventing pathogen reaching consumer remains a valid strategy
- Identify incubators of pathogens and routes of dissemination
- Opportunistic pathogens adding to the list
- One Health approach to limit pathogen entry
- Monitoring of hazards in real time across the chain
- Post-harvest interventions
- Big Data will open a new chapter in food safety
- What is the overall target of pathogen control?