



# ***THE PHYTOBIOMES INITIATIVE***

**An initiative from the American  
Phytopathological Society (APS)**

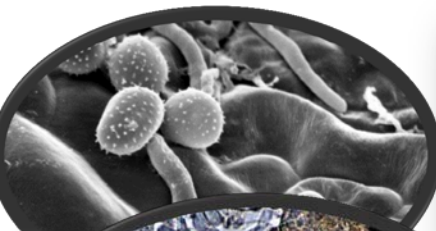
**Jan E. Leach, Chair  
APS Public Policy Board  
Colorado State University**



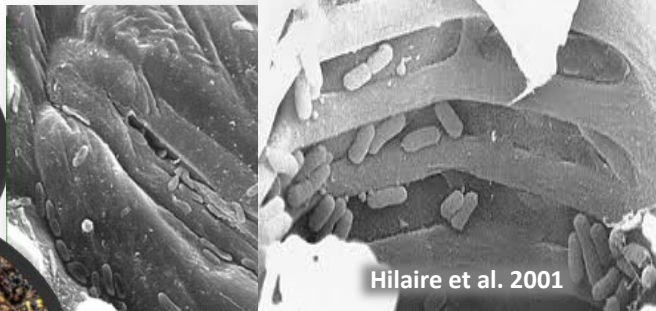


# What is the *Phytobiome*?

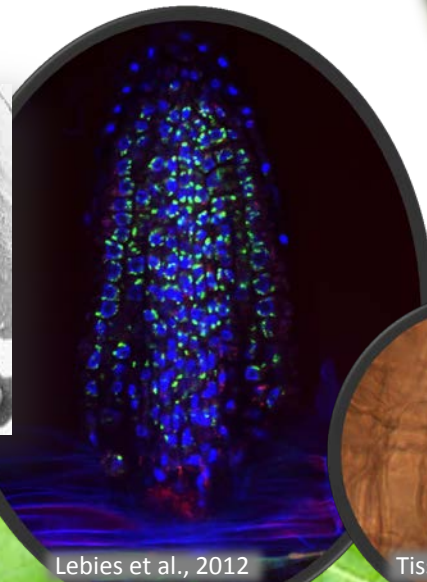
- All organisms living in, on and around plants
  - microbes (the plant microbiome)
    - animals (insects, nematodes, etc)
    - other plants



Hoch et al. 1987



Hilaire et al. 2001



Lebies et al., 2012



Wergin et al.,  
USDA

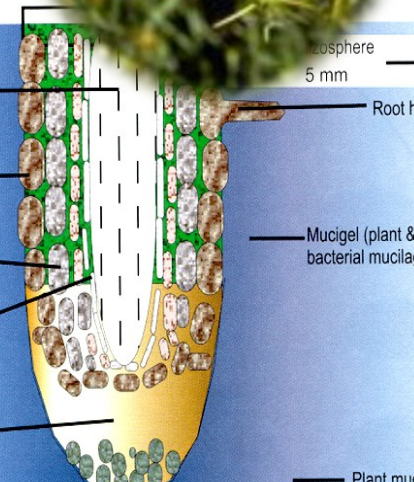
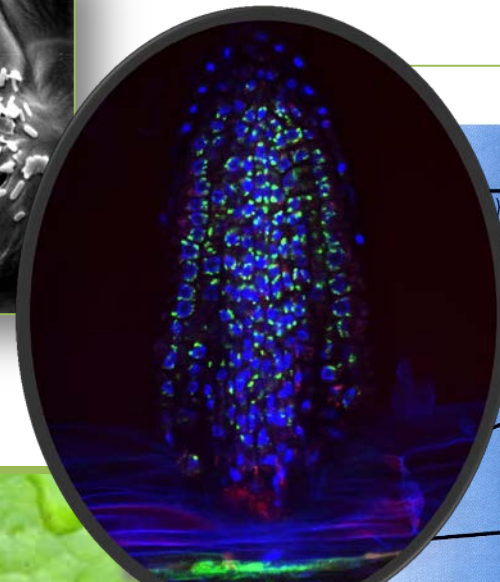
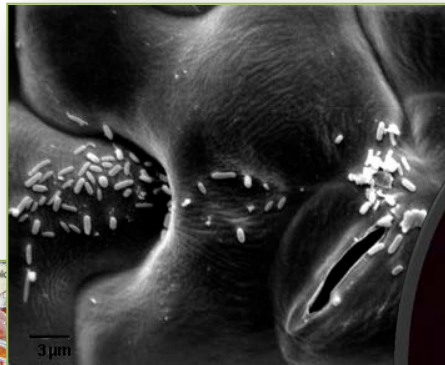
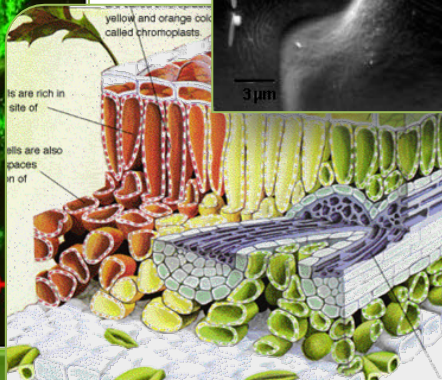
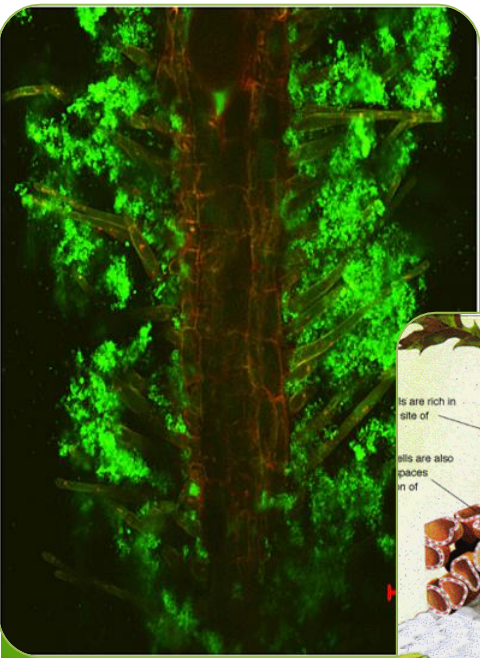
Tisserat, 2014





# What is the *Phytobiome*?

- Encompasses the many organisms that influence or are influenced by the plant or plant environment (including the soil)

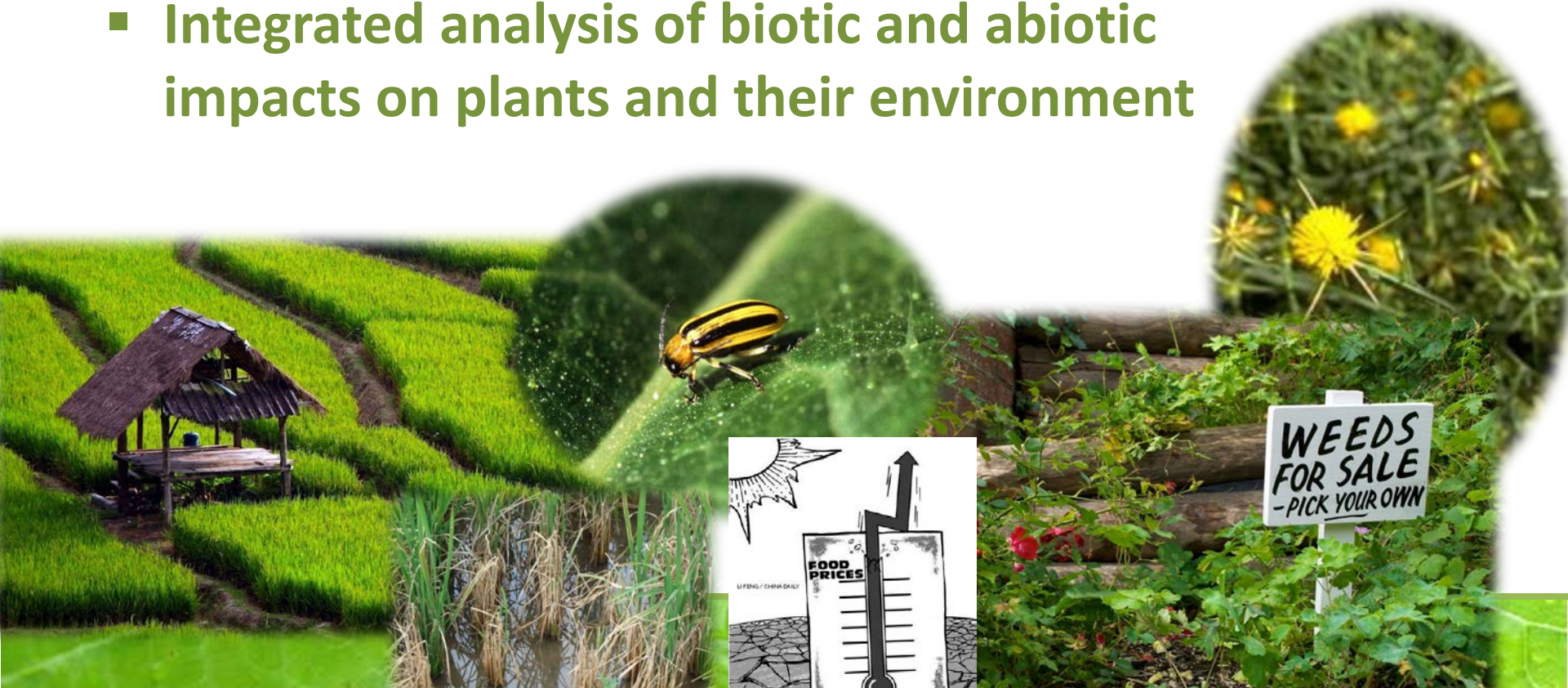






## ***Phytobiomics* is focused on systems biology:**

- **Understanding interactions in context**
- **Integrated analysis of biotic and abiotic impacts on plants and their environment**





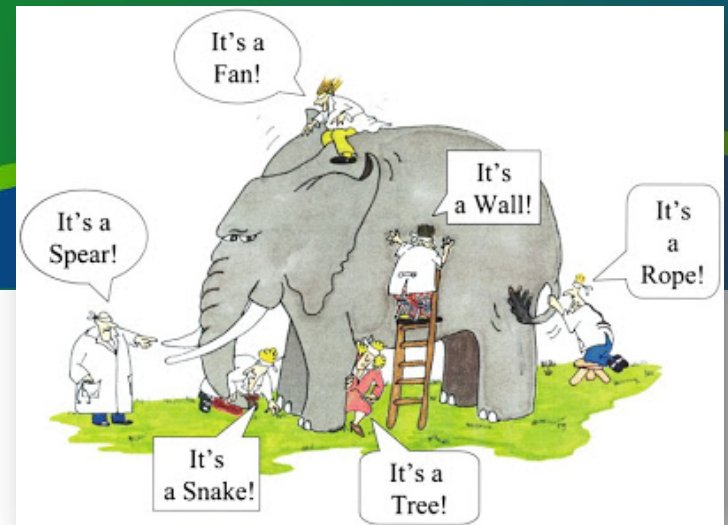
# The Phytobiomes Initiative targets an understanding of:

- how organisms associated with plants influence or are influenced by the plant or the plant environment,
- how that information can be used to improve crop productivity, quality, and safety

## GOAL

- **By 2025, a comprehensive understanding of phytobiomes to improve crop productivity**





# Where are we starting?

## *Phytobiomes:*

- include individual organisms that function as commensals, pathogens and beneficials

Most studies of one/few organisms → What about communities?

- include cultured and non-cultured organisms

Most studies of cultured organisms → Roles for non-cultured?

- are influenced by many biotic and abiotic stresses

Most studies of one plant/microbe/stress at a time

→ Can we integrate our knowledge of the *SYSTEM*?







# Why the Phytobiomes Initiative now?

- Advances in metagenomics-enabling technologies:
  - high-throughput sequencing
  - computational biology
  - other 'omics' technologies
- Systems-level approaches
- Human Microbiome discoveries
  - lessons learned
  - paradigm shifts
  - applications



*These advances are enabling us to assess the community composition, function, and activity of culturable and non-culturable organisms in the phytobiome*





**Sample collection**

**Community DNA extraction**



**Community RNA, protein, metabolite extraction**



**PCR amplify  
(16S-18S rRNA, ITS)**

**Amplicon sequencing**

**Metagenome sequencing**

**Meta-transcriptome sequencing**

**Metaproteome analysis**

**Metabolome analysis**

**Species (taxa)  
number, abundance,  
composition**

**Community function**

**Community activity**

**“Who is there?”**

**“What can they do?”**

**“What are they doing?”**



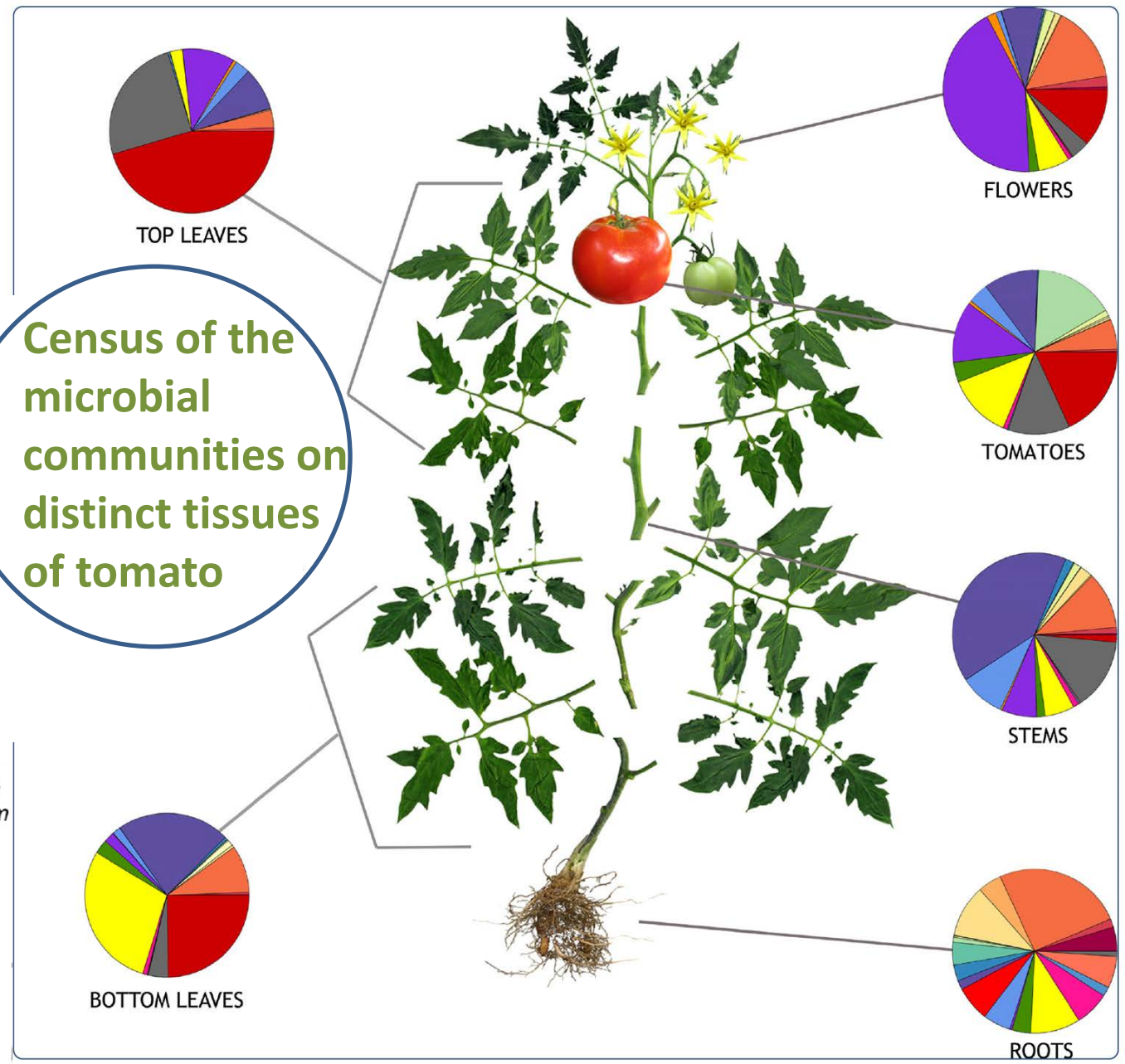


# Who is there?

## *Bacterial communities*

### Census of the microbial communities on distinct tissues of tomato

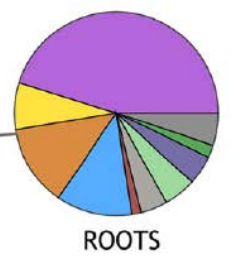
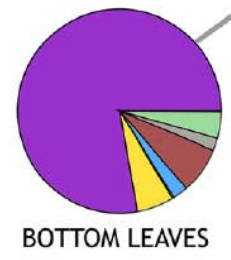
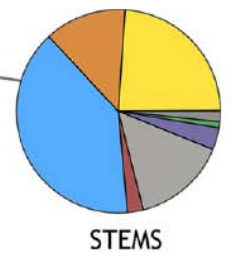
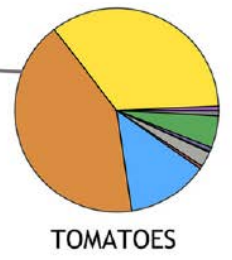
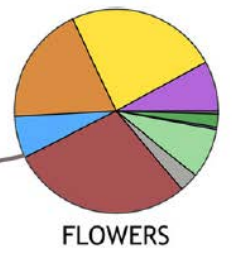
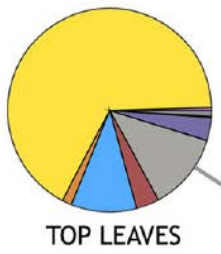
- Acidobacteriaceae\_Gp1
- Actinomycetales\_Frankineae
- Actinomycetales\_Micrococcineae
- Actinomycetales\_Propionibacterineae
- Bacteria\_Other
- Comamonadaceae\_Acidivorax
- Enterobacteriaceae\_Erwinia
- Enterobacteriaceae\_Other
- Flavobacteriaceae\_Chryseobacterium
- Gemmatimonadaceae\_Gemmatimonas
- Methylobacteriaceae\_Methylobacterium
- Phyllobacteriaceae\_Mesorhizobium
- Proteobacteria\_Other
- Pseudomonadaceae\_Chryseomonas
- Pseudomonadaceae\_Pseudomonas
- Rhizobiaceae\_Agrobacterium
- Rhizobiaceae\_Rhizobium
- Rhizobiales\_Other
- Sphingomonadaceae\_Other
- Sphingomonadaceae\_Sphingobium
- Sphingomonadaceae\_Sphingomonas
- Xanthomonadaceae\_Xanthomonas



# Who is there?

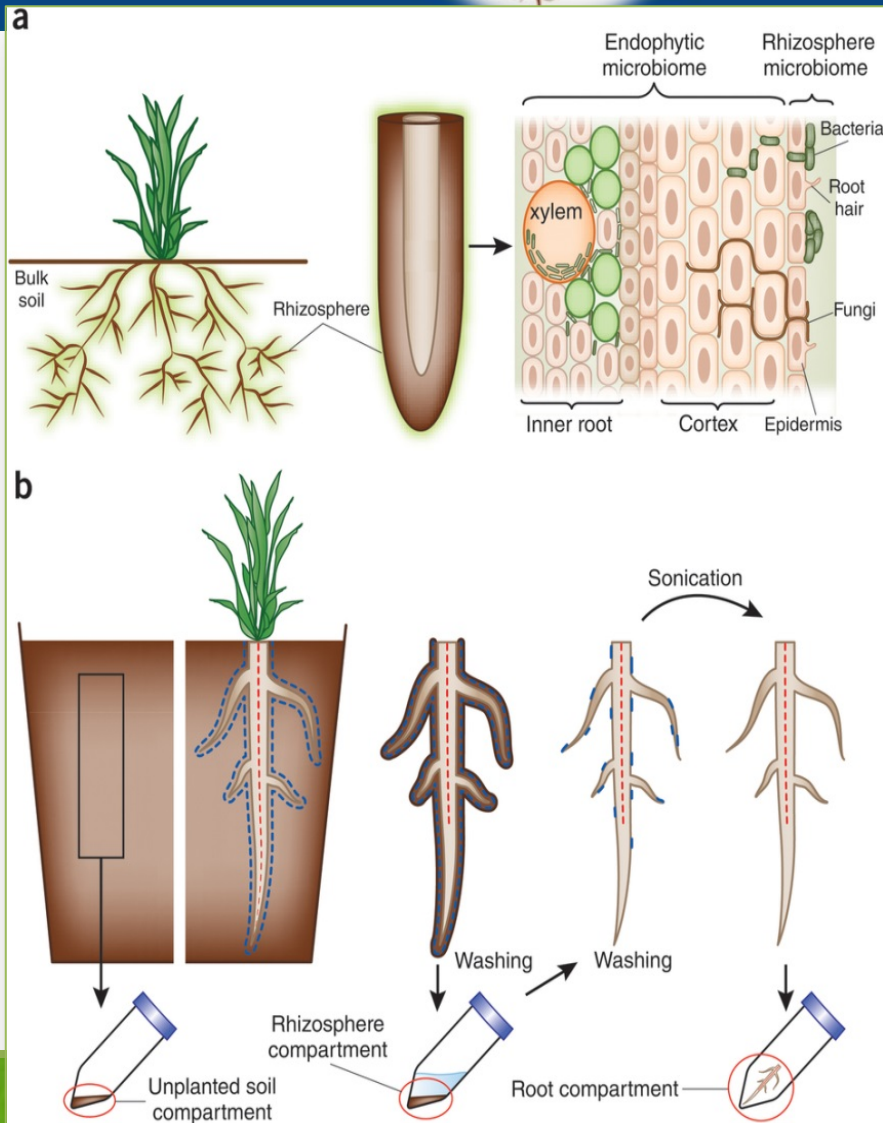
## *Fungal communities*

Census of the microbial communities on distinct tissues of tomato



- Dikarya *Hypocrea*
- Eukarya Other
- Root Other
- Dikarya *Aureobasidium*
- Dikarya Environmental
- Dikarya *Cryptococcus*
- Dikarya *Chaetomium*
- Fungi Other
- *Fusarium oxysporum*
- Dikarya *Aspergillus*





# Is there a core rhizosphere microbiome?

- DNA from microbes in the soil, rhizosphere, and endophytic compartments
- amplicon sequencing

Lundberg et al, Nature 2012

Bulgarelli et al, Nature 2012

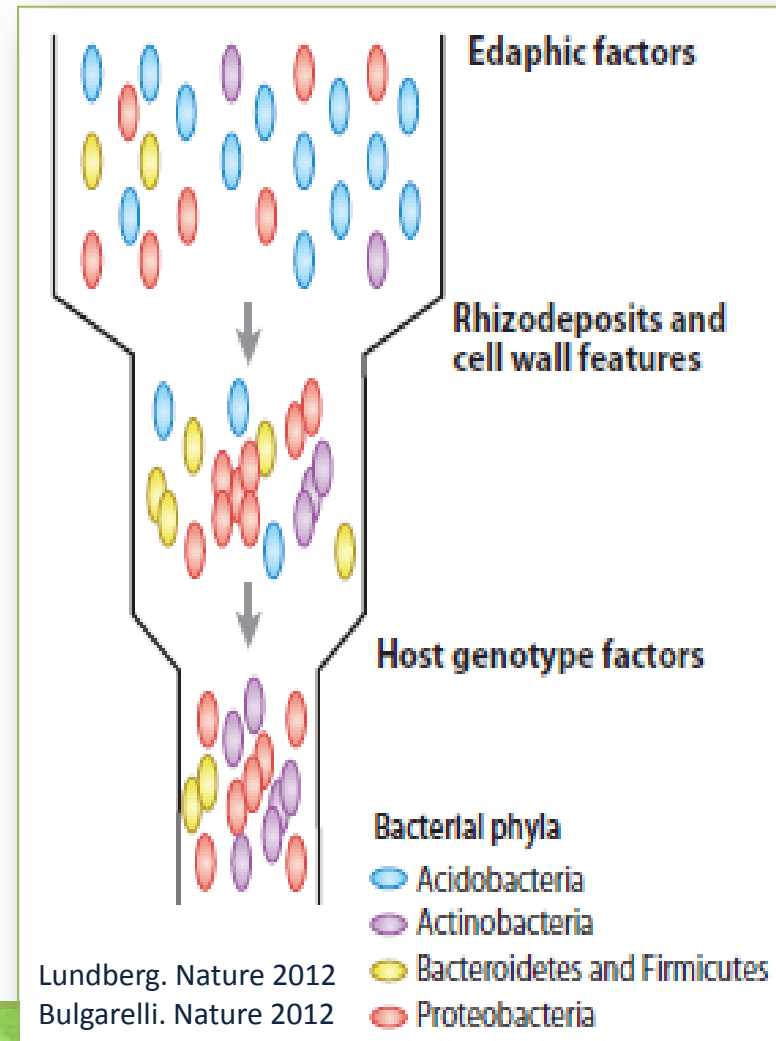
Hirsch et al, Nature Biotech 2012





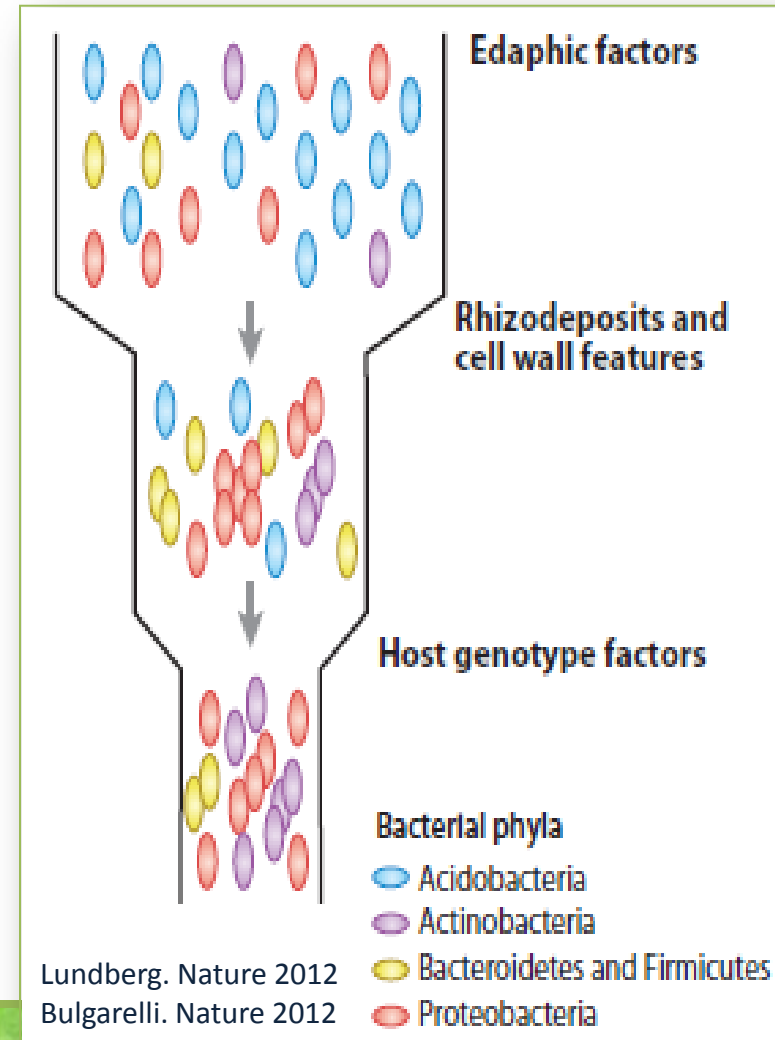
## What did they find?

- Many microbes abundant in the soil were **NOT** found in the **endophytic** communities
- Endophytic communities in roots from different parts of the world were surprisingly **similar**
- **Host genotype** –dependent selection within the root corpus fine-tunes community profiles
- **Bottom line:**
  - *Communities are not a product of random assembly,*
  - *may be predicted based on knowledge of the processes that drive their development*





- Can we breed plants that select for a beneficial phytobiome?
- Have we inadvertently selected against plant traits that help support beneficial microbes by breeding for high yield under conditions of high inputs and soil tillage?





**Conducive Environment**

**Plant  
Disease**

**Virulent  
Pathogen**

**Susceptible  
Host**







# Genome-Genome Interactions

**ENVIRONMENT**



## Influence of disease on the microbiome?

- Extracted DNA from bacteria in the rhizosphere for:
  - Amplicon sequencing (Who is there?)
  - Analysis of functional genes via hybridization (What can they do?)

Healthy orange tree



Tree with citrus greening (Huanglongbing)

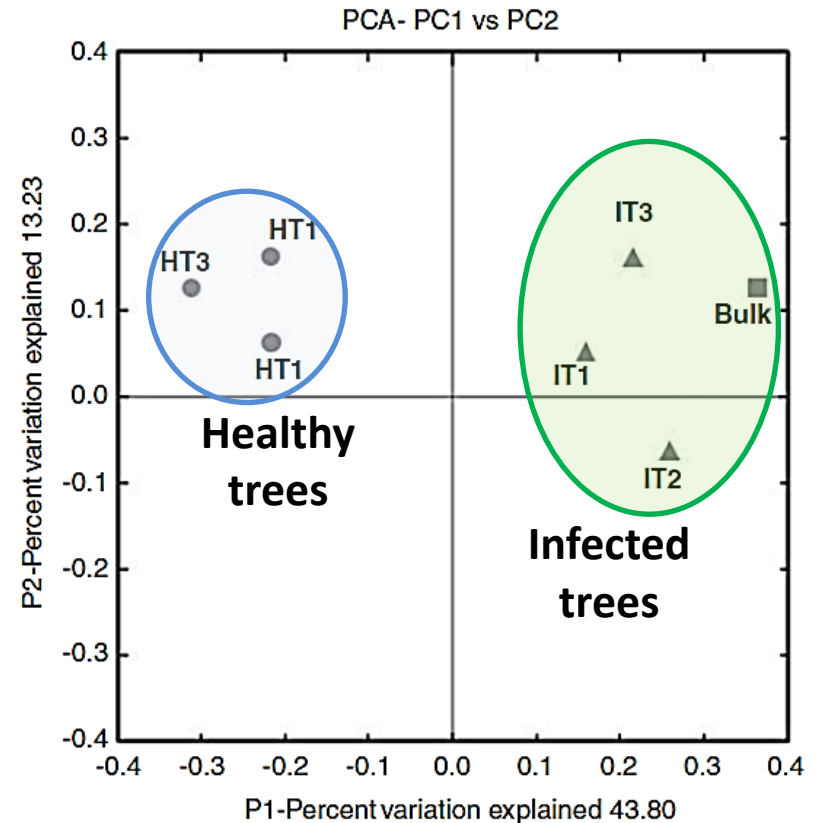
*Does the genome of the pathogen affect the genome response of the plant, and alter the genome content/function of the microbiome???*





# What did they find?

- Rhizosphere communities on infected trees were different from those on uninfected trees
- Disease is associated with detectable shifts in the phytobiome



Trivedi et al. 2012. ISME J 6:363





Citrus greening is associated with:

• a shift away from use of easily degraded carbon

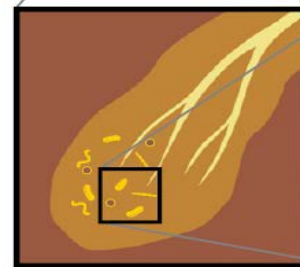
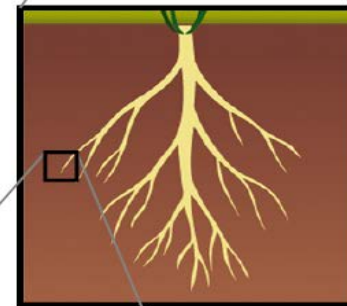
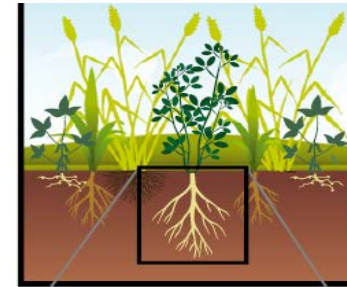
- **Phytobiomes studies may:**
  - provide more precise insights into the mechanisms and consequences of disease (and resistance)
  - identify microbial indicators of disease (and resistance) progress



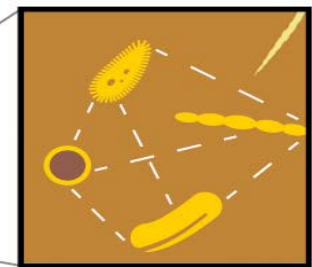


- What factors most influence the phytobiome content/function or plant health?
- What functions that affect microbe-microbe interactions can be manipulated to improve soil health or control disease?

## Plant-Plant Interactions



Plant-Microbe



Microbe-Microbe



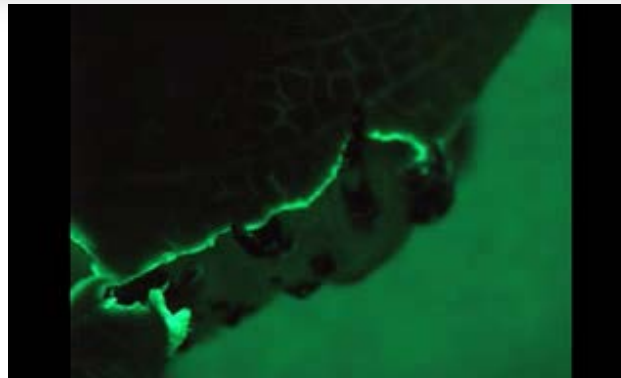
# Insects and the Phytobiome?

## Herbivore exploits orally secreted bacteria to suppress plant defenses

PNAS 110:15728

Seung Ho Chung<sup>a</sup>, Cristina Rosa<sup>a</sup>, Erin D. Scully<sup>b</sup>, Michelle Peiffer<sup>a</sup>, John F. Tooker<sup>a</sup>, Kelli Hoover<sup>a</sup>, Dawn S. Luthe<sup>c</sup>, and Gary W. Felton<sup>a,1</sup>

- **Bacteria** associated with the Colorado potato beetle manipulate plant defenses to facilitate beetle feeding







# Deciphering the Rhizosphere Microbiome for Disease-Suppressive Bacteria

Rodrigo Mendes,<sup>1\*</sup> Marco Kruijt,<sup>1\*</sup> Irene de Bruijn,<sup>1</sup> Johannes H. M. Schneider,<sup>2</sup> Yvette M. Piceno,<sup>3</sup> Peter A. H. M. Bakker,<sup>5</sup> Jos M. Raaijmakers<sup>1†</sup>

**Unraveling plant–microbe interactions: can multi-species transcriptomics help?**  
*Trends Biotech (2012) 30:177*

**Beyond the Venn diagram: the hunt for a core microbiome** Ashley Sharda

**The rhizosphere microbiome and plant health** *Trends Plant Sci (2012) 17: 478*

**Diffuse symbioses: roles of plant–plant, plant–microbe and microbe–microbe interactions in structuring the rhizosphere microbiome**

*Mol Ecol (2014) 23:1571*

MATTHEW G. BAKKER,\* DANIEL C. SCHLATTER,† LINDSEY OTTO-HANSON† LINDA L. KINKEL†

**Chemical Signaling Between Plants and Plant-Pathogenic Bacteria** *Annu Rev Phytopathol (2014) 51:17*

Vittorio Venturi<sup>1,\*</sup> and Clay Fuqua<sup>2</sup>

**Functional soil micro**  
[Laksmanan V<sup>1</sup>](#), [Selvaraj V<sup>1</sup>](#)

**A Synthetic Community Approach Reveals Plant Genotypes Affecting the Phyllosphere Microbiota**

**The rhizosphere microbiota of plant invaders: an overview of recent advances in the microbiomics of invasive plants**

*Vanessa C. Coats<sup>1</sup> and Mary E. Rumpho<sup>2\*</sup> Frontiers Microbiol (2014) 5:1*

## Many questions to address:

- How do phytobiomes affect plant disease, plant resistance or plant performance?
- How does the phytobiome influence plant tolerance to abiotic stresses?
- What useful organisms, genes and products can be mined from phytobiomes?
- Can phytobiomes be 'managed' to maintain soil health, or to rebuild depleted soils, in an environmentally sound manner?



# By 2025, build a foundation to:

- Assess climatic impacts on crop-related phytobiomes
- Understand inter-relationships with nutrient uptake and their utilization
- Relate the phytobiome to its impacts on animal and human health and safety
- Safely and sustainably intensify production of food, feed and fiber
- Change the discovery paradigms for plant disease control, crop improvement, etc.







## On the *Phytobiomes Initiative* near-horizon:

- **APS PPB Policy Fellowship for an early-career plant pathologist to work at a high level of government for 1 year.**
  - **Negotiating placement of the Fellow with OSTP**

Supported by APS Council  
and  
APS Foundation

PHYTOBIOMES are important...

I agree. Let's fund research.





## On the *Phytobiomes Initiative* horizon:

- *Phytobiomes 2015: Designing a New Paradigm for Crop Improvement: A Workshop, May 2015, Washington, D.C.*
  - Bring together a broad community of scientists to establish current and future priorities in phytobiomes research
  - Forge interdisciplinary, interagency, international, and public-private collaborations
  - Translate phytobiomes knowledge to safe and sustainable crop production practices






# Seeking *Phytobiomes Initiative* Partners:

[www.phytobiomes.org](http://www.phytobiomes.org)



 Follow the Phytobiomes Initiative @Phytobiomes



THE SAMUEL ROBERTS  
**NOBLE**  
FOUNDATION

**IS-MPMI**  
International Society for  
Molecular Plant-Microbe Interactions







# What can you do?

- **Ask your local and national representatives to add \$100 million/year in NEW funding to Phytobiomes Research!**



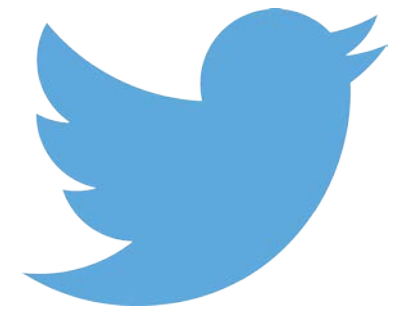
**Let's get congress to agree to something!!!**





# Tweet Your Representative!

**@SenBennetCo Let's double  
production of safe and nutritious food,  
feed and fiber #phytobiomes  
[www.phytobiomes.com](http://www.phytobiomes.com)**



## **Vision**

Comprehensive  
knowledge of  
phytobiomes

**New strategies for reducing:** plant disease, environmental degradation, resistance to antimicrobials, non-renewable inputs, and impacts of weather extremes; and **for increasing:** food safety, soil health, human health, and the beneficial impacts of microbial communities. **Increased and more robust human, genetic and technological infrastructure**

## **Impact**

increase in  
safe and  
healthy  
food, feed,  
and fiber

