Learning from Foodborne Outbreaks: Improving the Processes of Public Health

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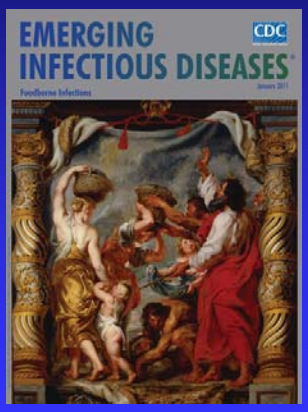
Foodborne disease - 2011
a continuing public health concern

- **Common:**
  - **~1,200 outbreaks reported each year**
  - **Outbreaks a small part of problem; most reported illnesses**
  - **One in 6 Americans become ill, 3,000 die each year**
- **Complex:**
  - **At least 250 different diseases**
  - **Growing variety of foods**
  - **Can be prevented with barriers from farm to fork**
- **Continuing:**
  - **Some progress, little in recent years**
  - **Dispersed outbreaks challenge the food safety system**
  - **New problems need new strategies**

The burden of foodborne illness acquired in the United States



New estimates in 2011

- 48 million illnesses
- 128,000 hospitalizations
- 3,000 deaths

- 31 known pathogens
- Undetermined agents

Scallan et al (2011) EID 17: 7-15, 16-22.

CDC

Many different pathogens and toxins

- **More than 250 pathogens and toxins transmitted by food**
- **More pathogens continue to be identified**
- **Many pathogens also spread through water, direct animal or human contact**
- **Six of the most important pathogens**

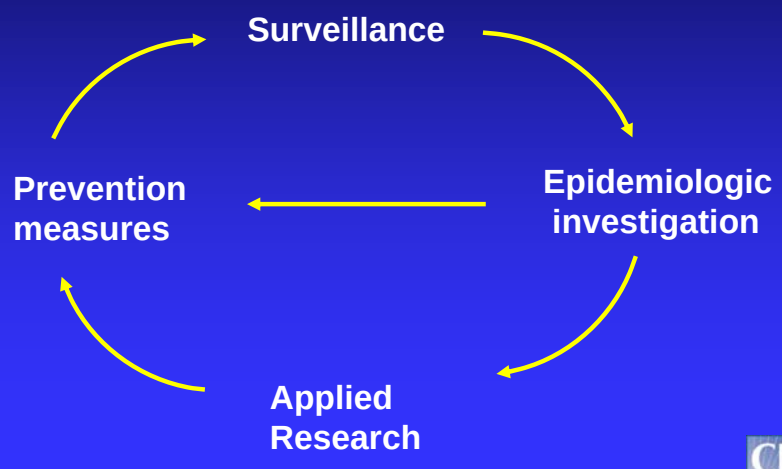
Estimates of Annual Domestic Food-Related		
	Illnesses	Deaths
Listeria	1,600	255
Toxoplasma gondii	87,000	325
E. coli O157:H7 *et alia**	176,000	20
Campylobacter	845,000	75
Salmonella	1,027,000	380
Norovirus	5,460,000	150

Scallan, EID 2011

*And other Shiga toxin-producing *E. coli*

CDC

The cycle of public health prevention



Our public health infrastructure

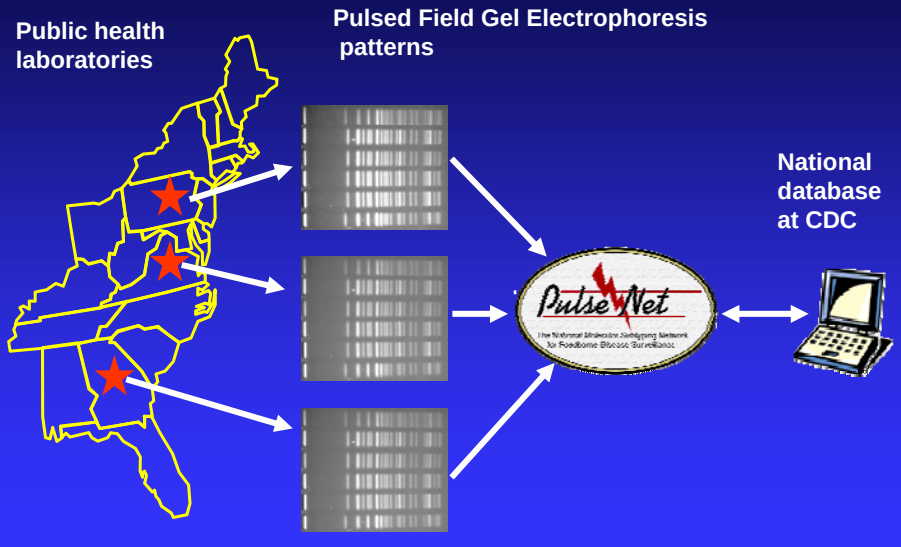
- The county or city health department
  - The front line of public health
- The State Health department
  - Epidemiologists
  - Laboratorians
  - Sanitarians
- The state ag department
  - Regulators
  - Inspectors
  - Laboratorians
- The federal agencies:
  - Risk identification agency: CDC
  - Risk management/regulatory agencies: FDA, USDA, EPA
- Tiered response to emergencies. CDC provides back-up to States: epidemiologists, laboratory support, coordination

Federal agency roles and responsibilities

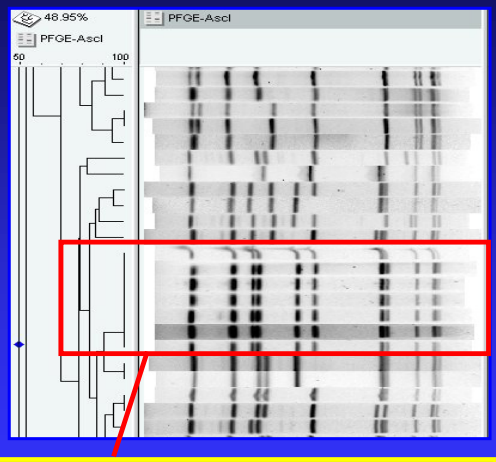
- CDC
  - Non-regulatory
  - National disease surveillance
  - Outbreak detection and investigation to determine vehicle and source
  - Tracks burden and trend time
  - Tools and training for public health
- Problem identification
- Provide information to guide regulatory action

- FDA, FSIS
  - Regulatory
  - Food safety policies
  - Inspect, monitor, enforce
  - Product recall and traceback
  - Investigation of farm and production facilities
- Problem management
- Regulation and enforcement

1996, PulseNet launched in United States



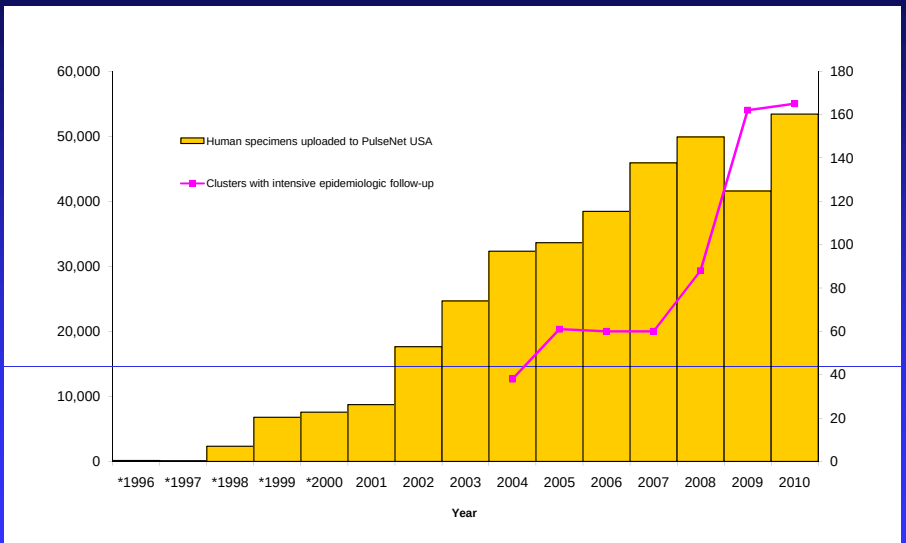
PulseNet Data Analysis: Searching for Clusters



Cluster of indistinguishable patterns

- State public health laboratories submit patterns electronically
- CDC and states search for similar patterns in past 2-4 months
- When cluster identified, PulseNet contacts epidemiologists

Human specimen isolates uploaded to PulseNet USA, and investigated clusters, 1996-2010†



† Data are preliminary and subject to change
* data type information may not be complete for these years

What makes PulseNet surveillance work?

- Central leadership and support
- Standardized methods across the entire system
- Real time subtyping in public health labs, useful at local, state and national level
- National database to which all partners have access 24/7
- Rapid linkage to epidemiologists at each level
- New methods are evaluated in state labs before adopting

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The spectrum of foodborne disease outbreaks

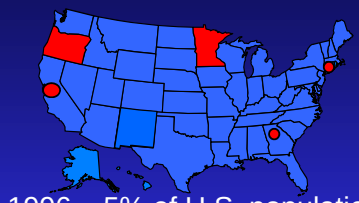
➢Focal scenario

- Large number of cases in one jurisdiction
- Detected by affected group themselves
- Local investigation
- Local food handling error
- Local solution

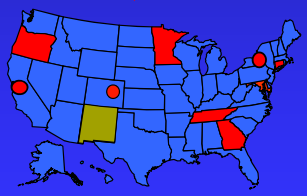
➢Dispersed scenario

- Small numbers of cases in many jurisdictions
- Detected by lab-based subtype surveillance
- Multistate investigation
- Industrial contamination event
- Broad implications

FoodNet Active Surveillance Network



1996 – 5% of U.S. population



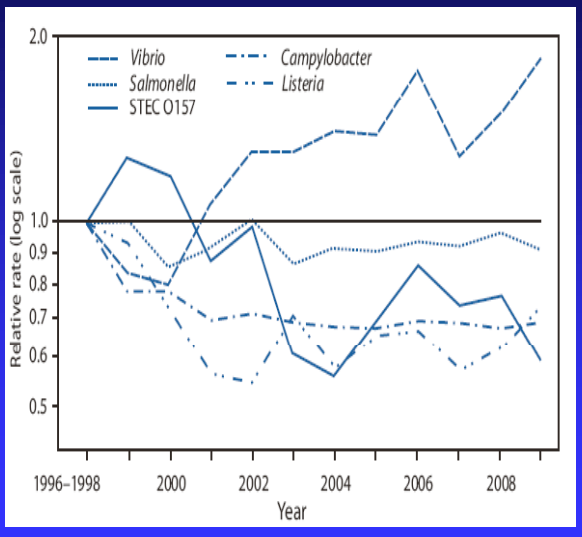
2003 - 14% of U.S. population

Year	Population in millions
1996	14.3
1997	16.1
1998	20.7
1999	25.9
2000	30.5
2001	34.1
2002	38.0
2003	41.5

FoodNet Objectives

1. **Determine the burden** of foodborne illness in the United States
2. **Monitor trends in the burden** of specific foodborne illness over time
3. **Attribute the burden** of foodborne illness to specific foods and settings
4. **Disseminate information** that can lead to improvements in public health practice and the development of interventions to reduce the burden of foodborne illness

Trends in foodborne diseases,FoodNet,1996-2009



Since 1996-98, significant drops in:
E. coli O157 – 41%
Campylobacter – 30%
Listeria -- 26%
Salmonella – 10%

Significant increase in *Vibrio* + 85%

In last 4 years, significant drop in:
E. coli O157- 25%

MMWR 2010; 59:418-422 (April 16, 2010)

Outbreak investigations are a major driver for enhancing overall food safety

- **Prevent additional cases in the current outbreak**
- **Identify a new pathogen or problem**
- **Determine what went wrong in order to prevent future similar outbreaks**
  - **Define higher risk foods**
  - **Define gaps in the system**
  - **Stimulate further specific research**
  - **New processes or regulations**

Stages in a foodborne outbreak investigation

- **Detection: "Is something unusual happening? To whom?"**
- **Developing hypotheses: "What is on the menu?"**
- **Testing the hypotheses: "Which foods are associated with illness?"**
- **Traceback and environmental assessment: "Where did that food come from, and what happened to it along the way?"**
- **Control: "Is that contaminated food no longer available?**
- **Long term prevention: "What needs to change to keep something like this from happening again?"**

Three elements of proof in a foodborne outbreak investigation

1) Epidemiological association between illness and eating the food

2) Pathogen found in food or food ingredient (when possible)

3) Suspected food or ingredient found to come from one source (Source tracing converges)

- **Rarely have all three**
- **Typically depend on the first, increasingly incorporating the third into investigations ("supply side epidemiology")**
- **Cannot wait for the second, which is often not possible**

The essential statistical comparison: Who ate what (and did or did not get sick)?

- **Divide the people into ill and well**
- **Divide them into those who ate, did not eat Food X**
- **Put the information together**
- **Calculate the probability of getting this distribution by chance alone**

- Take a group of 44 people, of whom 12 are ill, and 15 ate Food X

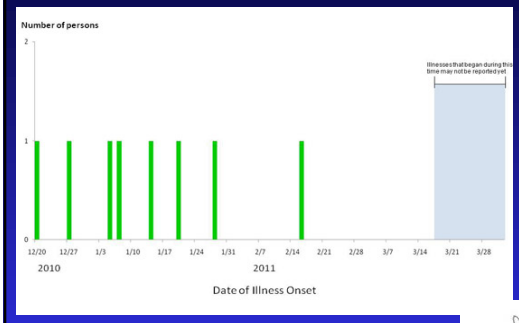
	Ill	**Well**
Ate Food X	10	5
Did not eat Food X	2	27

Probability of this or more extreme distributions = 0.0001 or 1 in 10,000

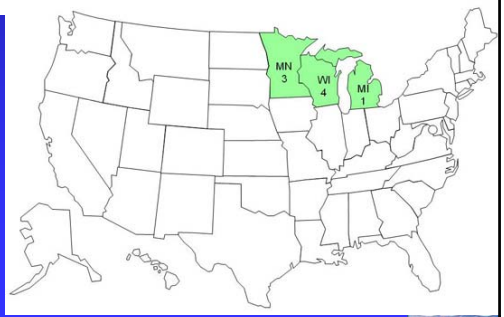
The specificity challenge: subtyping exposures

- **One side of the 2 x 2 table is a highly refined case definition:**
  - **Salmonella serotype Heidelberg of a particular PFGE pattern**
- **The other side is "ate eggs?" yes/no**
- **Challenge: To achieve more specificity in food exposure**
  - **Ate Grade A Brand X eggs from Store Y, from Farm Z**
- **Barriers:**
  - **Time**
  - **Memory**
  - **Data complexity**

E. coli O157 and ? – 2011



- 8 cases with rare PFGE pattern
- Onset Dec 20, 2010 – Feb 18, 2011
- Median age 62 years
- 6 are in men



State of residence for 8 persons with outbreak pattern, Dec 20, 2010 – Jan 28, 2011

Findings preliminary and may change

E. coli O157 and hazelnuts – 2011

- Investigation by MN and WI
- Systematic interviews covering many exposures, and open-ended questions
- All reported eating hazelnuts in week before onset
- Quick survey of persons with salmonellosis
  < 21% ate any "other nuts"

- Source tracing: All from one supplier in California from source orchards in Oregon

- Result: March 4, 2011: California company recalled hazelnuts

- Culture of leftover nuts in one patient's home: yielded outbreak strain of *E. coli*

Data as of April 1, 2011. Preliminary and subject to change

E. coli O157:H7 and hazelnuts - 2011 Prevention lessons learned

- A new food vehicle
- Hazelnuts are often eaten raw, unroasted
- Harvest: shake trees, then vacuum nuts up off the ground
- No step between the nut orchard and consumer that would eliminate a pathogen

- Possible sources of contamination? Animals that browse in nut orchards, as well as later in distribution

- Previous problem with raw almonds and *Salmonella* – almond industry now heat treating most almonds

- New arena for applied research and prevention
  (How about pecans, walnuts, other tree-nuts?)

E. coli O157:H7 and hazelnuts Process lessons learned

- Outbreak would not have been identified without PulseNet
- Rare pattern, distinctive age and sex distribution of cases
- Hypothesis from extensive patient interviews
- Case-control comparison and source tracing rapidly implicated a single food
- Company voluntarily withdrew product immediately

Salmonella Typhimurium infections and peanut butter-containing products: Initial phase

- November 2008: PFGE cluster detected by PulseNet
  - 35 cases in 16 states
  - continued to grow, without any focal clusters
  - All ages, all over the country
- Extensive hypothesis generation over the next month did not identify a suspect food
  - 86 trawling questionnaires with 471 exposures
    - 86% ate chicken ---------- 85% on population survey
    - 71% ate peanut butter ------ 59% of population survey
  - In Minnesota, central "team diarrhea" noted cases in two nursing homes and a school
    - Identified one food that went to all three institutions, and began looking at more institutions with a case

Salmonella Typhimurium infections and peanut butter-containing products: First cycle

- First case-control study: Data collected Jan 3-4 : Some association with
  - Peanut butter – 68% vs 48% mOR = 2.5 (1.3 – 5.3)
  - Frozen chicken – 46% vs 35% mOR = 4.6 (1.7 – 14.7)
  - But many different brands and types, No association with major store brands of PB, no type or brand of chicken consumed by more than 10%
- In Minnesota, more institutional cases found in more institutions: all had received the same single food item, while no control institutions had:
- Brand X institutional peanut butter, produced by Peanut Corporation of America (PCA) at plant in Georgia
  - Production halted on Jan 8, Brand X product recalled Jan 9
  - Outbreak strain isolated from that peanut butter later that day
- This is one of three plants run by PCA, initial inspection of the other two revealed no problems, and no links with Georgia plant.

CDC

Salmonella Typhimurium infections and peanut butter-containing products: Second cycle

- Cases continued to occur. Continue to interview them with CC study 1 questionnaire, with more questions about peanut butter. Few ate institutional peanut butter, but many ate a variety of peanut butter flavored foods. Jan 13 conference call: several mentions of Brand A peanut butter flavored crackers
- FDA/CDC investigation at PCA plant in Georgia:
  - Also produced peanut paste
  - Sold in large volume to many other companies
  - An ingredient in many other products, like Brand A PB crackers

CDC

Salmonella Typhimurium infections and peanut butter-containing products: Second cycle, continued

- 2nd case-control study Jan 17-19. 95 cases, 362 controls, implicated
  - Eating peanut butter outside the home
  - Eating peanut butter crackers (two popular brands)
- Conditions in plant suboptimal
  - rainwater leaking through roof
  - raw and roasted peanuts stored together
  - roasting process not validated or monitored
  - Company tests found *Salmonella* in peanut butter for six months (but negative on retest at second lab, so never held)
- Over next month: recall of 3,913 products made with peanuts or peanut paste from PCA plant – an "ingredient driven" outbreak
- Jan 20. President Obama sworn in as President. This is first crisis

CDC

Salmonella Typhimurium infections and peanut butter containing products: Third cycle

- Late January 2009: cluster of 5 cases in Colorado who ate peanut butter ground in a local store chain, from roasted peanuts roasted at 2nd PCA facility. This peanut butter yields outbreak strain.
  - FDA investigated second facility again
    - major sanitation issues
    - discovered connections with Georgia facility
- Outbreak slowly ended. (Some products have shelf life of 2 years)
- Communication challenges
  - recalling an increasingly huge number of products
  - re-introducing them later

CDC

Salmonella Typhimurium Outbreak Strain Isolated from…

Opened and unopened containers of Brand X peanut butter

Salmonella Typhimurium Outbreak Strain Isolated from…

Intact packages of peanut butter crackers

Salmonella Typhimurium Outbreak Strain Isolated from…

Peanut paste from tanker truck

CDC

Salmonella Typhimurium Outbreak Strain Isolated from…

Fresh in-store ground peanut butter

CDC

Salmonella Typhimurium Outbreak Strain Isolated from…




Peanut granules

CDC

Salmonella Typhimurium Outbreak Strain Isolated from…





Peanut butter-flavored dog biscuits

CDC

Salmonella Typhimurium infections and peanut butter-containing products – 2008-2009

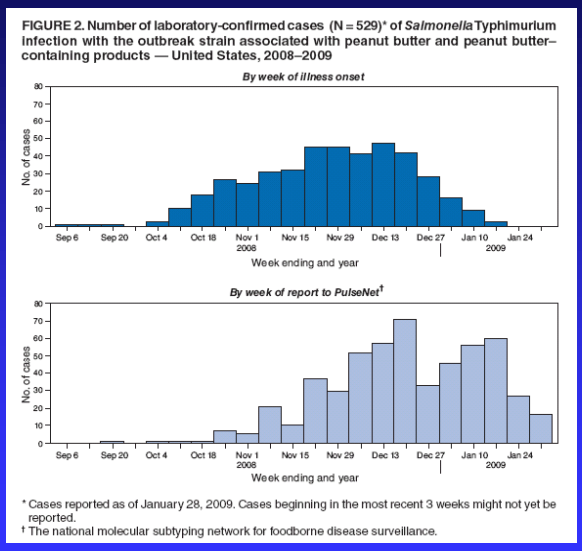


FIGURE 2. Number of laboratory-confirmed cases (N = 529)* of *Salmonella* Typhimurium infection with the outbreak strain associated with peanut butter and peanut butter–containing products — United States, 2008–2009

* Cases reported as of January 28, 2009. Cases beginning in the most recent 3 weeks might not yet be reported.
† The national molecular subtyping network for foodborne disease surveillance.

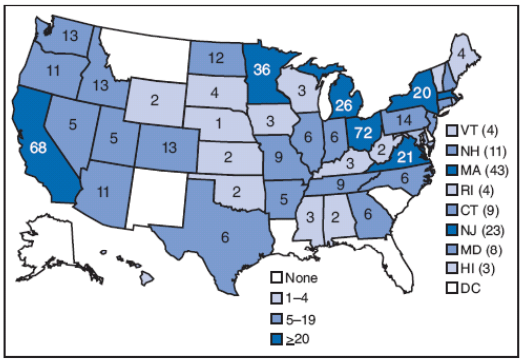
As of March 17,
691 cases
46 states,
23% hospitalized
9 deaths

Median 16 days time lag between onset of illness and upload to PulseNet

MMWR 2009: vol 58, p 85-90, Feb 5

Preliminary data, subject to change

Salmonella Typhimurium infections and peanut butter-containing products – 2008-2009



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MMMWR 2009: vol 58, p 85-90

Preliminary data, subject to change

Salmonella Typhimurium infections and peanut butter-containing products – Prevention lessons learned

- One processing facility contaminated a food and an ingredient used in many other foods
- First food implicated was sold only to institutions
  - Found by "supply side epidemiology"
  - No one knew they had eaten it: a "generic" food
- Case-control studies did not implicate a food at first
  - Initial case control study did not implicate a food
  - Many different foods involved (all containing peanuts)
- Outbreak lasted for months, could have gone on indefinitely
- Current inspection practices did not identify problems before the outbreak, nor did third party audits
- Company internal testing data was not acted upon

CDC

Salmonella Typhimurium infections and peanut butter-containing products – Process lessons learned

- A large and highly dispersed outbreak
  - Found because of PulseNet
  - No large focal clusters
  - Detailed local case investigations critical
  - Foods in common to institutions with cases
- Hypothesis missed with usual methods
  - Found with supply comparison: "Supply side epidemiology"
- First vehicle identified did not explain ongoing cases: consider more hypotheses and continue investigation
- Critical to link epidemiological investigations with plant investigations

CDC

The volume challenge: the large number of clusters detected by PulseNet

- 60,000 patterns reported to PulseNet each year
- Thousands of pattern types – many thousands of "matches"
- A group of strains with a matching pattern = "cluster"
- Local clusters are detected locally, state clusters detected at state level
- CDC focuses on multi-state clusters, hundreds each year
  - How severe is the illness? *E. coli* O157, *Listeria* at top
  - Is the number of cases in the cluster increasing?
  - Is the number of affected states increasing?
- How can we improve the triage of these clusters?

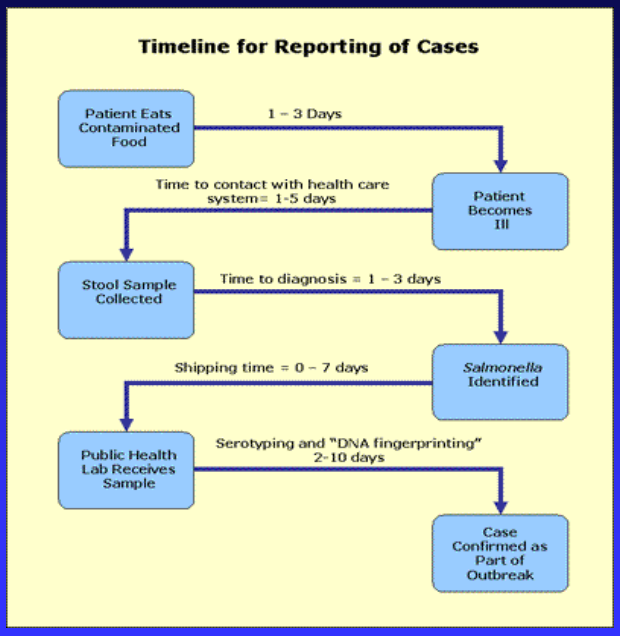
CDC

The complexity challenge: sorting through the many possible exposures to an hypothesis

- Consider many possibilities rapidly
  - Foodborne, waterborne, animal contact, person-to-person
  - 5 days before onset, but Listeria, S. Typhi , Hep A can be a month
  - Large number of meals, of food items
  - It might be a stealth food that few remember eating, or a generic food , or one ingredient used in many foods
- Looking for signals that a group exposure is involved:
  - Event in common
  - Shop at one grocery store chain
  - All are eating institutional food
  - Patrons of one restaurant chain
  - A localized cluster that is part of a larger outbreak

CDC

The time challenge: Inherent delays in surveillance



The time challenge: It takes time to get back to the cases and memories are fading

- Interviewing them about what they ate a month before
- Solutions:
  - Faster throughput in the public health labs
  - Interview everyone in detail as soon as their infection is reported
  - Use shopper card data
- Need more dedicated resources in health departments

The coordination challenge: multi-site outbreaks require more standardized approaches

- Multi-site outbreaks demand more uniform approaches to
  - Triage clusters - prioritize among hundreds detected
  - Generate and test hypotheses
  - Collect, combine, and share data
- Integrating product traceback into investigations (making exposure data more precise)
- Rapid data sharing and communication platforms

Critical tools and methods for foodborne outbreak investigations

- Standard hypothesis generation questionnaires
- Team to conduct rapid
  - interviews of cases as soon as they are reported – before the clusters are defined
  - control interviews,
  - product source tracing
- Increasing use of "supply side epidemiology" like
  - use of shopper card information
  - institutional food purchase history
- Environmental health investigations that go beyond inspection
- Rapid data sharing and communication platforms

Starting in 2011: OutbreakNet Sentinel Sites

- Modeled on success of PulseNet
- 5 sites (4 states and 1 city) selected
- New network for developing and assessing methods
- Improve public health methods for foodborne outbreak detection, investigation and control
  - Faster interview and other investigative methods
  - Faster and newer laboratory procedures
  - Standardized approaches
  - "Investigate more outbreaks faster"
  - Better IT tools to support investigations
- Replicate successful models across the country
- Supported by CDC and USDA

Large multi-jurisdiction foodborne outbreaks identifying new hazards: 2006-2011

2006 - *E. coli* O157 and bagged spinach
2006 - Botulism and commercial pasteurized carrot juice
2007 - *Salmonella* and peanut butter
2007 - *Salmonella* and a vegetarian snack food
2007 - *Salmonella* and dry dog food
2007 - *Salmonella* and microwaveable pot pies
2007 - *Salmonella* and dry puffed breakfast cereal
2007 - Botulism and canned chili sauce
2008 - *Salmonella* and fresh produce items (jalapeno and serrano peppers)
2008 - *Campylobacter* and fresh peas
2009 - *Salmonella* and white pepper
2009 - *E. coli* O157 and raw cookie dough
2010 - *Salmonella* and black pepper crusted salami
2010 - *Listeria* and pre-chopped celery
2010 - *E. coli* O145 and shredded lettuce
2010 - *Salmonella* and frozen rodents (snake food)
2010 - *Salmonella* and dwarf water frogs
2011 - *E. coli* O157 and hazelnuts

•A new food vehicle in 17 outbreaks
•A new foodborne pathogen in 1

Themes in recent multi-state outbreaks

- Detected with molecular subtype-based national surveillance
- Epidemiological investigation → food recall
  - Rapid source tracing often an important part
  - before pathogen isolated from product
- Investigations can be prolonged, and depend critically on local and state health department capacity to
  - investigate cases,
  - detect clusters
  - and collaborate with other jurisdictions
- Fresh produce
  - Leafy greens, peppers, tomatoes, carrots, nuts
  - Produce easily contaminated in field
  - Complex ecologies link pastures, streams, and vegetable fields
- Processed foods contaminated in factory
  - Snacks, peanut butter, dog food kibble, pot pies, frozen pizza
  - Major sanitation issues in food factories
  - Better strategies for inspection and enforcement

CDC

Why are we seeing so many multi-state foodborne outbreaks?

- Better surveillance with DNA "fingerprinting" means we detect some we would have missed before
- Centralized production of foods means when a problem occurs it may be widespread
- More imported foods and food ingredients, depending on food safety systems in other countries
- Gaps in our own food safety system:
  - New technologies adopted without clear process controls
  - Limited capacity for inspection and enforcement
  - Limited research into ecologies that lead to contamination

CDC

These outbreaks point to ways to improve public health processes

- **Our public health system developed to deal with local foodborne problems**
- **Most outbreak response is a local and state responsibility**
- **Nationwide outbreaks raise new challenges:**
  - **Faster identification of clusters**
  - **Faster investigation to identify the food vehicle**
  - **Faster determination and control of source of contamination**
- **New vocabulary:**
  - **"Stealth" and "generic" vehicles**
  - **"Ingredient-driven" outbreak**
  - **"Supply side epidemiology"**

Sporadic cases are important too

- Most infections are not part of recognized outbreaks
- May be part of small highly dispersed outbreaks?
- Important to understand their sources
- Special effort to investigate them - FoodNet
- FoodNet case-control study of *Campylobacter* infections in young children

Campylobacter in young children – FoodNet case-control study

- The highest risk age group
- Data intake 2002-2004
- 123 cases and 928 controls

- If < 6 months old
  - Breast feeding protective
  - Riding in shopping cart with fresh meat or poultry

- If > 6 months to 23 months old
  - Visiting a farm
  - Having pets with diarrhea

Fullerton, 2007 Ped Inf Dis J 26:19-24

Surveys of retail packages of poultry

- New Zealand: 300 packages purchased at 17 stores
- Examined and rinsed the outside of the packaging,
  - 24% of the external samples yielded *Campy*
    - Offal packs: 52%
    - Whole chicken: 34%
    - Parts: 14%
  - Only 0.3% yielded *Salmonella*

- United Kingdom: 895 packages of raw chicken
  - 3% of external samples yielded Campylobacter
  - 0.2% yielded Salmonella

- (cross contamination begins in the grocery cart)

Whyte, et al., Poster P126, IAFP 2003, New Orleans
Burgess, J Food Protect 2005; 68:469-475

Research at retail level: behavior and microbiology at the grocery store

- Surface of meat or poultry package may have pathogens on it.
  - A simple survey could find out how often
  - Cross-contamination in shopping cart
    - of other foods
    - of the cart itself
    - of child riding in cart
  - Cross contamination of conveyor belt at checkout
- Observing consumer behavior (knowledge, attitude, practices)
  - How often do people place meat and poultry
    - in a plastic bag before putting in cart
    - in a separate place in cart
    - bag separately to take home
  - How long before they get it home and into refrigerator?
- Conditions and sanitation of the deli counter slicing machines

CDC

Research at consumer level: behavior and microbiology in the kitchen

- How aware are people that pathogens are easily transferred from raw meat and poultry to other foods, and what do they do to avoid it?
- What is the best way to handle a whole cantaloupe? Wash before cutting, or cut it dry? Which is more likely to contaminate the interior?
- What is the average temperature of people ‘s refrigerator? Does it differ between salmonella cases and controls?
- What do people think about their microwave oven?
  - does it cook food or just warm it?
  - what power output does it have?
  - do they cook raw meat and poultry in it?
  - How do you tell something is done?

CDC

We can prevent more foodborne illnesses

- Strengthen surveillance networks
- Identify more outbreaks and investigate them faster
- Find more gaps in the food safety system
- Applied research can identify new points of control
- Target better prevention strategies to those gaps
- We can expect further declines in incidence

- We can also expect new challenges to arise
  - new pathogens
  - new food vehicles
  - New sources of contamination

Foodborne diseases in the 21st century

- Will continue to be a major public health problem

- New pathogens, new foods in new combinations from
  - Zoonotic reservoirs
  - Fresh produce
  - Processed foods

- Attention to ecological settings in which we raise animals and plants

- More multi-jurisdictional outbreaks

- Need robust public health networks with capacity for surveillance and response

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Thank you

The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of the Centers for Disease Control and Prevention

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Our websites

E. coli:
www.cdc.gov/ecoli

Salmonella:
www.cdc.gov/salmonella

FoodNet:
www.cdc.gov/foodnet

PulseNet:
www.cdc.gov/pulsenet

Foodborne outbreak surveillance:
www.cdc.gov/foodborneoutbreaks

Foodborne burden of illness:
www.cdc.gov/foodborneburden

General Information About Diseases:
www.cdc.gov/health
www.foodsafety.gov

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