Breeding Crops for Enhanced Food Safety

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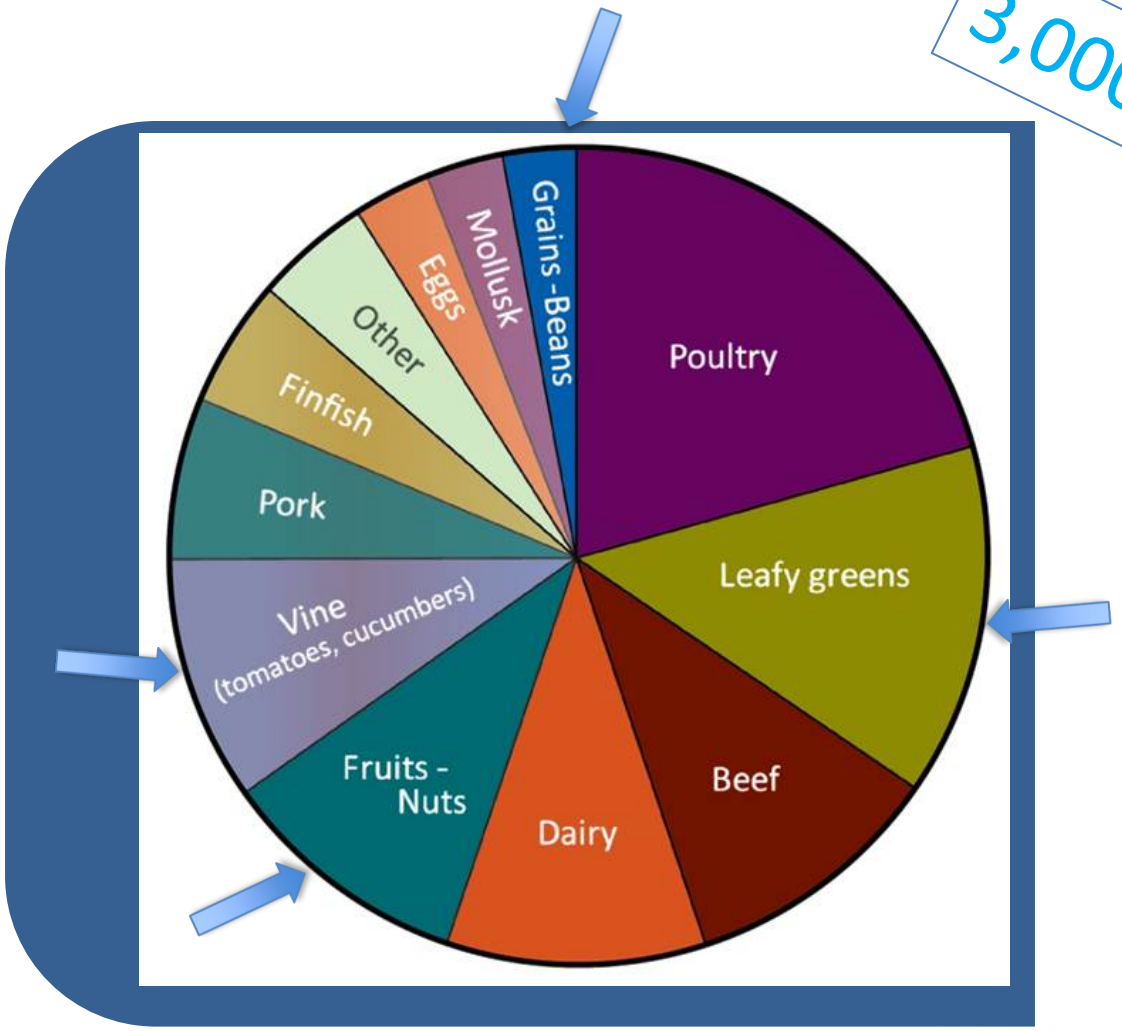
June 5-6, 2019

UC Davis

Almost any type of food can spread illness

48 M Sick

3,000 Deaths



Slide courtesy of CDC

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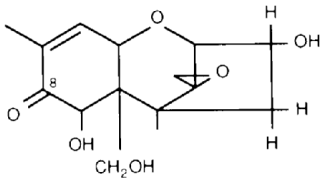
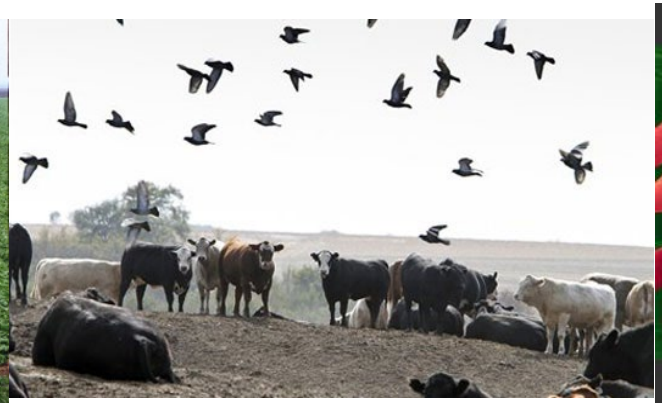
Food Safety Concerns in Crops

(Low probability, High Consequence)

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





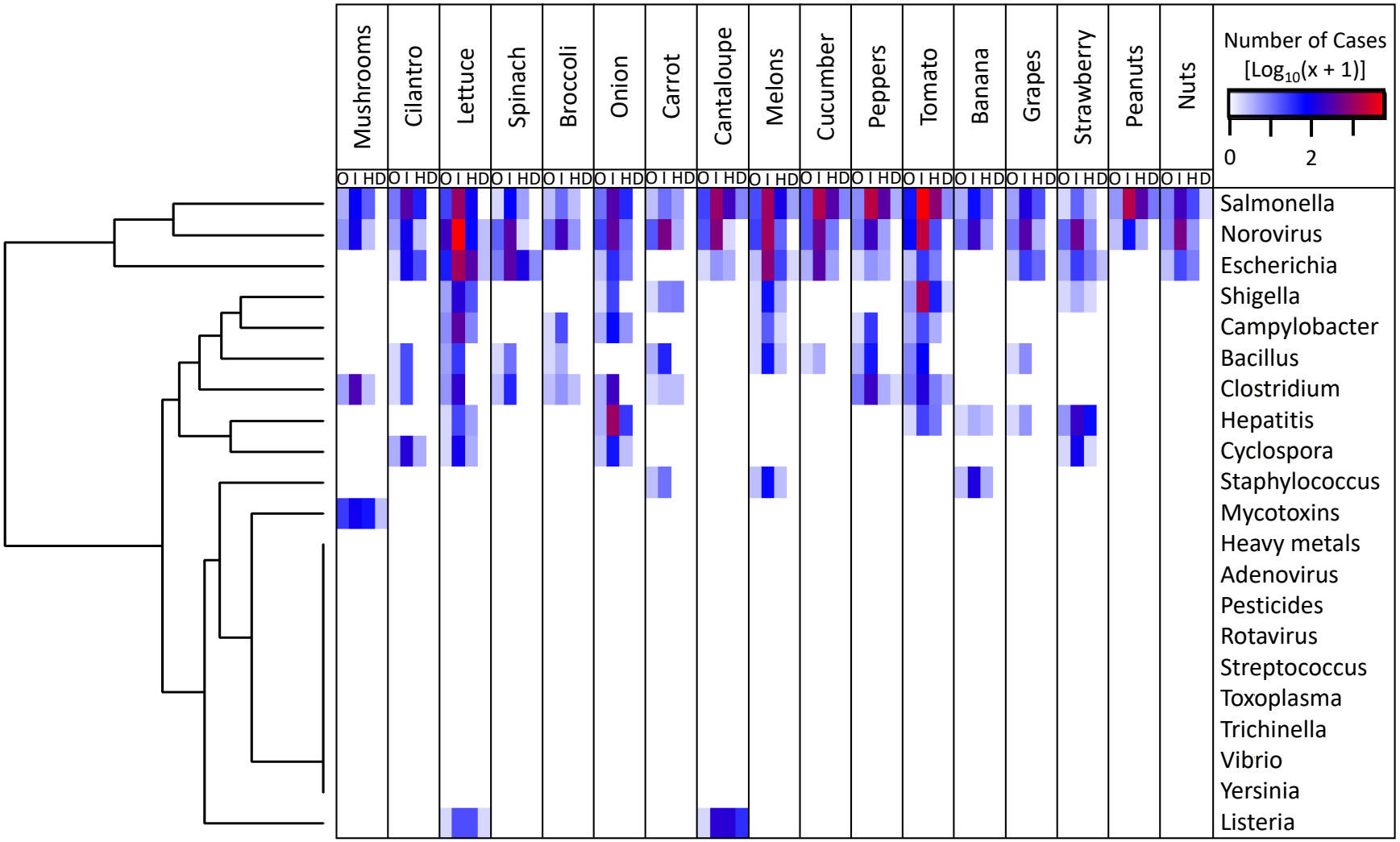
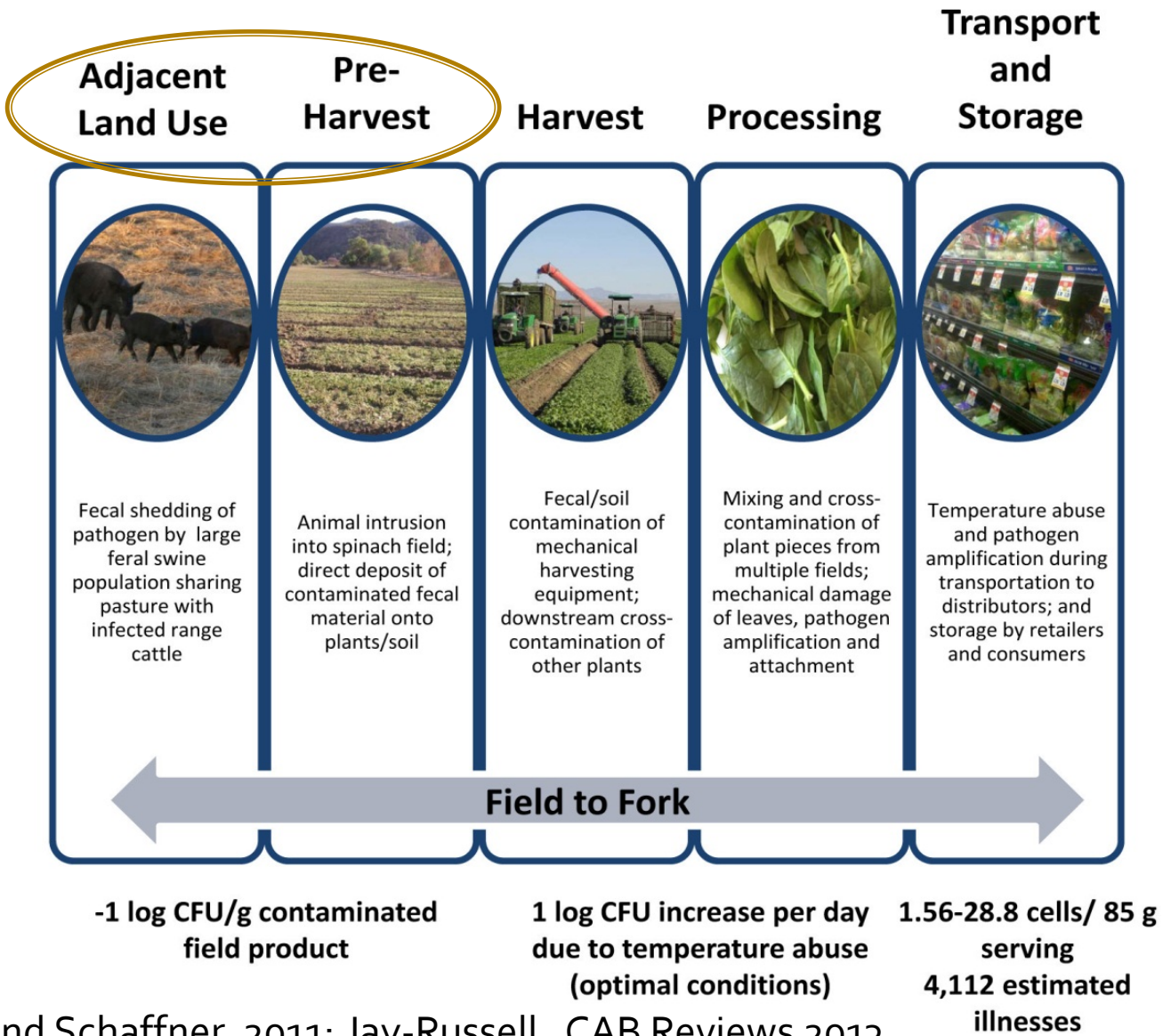


Figure 1 | Number of outbreak (O), illness (I), hospitalization (H), and death (D) episodes of human diseases caused by the consumption of fresh produce contaminated with different etiological agents between 1998 and 2017 in the USA, according to the National Outbreak Reporting System database (https://www.cdc.gov/nors/index.html). 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

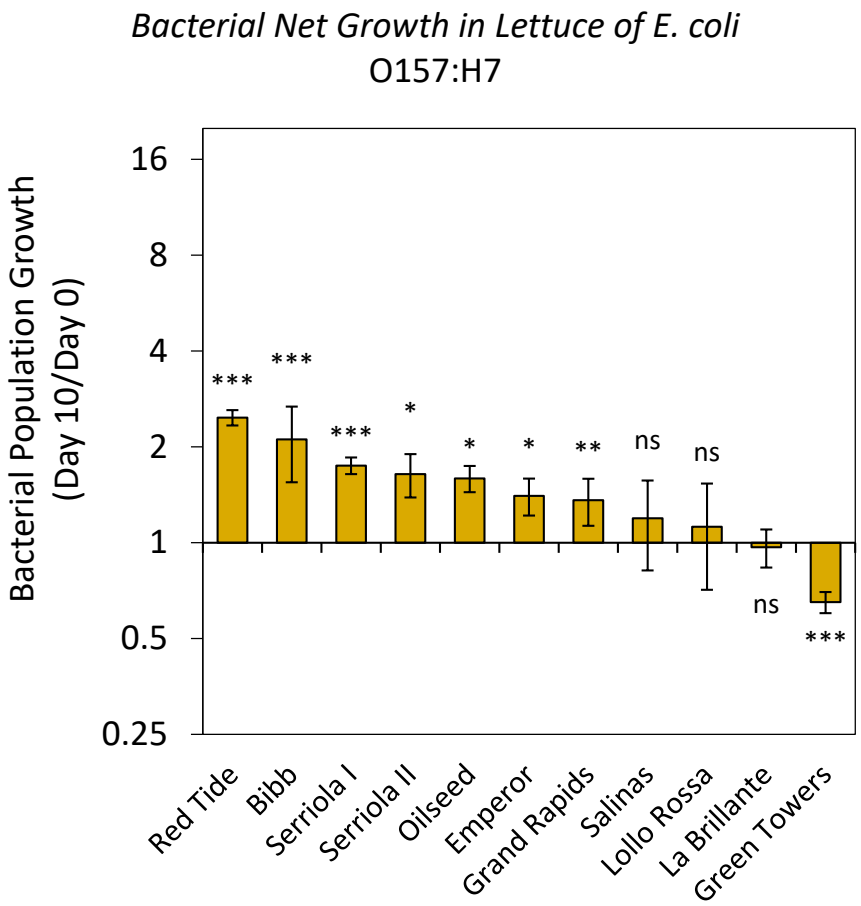


Danyluk and Schaffner, 2011; Jay-Russell , CAB Reviews 2013

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



Red Tide

Salinas

Lollo Rossa

Melotto, M. 2019

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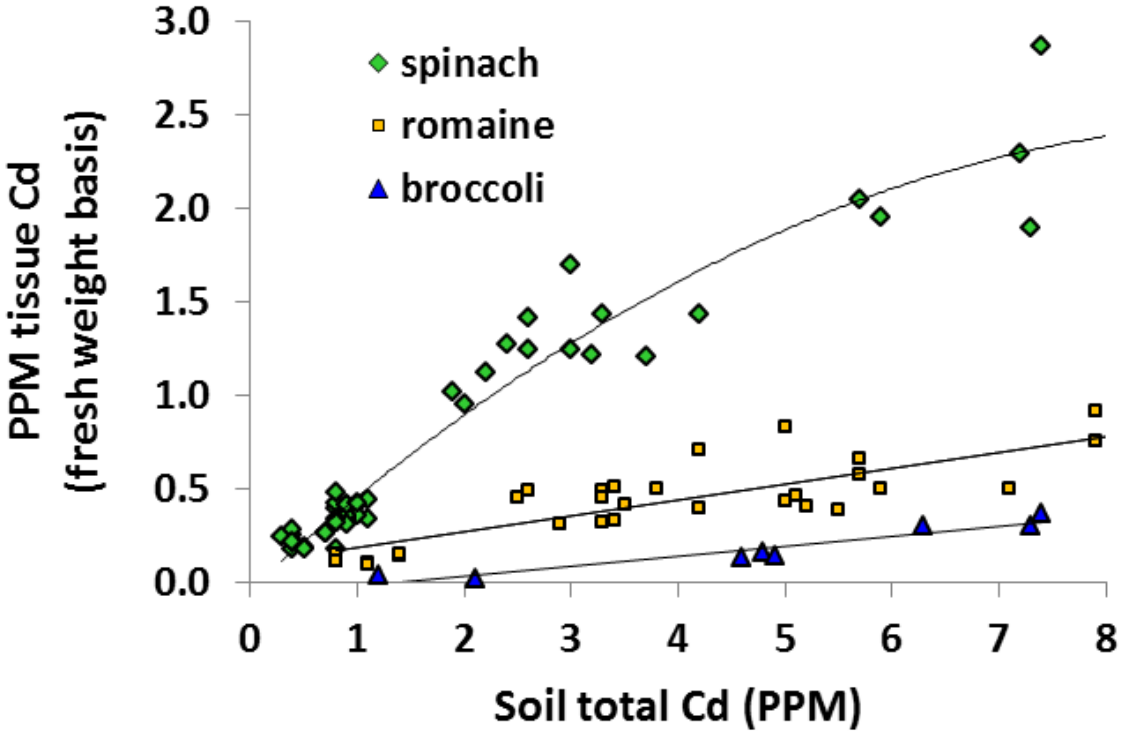
What Plant-based Traits Might be of Value for Food Safety?

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 again 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

Taylor and Arnold, 2019

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



Smith, R, Greenhut, R. 2019

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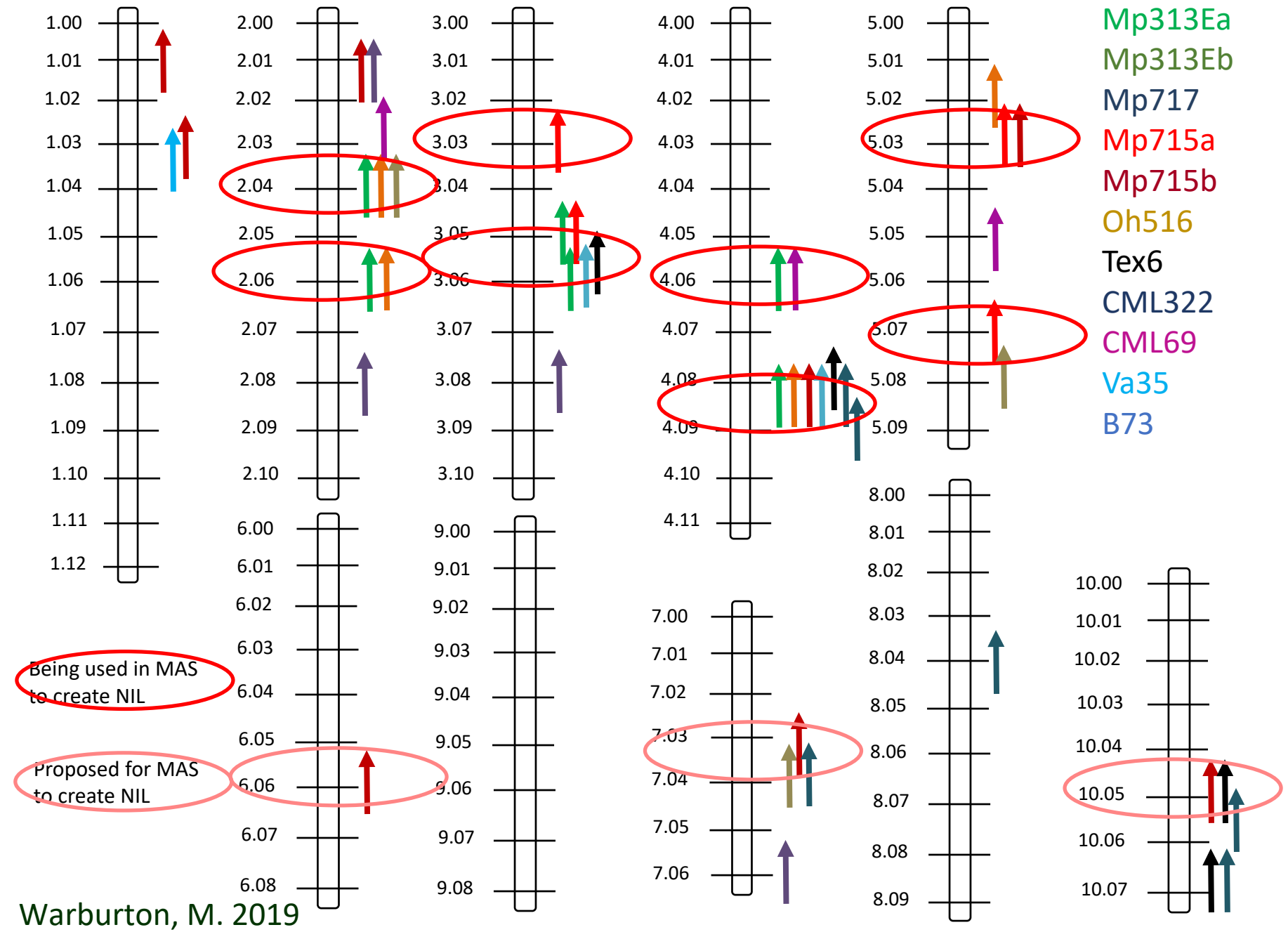
QTL for Aflatoxin in Maize



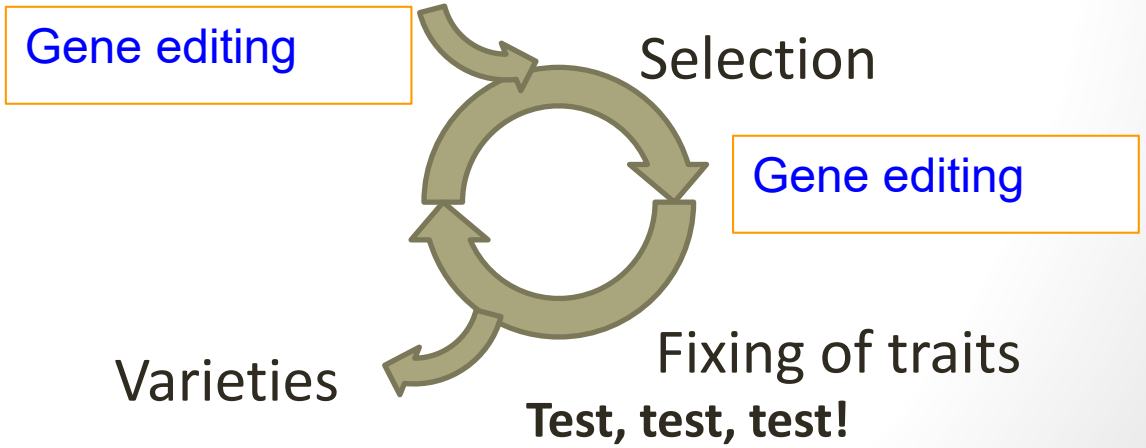
Warburton, M. 2019

Plant Breeding

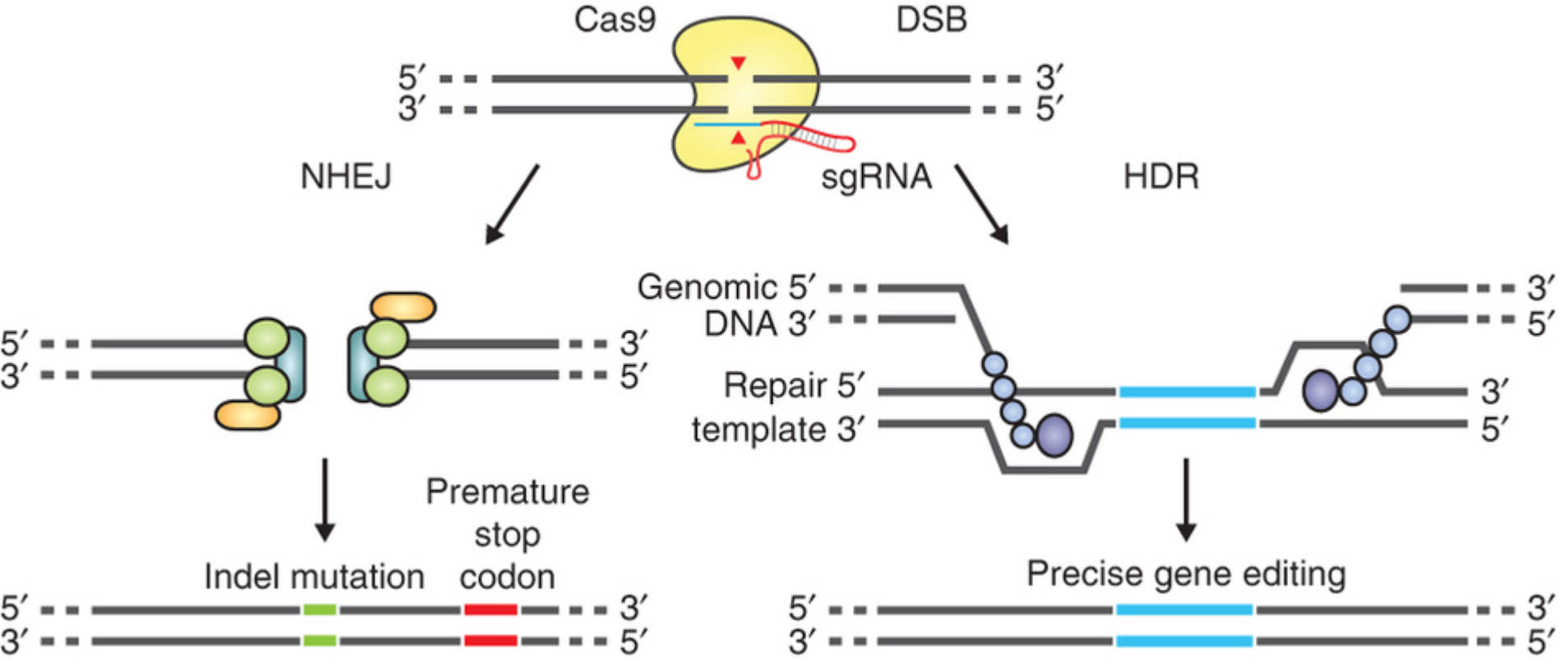
a product-oriented discipline of sciences rooted in breeding, quantitative genetics and statistics for crop improvement that encompasses an increasing number of support technologies to sustain society

Components:

Generate diversity-controlled crosses

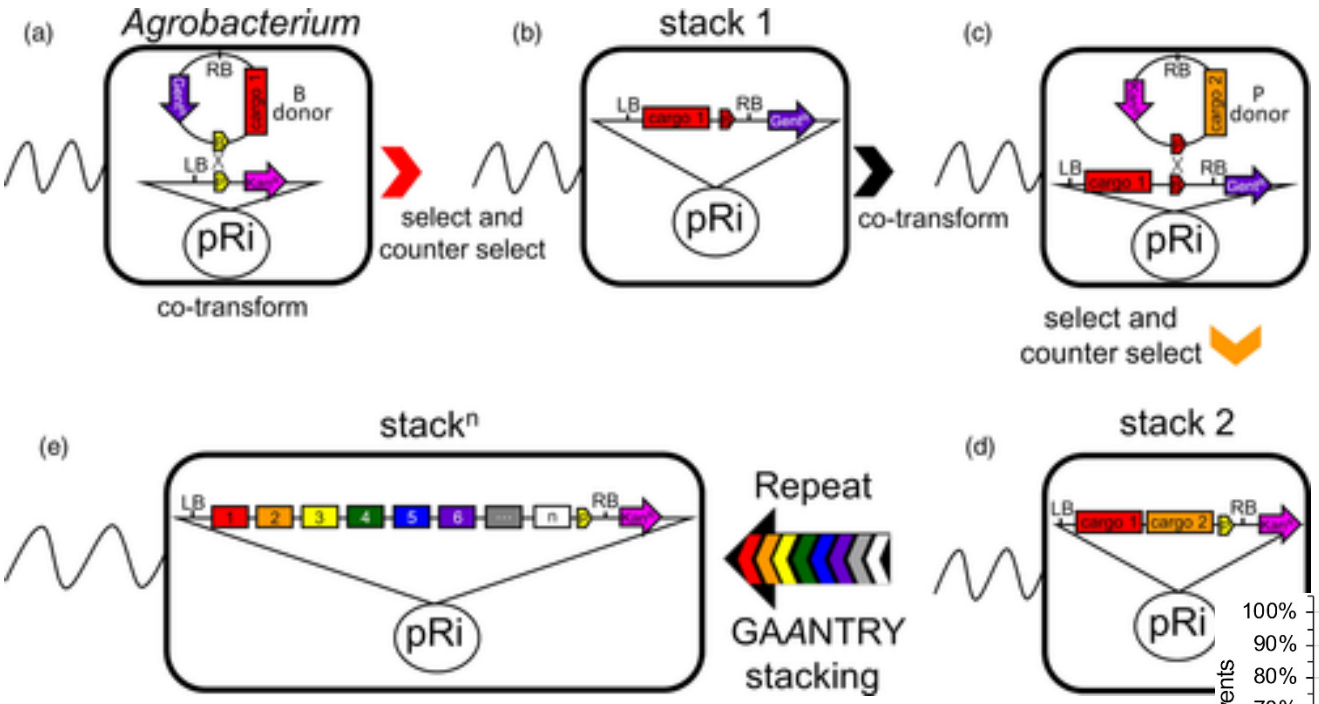


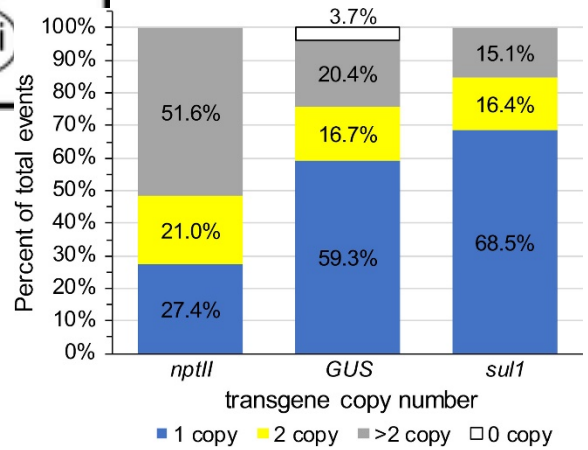
Precision Breeding-Cas9/CRISPR



DSBs induced by Cas9 (yellow) can be repaired in one of two ways. In the error-prone NHEJ pathway, the ends of a DSB are processed by endogenous DNA repair machinery and rejoined, which can result in random indel mutations at the site of junction. Indel mutations occurring within the coding region of a gene can result in frameshifts and the creation of a premature stop codon, resulting in gene knockout. Alternatively, a repair template in the form of a plasmid or ssODN can be supplied to leverage the HDR pathway, which allows high fidelity and precise editing. Single-stranded nicks to the DNA can also induce HDR.

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



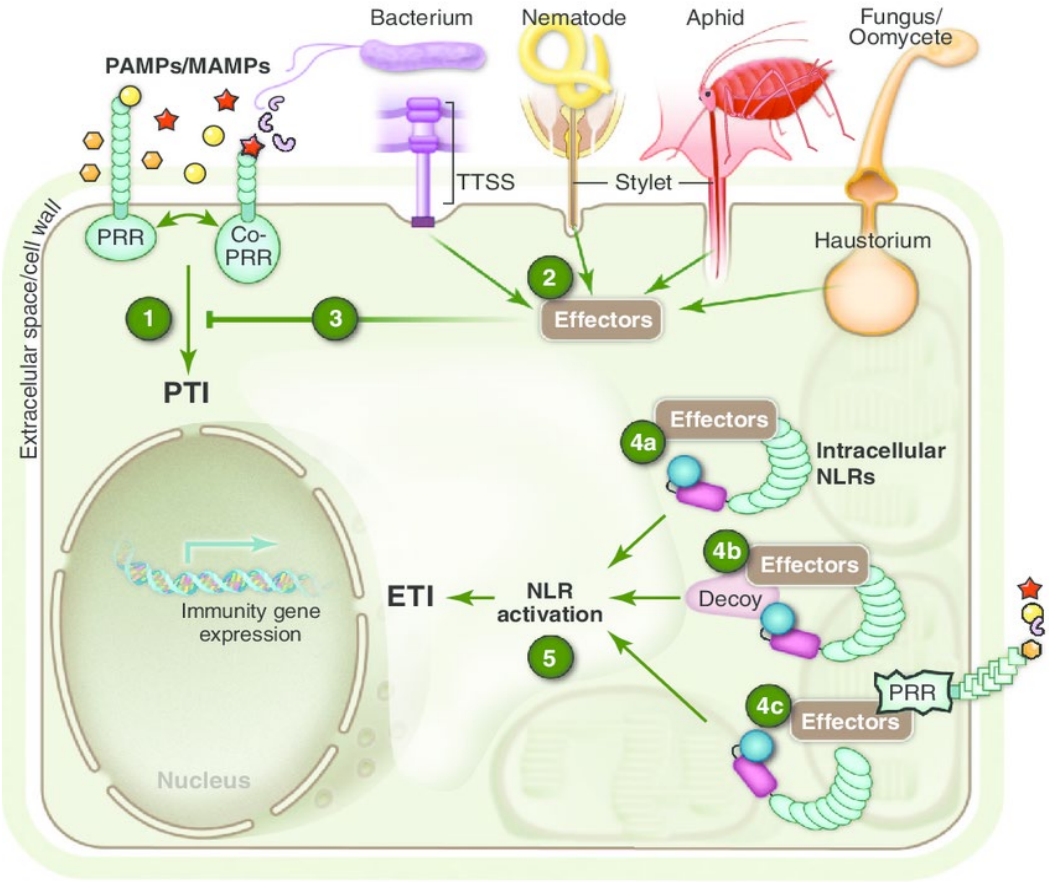


Collier et al. The Plant Journal, Volume: 95, Issue: 4, Pages: 573-583, First published: 14 June 2018, DOI: (10.1111/tpj.13992)

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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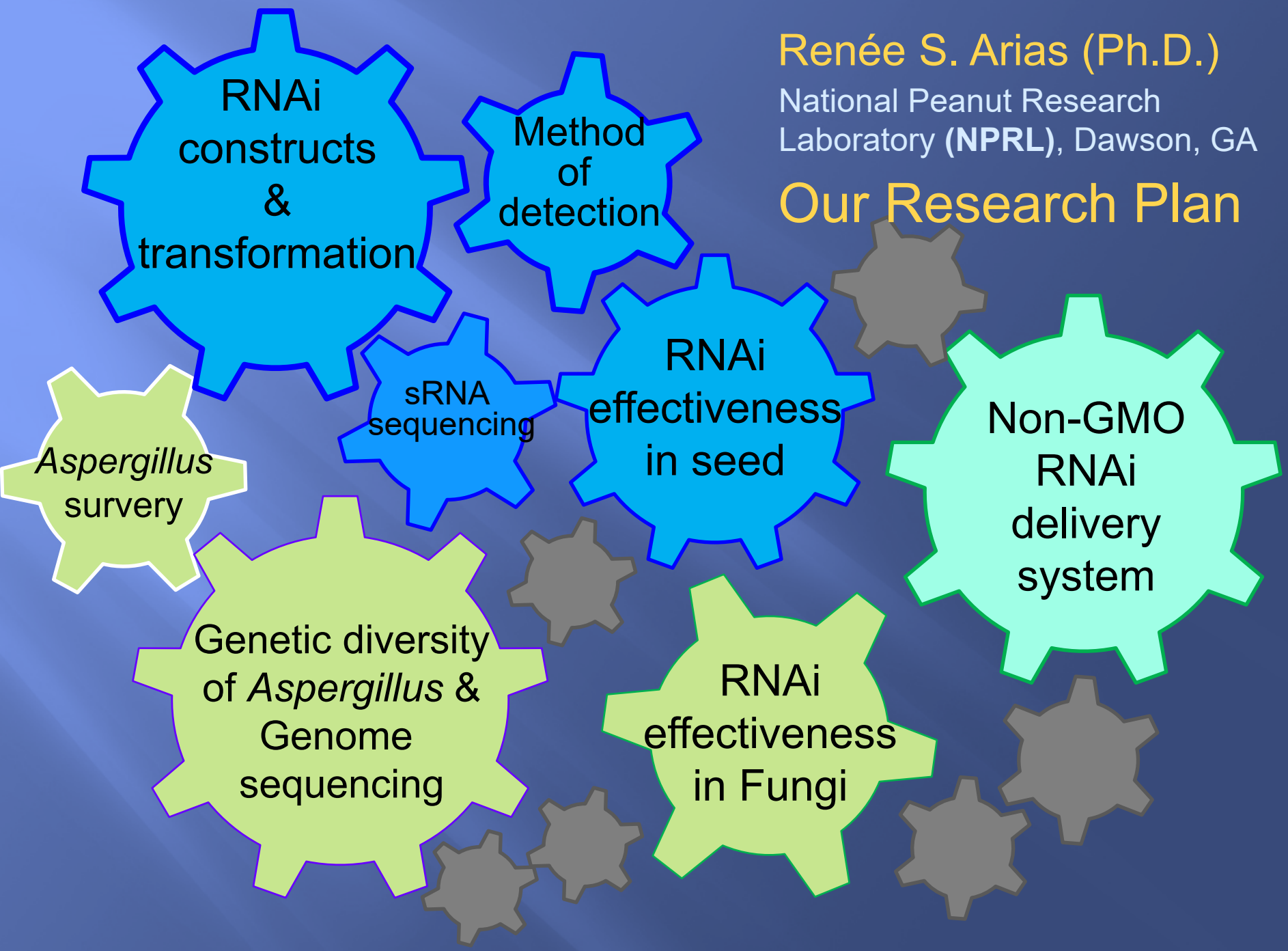
Our Research Plan



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 for interviews and articles

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