A Growing Dilemma: the Future of Food
Is our food Safe?

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Sick from food

1 in 6 Americans

Economic: $83 billion per year

Source CDC (http://www.cdc.gov/)
Contribution of Different Food Commodities (Categories) to Estimated Domestically-Acquired Illnesses and Deaths, 1998-2008

Human bacterial pathogens contaminate fresh fruits and vegetables

<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Disease</th>
<th>1999 Cases</th>
<th>2010 Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salmonella - sprouts</td>
<td>(36 cases)</td>
<td>(87 cases)</td>
<td>(119 cases)</td>
</tr>
<tr>
<td></td>
<td>STEC - lettuce</td>
<td>(65 cases)</td>
<td>(40 cases)</td>
<td>(6 cases)</td>
</tr>
<tr>
<td>2010</td>
<td>Salmonella - sprouts</td>
<td>(124 cases)</td>
<td>(44 cases)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>tomatoes</td>
<td>(23 cases)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>STEC - lettuce</td>
<td>(50 cases)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Only ~5% reported = **684 ill**
Who causes the problem?

*Salmonella enterica*
*Shiga-toxin producing E. coli (STECs)*
*Listeria monocytogenes*
How often are vegetables contaminated with *Salmonella*?

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Imported</th>
<th>Domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cilantro</td>
<td>16/177 (9.0%)</td>
<td>1/85 (1.2%)</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>11/151 (7.3%)</td>
<td>5/164 (3.0%)</td>
</tr>
<tr>
<td>Lettuce</td>
<td>2/116 (1.75%)</td>
<td>1/142 (0.7%)</td>
</tr>
<tr>
<td>Celery</td>
<td>3/84 (3.6%)</td>
<td>0/120</td>
</tr>
<tr>
<td>Parsley</td>
<td>2/84 (2.4%)</td>
<td>1/90 (1.1%)</td>
</tr>
<tr>
<td>Green Onions</td>
<td>3/180 (1.7%)</td>
<td>3/93 (3.2%)</td>
</tr>
<tr>
<td>Tomato</td>
<td>0/20</td>
<td>0/198</td>
</tr>
</tbody>
</table>

Imported produce 3.5 times more likely contaminated.
Is imported food important?

• 2004, first year the U.S. imported more food than exported
• 2005, 16% of total U.S. vegetable supply was imported
• 2006, 15% of total U.S. food was imported

Presently...> 60% of total U.S. vegetables imported

W. Florkowski, USDA-ERS, Univ. Georgia, 2006
**Salmonella enterica** lifecycle

Non-typhoidal
Host-generalist

Successful survival in the environment

Barak and Schroeder, 2012 Ann Rev Phytopath
• Cattle - primary reservoir of *E. coli* O157:H7
• Super-shedders can excrete >1,000 cells/g manure
<table>
<thead>
<tr>
<th>Animal</th>
<th>Plants</th>
<th>Pathogen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mammals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pigs</td>
<td>Leafy greens</td>
<td>STEC</td>
</tr>
<tr>
<td>Cattle</td>
<td>Spinach</td>
<td>STEC</td>
</tr>
<tr>
<td>Coyote</td>
<td>Spinach</td>
<td>STEC</td>
</tr>
<tr>
<td>Mouse</td>
<td>Spinach</td>
<td>STEC</td>
</tr>
<tr>
<td>Deer</td>
<td>Leafy greens</td>
<td>STEC</td>
</tr>
<tr>
<td>Goat</td>
<td>Leafy greens</td>
<td>STEC</td>
</tr>
<tr>
<td>Opossum</td>
<td>Tomato</td>
<td>Se</td>
</tr>
<tr>
<td>Sheep</td>
<td>Leafy greens</td>
<td>STEC</td>
</tr>
<tr>
<td><strong>Birds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American crow</td>
<td>Spinach</td>
<td>STEC</td>
</tr>
<tr>
<td>Brown-headed cow bird</td>
<td>Spinach</td>
<td>STEC</td>
</tr>
<tr>
<td>Sparrow</td>
<td>Tomato</td>
<td>Se</td>
</tr>
<tr>
<td><strong>Reptiles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iguana</td>
<td>Cantaloupe</td>
<td>Se</td>
</tr>
</tbody>
</table>
Persistence

STEPS TO COLONIZATION
Leafy greens grow on the Valley floor
HOW DO PATHOGENS REACH PLANTS?
• Since 1995, **30** outbreaks associated with fresh domestic lettuce or spinach

• **HALF** traced to, or near, the “salad bowl of America” – Salinas, CA

• Survey in Salinas Valley isolated *E. coli* O157:H7 from **surface water**: creek and streams

• *E. coli* O157:H7 more likely where **cattle** were present or following a **rain event**
• 2007 survey of surface water in the Georgia coastal plain found 80% of samples - **positive**
• Georgia – twice the national average
• Coastal plain of Georgia (58.3/100K) – four times the national average (14.9)
• Surface water used for **irrigation**
Tomato Outbreaks

- 2010 *Se* Newport, 46 cases
- 2005 *Se* Newport, 71 cases
- 2002 *Se* Newport, 512 cases
- 2002 *Se* Newport, 12 cases
• **One strain** of *S. enterica* Newport caused illness after tomato consumption in 2010, 2006, 2005, and 2002 *(TWICE!)*

• 2005, SeN outbreak strain was isolated from an *irrigation pond* near tomato fields; FDA has isolated *this strain* from a creek in 2009 and 2010

• Sporadic illness continues to occur caused by **THIS** *S. enterica* Newport strain
THE ROLE OF SOIL AND INPUTS
LISTERIA SP. – SOILBORNE ORGANISM
SALMONELLA ENTERICA – LONG TERM SOIL SURVIVOR
SeN outbreak strain was isolated from poultry litter
Salmonella enterica lifecycle

Animals

Water

Soil

Barak and Schroeder, 2012 Ann Rev Phytopath
Bacteria move toward root exudates (food!)
THE ROLE OF SEEDS
Market pressures...
Sprouts are special

• **Most likely** fresh produce associated with salmonellosis
• **Seeds** implicated as contamination source
• Pathogens **grow rapidly** to significant populations from root exudates
• Pathogens **can not be removed** from seed or sprouts
• Seed source not produced for human market
• **CLEAN SEED!**
Islam et al., 2004 AEM

Charkowski et al., 2002 AEM
Lettuce 64-80 days

Spinach 40 days

Lettuce 64-80 days

Spinach 40 days
BIOLOGICAL MULTIPLIERS
GROWTH AND PERSISTENCE
PERSISTENCE
Plants as vectors of pathogens to humans

- Many unanswered questions!
- Association with plants facilitates return to an animal host
- Human illness shows some specificity toward some crops (*Salmonella* – tomato)
- Mitigation strategies may not be one size fits all
Food Safety Modernization Act (FSMA)

Authorizes the Food and Drug Administration (FDA) to establish mandatory, science-based, minimum standards for growing, harvesting, sorting, packing, and storage of fresh fruits and vegetables.
Minimal:
Ground water – tested annually
Surface water – tested quarterly
Irrigation

Recreational standard

Diluent - Pesticide; Fertilizer

Potable
Irrigation – at harvest

Potable standard
Workers

Sanitation facilities

Health

Hygiene
Questions?