

# Breeding Crops for Enhanced Food Safety

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June 5-6, 2019

UC Davis



# Conference at UC Davis June 5-6, 2019

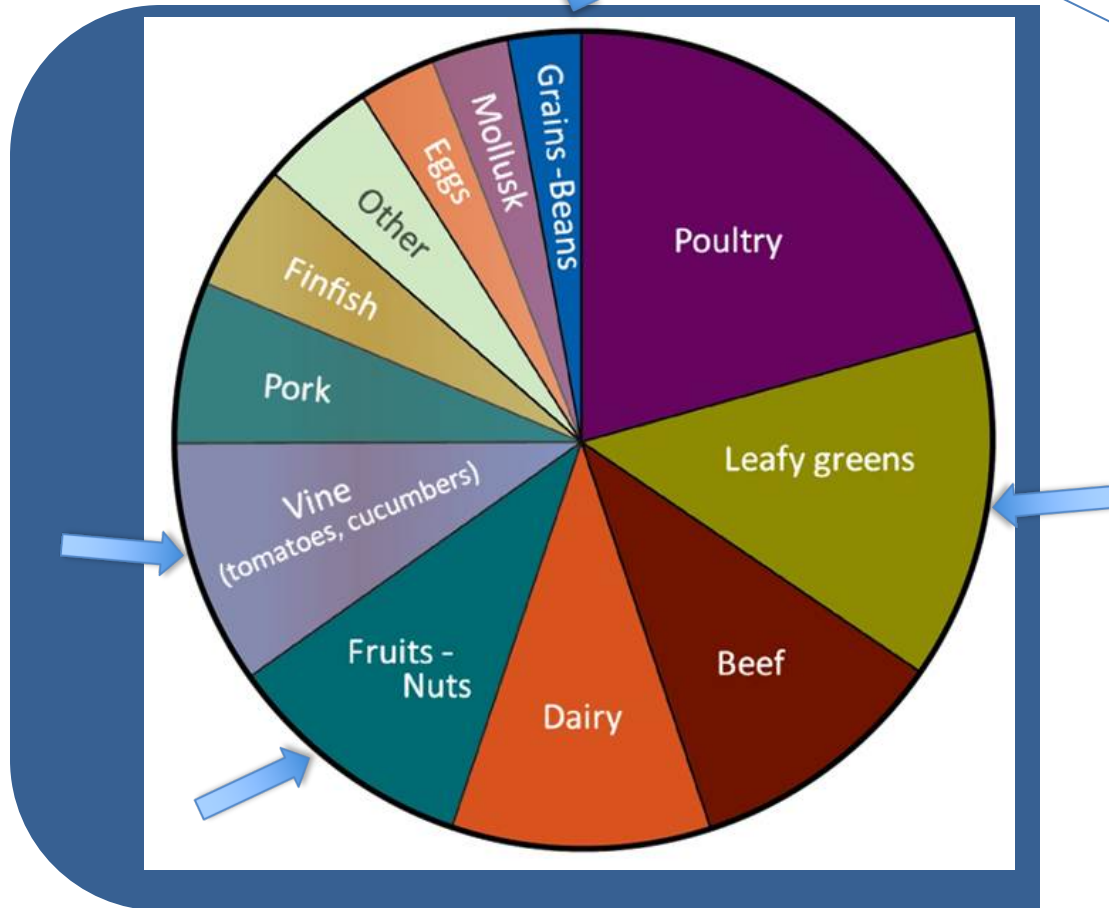
## 15 speakers

- Crop safety: regulatory and research perspective
- Genetic diversity in human pathogen-plant interactions
- *Disc. Topic 1: Challenges for breeding to enhance crop safety*
  
- Crop safety: extension perspective
- Programs currently breeding for crop safety
- Opportunities for breeding strategies for food safety
- *Disc. Topic 2: Opportunities for breeding to enhance crop safety*

# Almost any type of food can spread illness

48 M Sick

3,000 Deaths

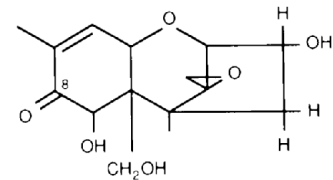


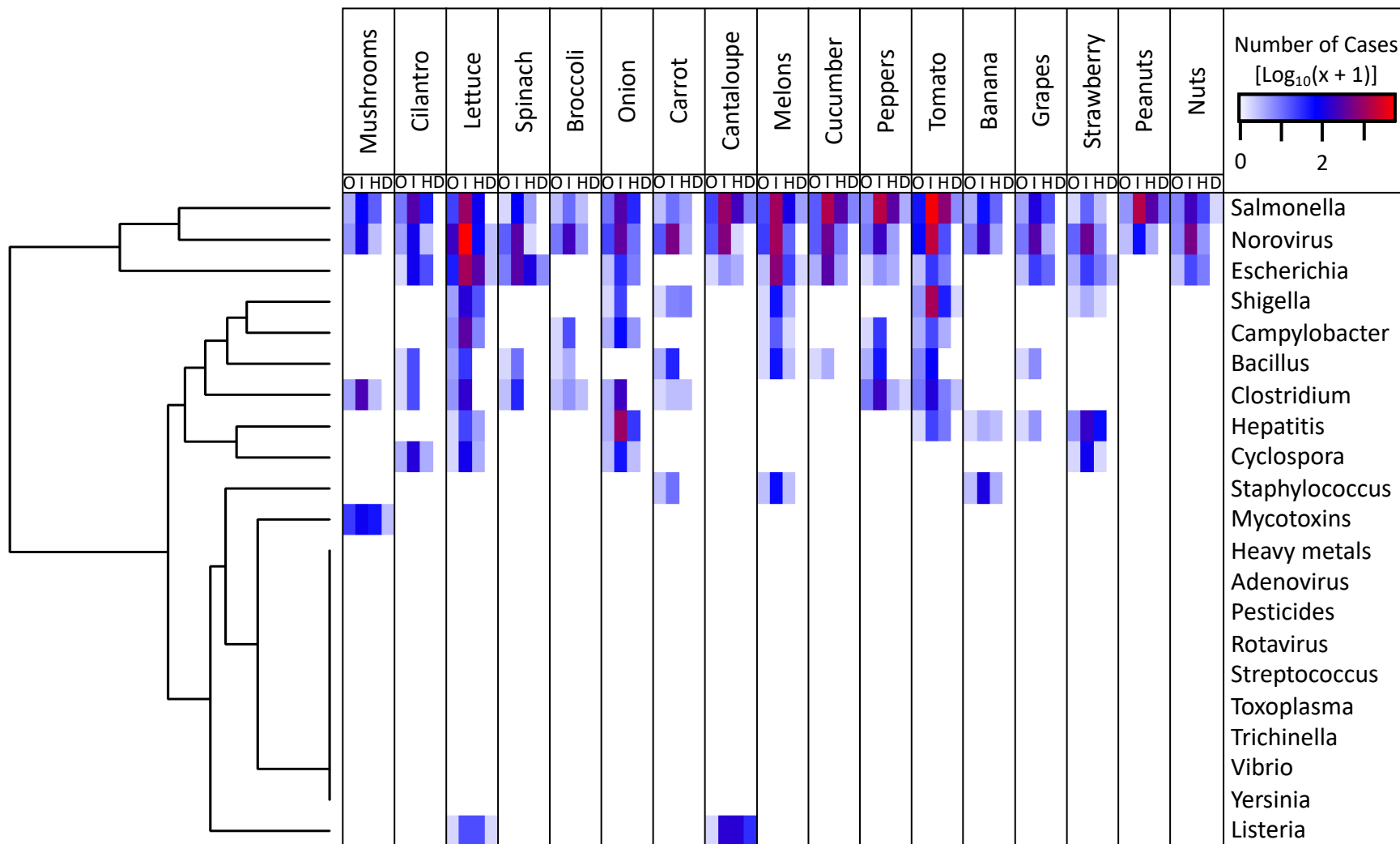
Slide courtesy of CDC

# Food Safety Concerns in Crops

(Low probability, High Consequence)

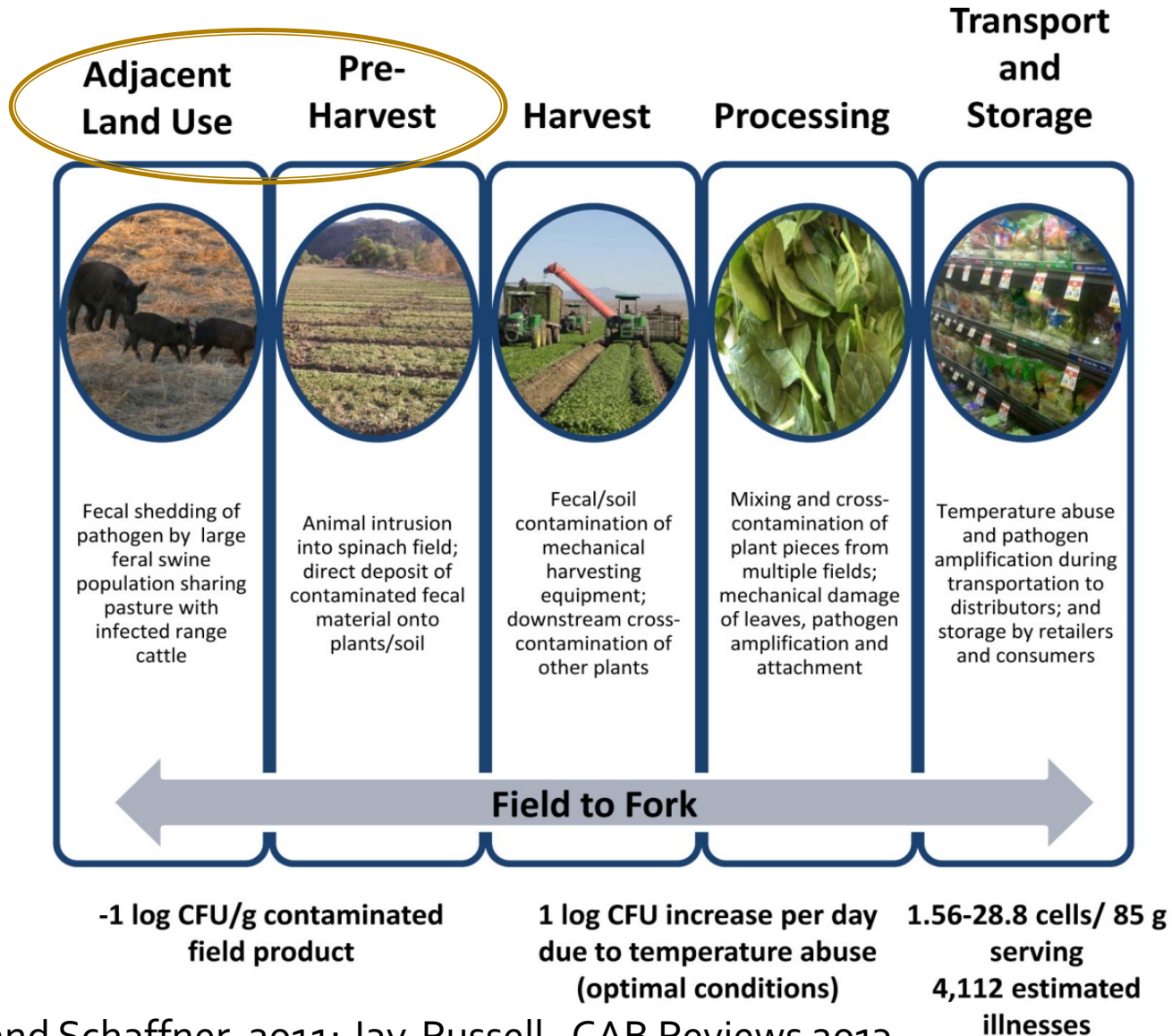
- Mycotoxins
- Salmonella
- Pathogenic E. coli
- Listeria, etc.
- Heavy metals
- Nitrates,
- Allergens





**Figure 1** | Number of outbreak (O), illness (I), hospitalization (H), and death (D) episodes of human diseases caused by the consumption of fresh produce contaminated with different etiological agents between 1998 and 2017 in the USA, according to the National Outbreak Reporting System database (<https://www.cdc.gov/nors/index.html>). Data was transformed with the  $\log_{10}(x + 1)$  function. The plot was constructed with the heatmap.2 package of R using hierarchical clustering analysis for etiological agents.

# An Integrated Approach is Required



Danyluk and Schaffner, 2011; Jay-Russell, CAB Reviews 2013





# PSA Grower Training Curriculum

## Seven hours of instruction in one day

- Introduction to Produce Safety
- Worker Health, Hygiene, and Training
- Soil Amendments
- Wildlife, Domestic Animals, & Land Use
- Water: Production and Postharvest Water
- Postharvest Handling and Sanitation
- How to Develop a Farm Food Safety Plan

*Course completion meets the Produce Safety Rule requirement in § 112.22(c), and results in eligibility for a certificate of completion from the Association of Food and Drug Officials (AFDO)*

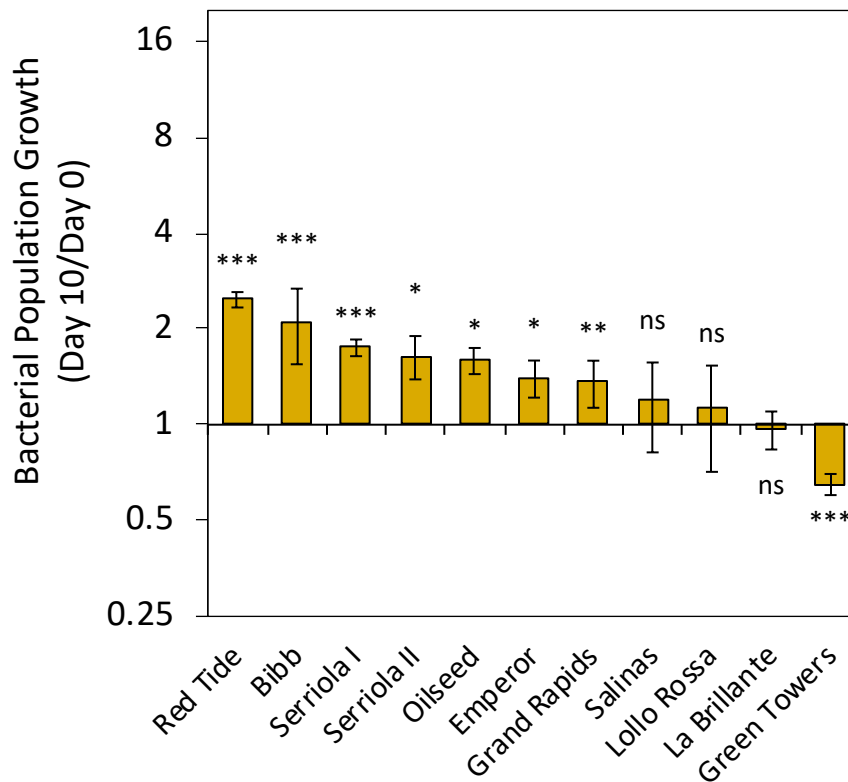
# Innovations in Plant Breeding

- Understanding genetic principles (Mendel, Hardy and Weiberg; 1865-1910)
- Statistics and Experimental Design (Fisher; Snedecor; Pearson; 1920-30s, Melchinger 2005)
- Hybridization and Heterosis (Shull 1908, East 1936, Gardner 1963)
- Biotechnology: tissue culture, mutation breeding, transgenics, **gene editing, genome editing**, synthetic biology (1950s+)
- Speed to market technologies: doubled haploids, counter seasonal nurseries
- Genomics and bioinformatics/**machine learning** (1990s+)
- **High Throughput Phenotyping** and **Artificial Intelligence** (2010s+)
- Intellectual Property and Regulation
- A Well-Educated Workforce



# Phenotypic Variation Exists in Lettuce for Capacity to Support *E. coli* Growth

*Bacterial Net Growth in Lettuce of E. coli*  
O157:H7



Red Tide



Salinas

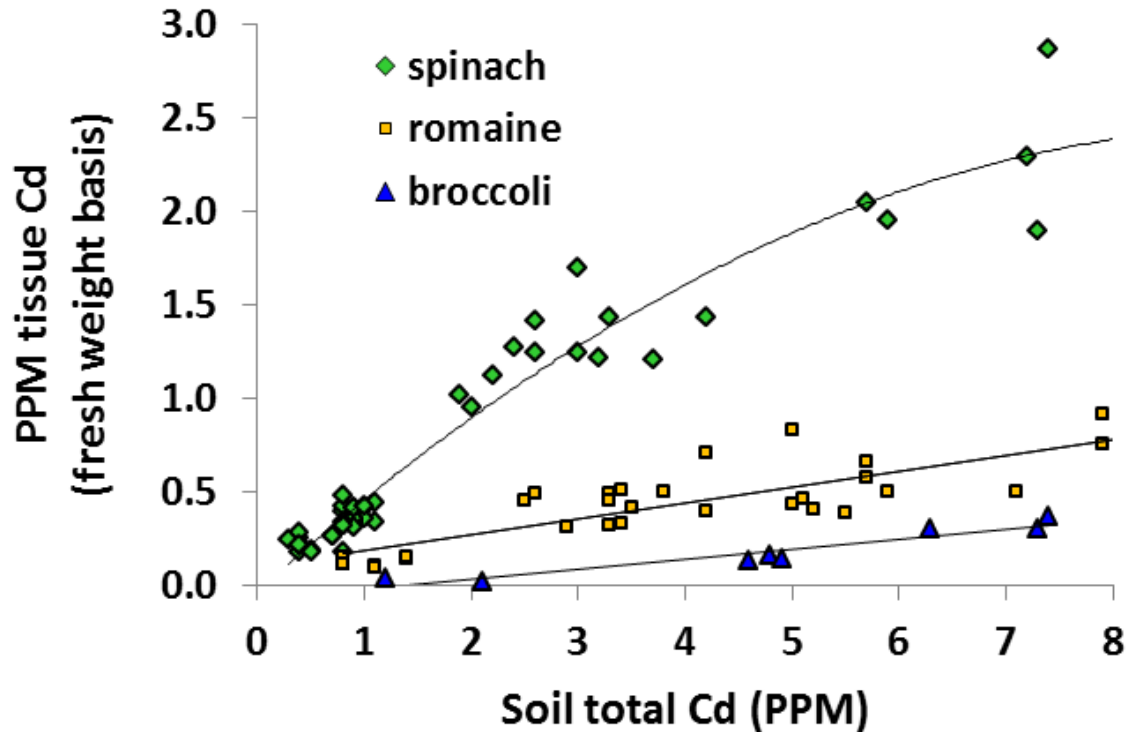


Lollo Rossa

# What Plant-based Traits Might be of Value for Food Safety?

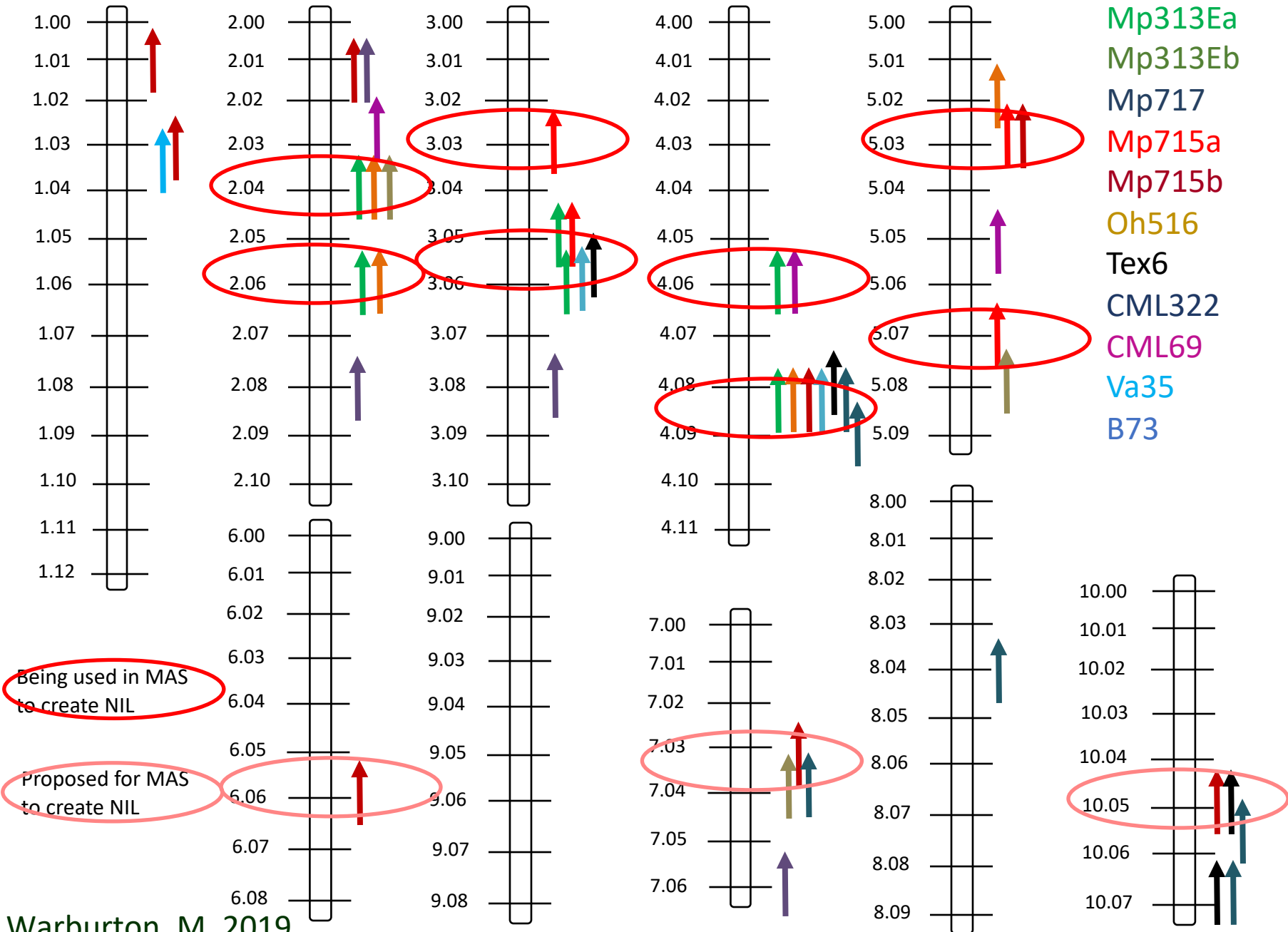
| Plant base traits for breeding for an enhanced microbiome                                | Possible negative and positive trade-offs  |
|--|--|
| Lower stomatal density and reduced stomatal size   | Lower photosynthesis, but improved WUE is possible with lower stomatal density   |
| Reduced trichome density, increased epidermal cell size and altered epidermal patterning | Reduced plant defence against biotic and abiotic stresses  |
| Increased leaf hydrophobicity through altered cuticular waxes                            | Waxy leaves may not be accepted by consumer  |
| Increased jasmonic acid, ethylene and other signalling defence molecules                 | May have better defence against pathogen and pest attack   |
| Plant chemistry- reduced available P, N and C to microbes                                | The interplay between altered plant nutrient status and impacts on leaf microbiome is complex and requiring further research |

**Spinach** is a heavy accumulator of **Cadmium**, but phenotypic variation exists for ability to take up Cd



Smith, R, Greenhut, R. 2019

# QTL for Aflatoxin in Maize



# Plant Breeding

a product-oriented discipline of sciences rooted in breeding, quantitative genetics and statistics for crop improvement that encompasses an increasing number of support technologies to sustain society

## Components:

Generate diversity-controlled crosses

Gene editing

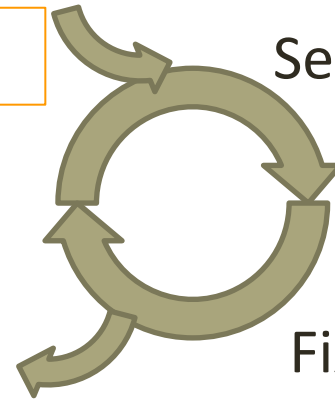
Selection

Gene editing

Varieties

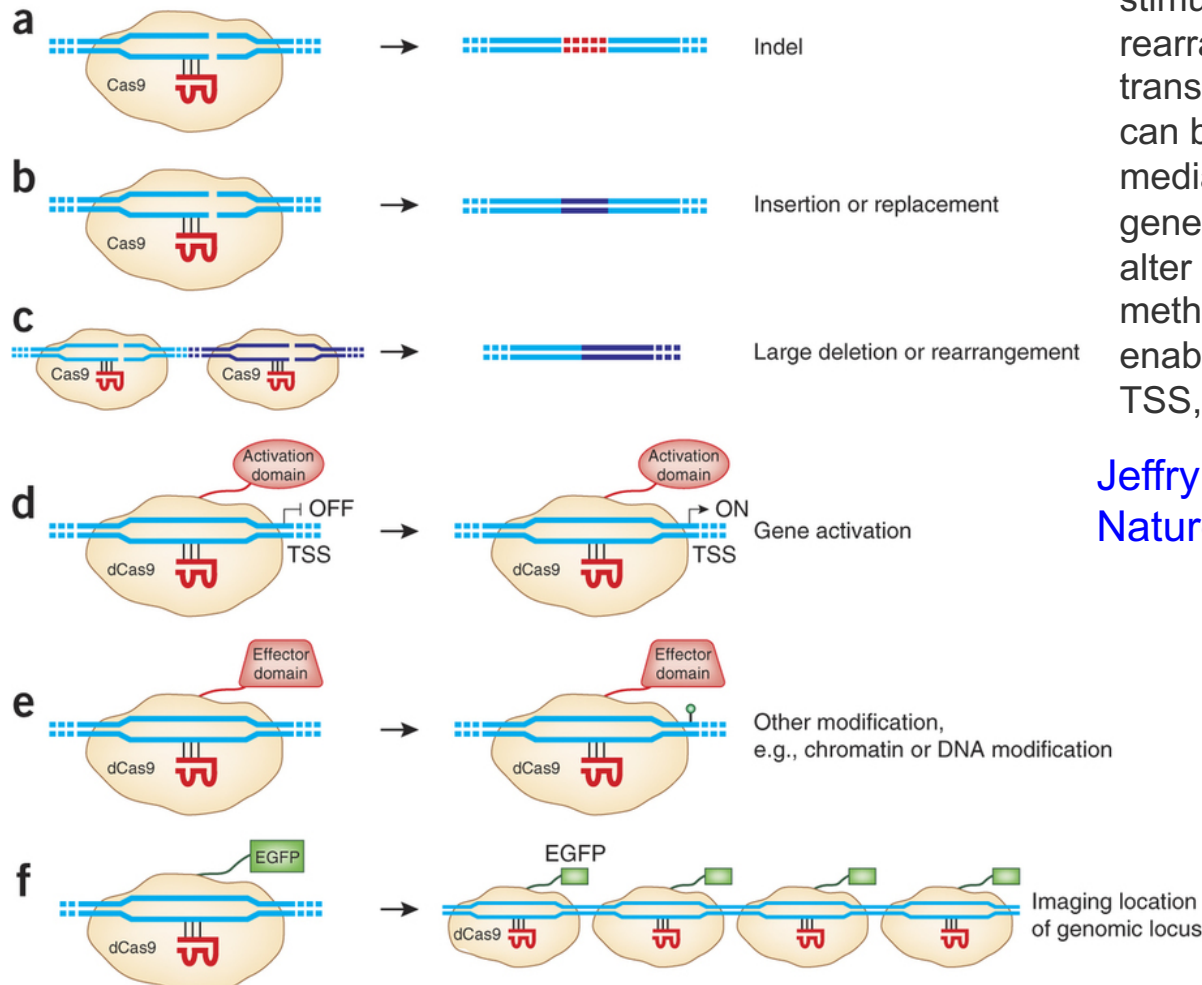
Fixing of traits

Test, test, test!





# CRISPR-Cas systems for editing, regulating and targeting genomes

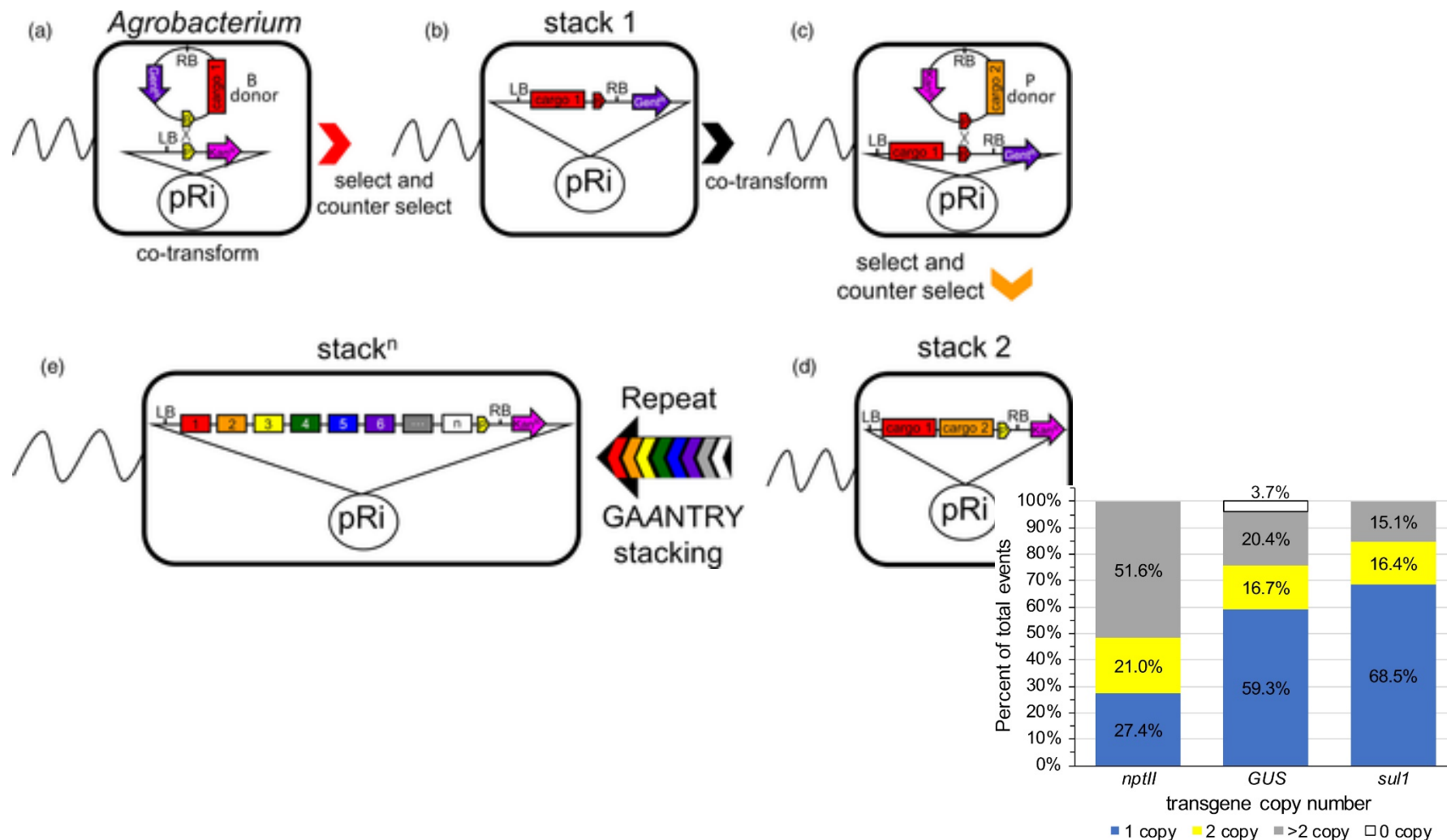


(a,b) gRNA-directed Cas9 nuclease can induce indel mutations (a) or specific sequence replacement or insertion (b). (c) Pairs of gRNA-directed Cas9 nucleases can stimulate large deletions or genomic rearrangements (e.g., inversions or translocations). (d-f) gRNA-directed dCas9 can be fused to activation domains (d) to mediate upregulation of specific endogenous genes, heterologous effector domains (e) to alter histone modifications or DNA methylation, or fluorescent proteins (f) to enable imaging of specific genomic loci. TSS, transcription start site.

Jeffrey D Sander & J Keith Joung  
Nature Biotechnology 32, 347–355 (2014)



# A versatile and robust *Agrobacterium*-based gene stacking system generates high-quality transgenic *Arabidopsis* plants

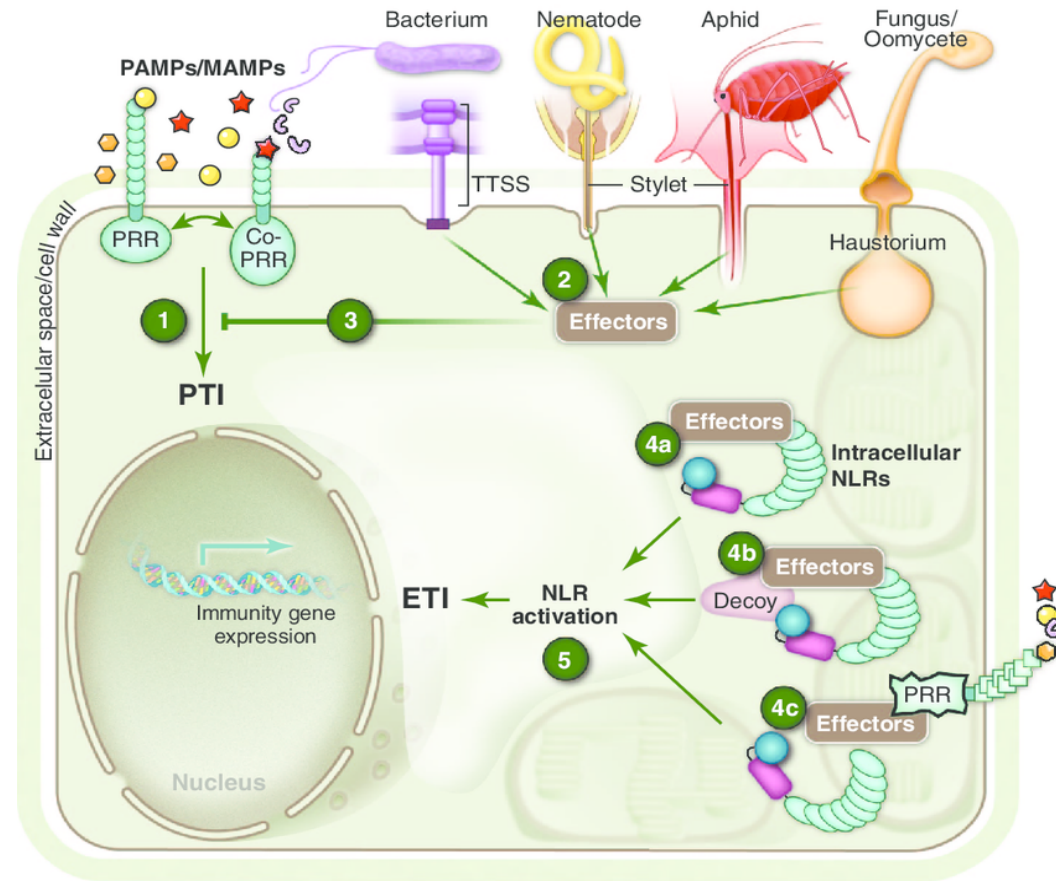


Collier et al. *The Plant Journal*, Volume: 95, Issue: 4, Pages: 573-583, First published: 14 June 2018, DOI: (10.1111/tpj.13992)

# Salmonella and plant immunity

Dangl et al., 2013  
*Science* 341:746-51

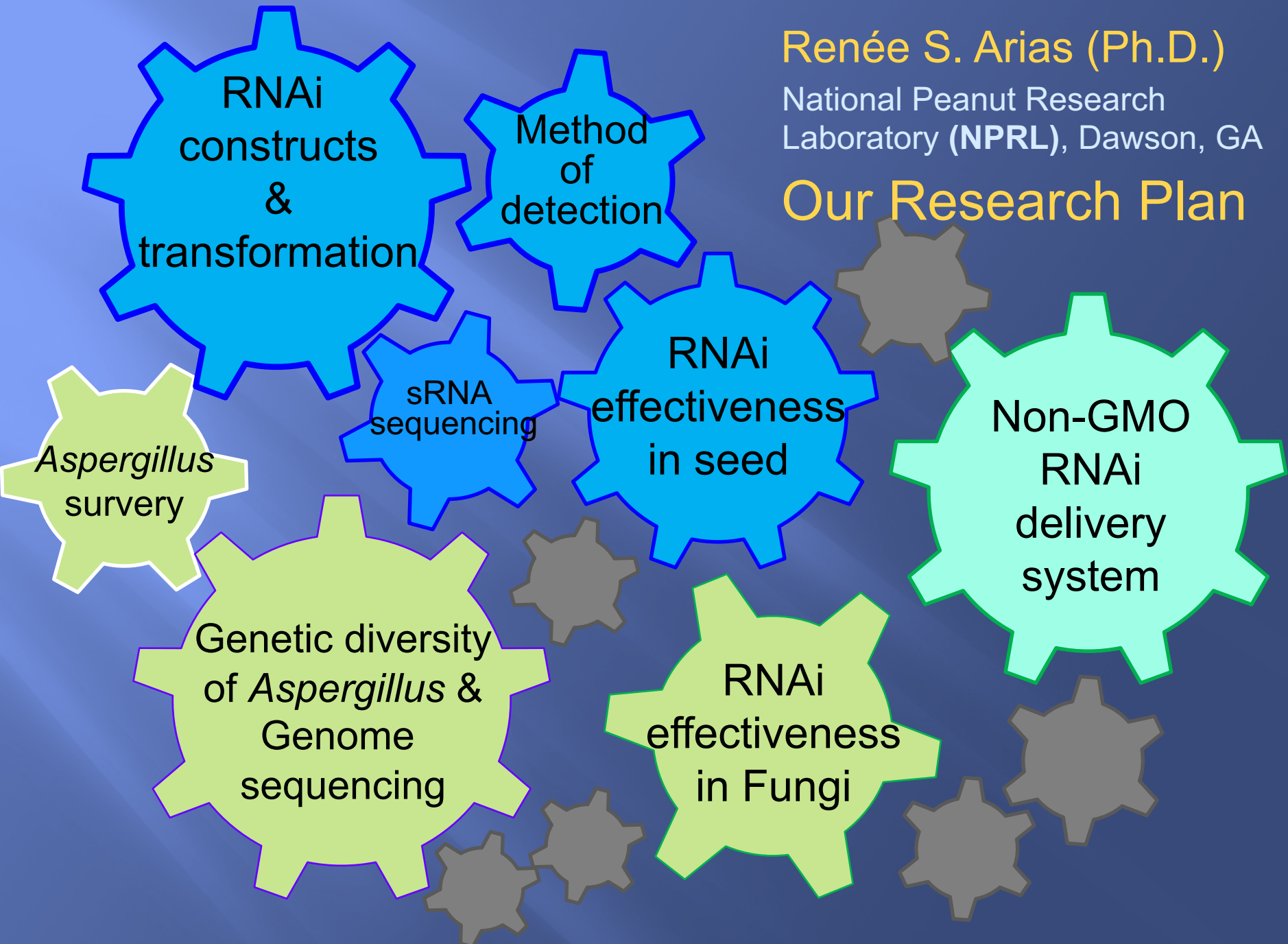
- Reactive oxygen species (ROS) are important signalling molecules in the plant immune response
- ROS response has been described in *S. Typhimurium Nicotiana tabacum* interaction (Shirron and Yaron, 2011)
- *S. Typhimurium* PAMP Flg22 is recognized by *Arabidopsis* (Chen et al., 2014)
- ROS production induced by *Salmonella* PAMP flg22 in tomato (Meng et al., 2013)



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## Our Research Plan



# Workshop Recommendations

- Continue foundational research to create crucial knowledge of plant interactions with human pathogens and contamination of food with microbes, mycotoxins, elements and allergens.
- Initiate pre-breeding strategies to characterize genetic variability, heritability and efficacy of target traits.
- Support breeding programs where genetic variation and efficacy of target traits are established, e.g. breeding lines that accumulate less aflatoxins and heavy metals.



# frontiers Research Topics

## Breeding Crops for Enhanced Food Safety

<https://www.frontiersin.org/research-topics/10623/breeding-crops-for-enhanced-food-safety>

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See [Seedworld.com](http://Seedworld.com) for interviews and articles



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