Microbes form the basis of life on our planet

Primary production
Photosynthesis and Nitrogen Fixation

100% of organic carbon, 100% of atmospheric oxygen and the vast majority of organic nitrogen come from microbes.

*Prochlorococcus*
A marine bacterium that may be the most abundant species on our planet. It is responsible for much of the ocean's organic carbon and generates the oxygen in one out of every five breaths you take.
Biologists now believe that much of what makes us human depends on microbial activity.

More bacterial cells in our body than human cells.

~35,000 genes in our cells is small by comparison to the millions of unique genes contributed by our microbes.

“We are, at least from the standpoint of DNA, more microbial than human. That’s a phenomenal insight and one that we have to take seriously when we think about human development.”

Tom Insel the director of the National Institute of Mental Health.
Like humans, plants are colonized by a diversity of microorganisms, and different plant organs have different microbial composition.

- Nutrient acquisition
- Drought tolerance
- Disease resistance
- Growth and development

We often don’t know the causal microbes ...

... nor do we understand of the impact of microbial diversity.

... but the benefits or harms are certain in many cases.
Microbial dynamics (distribution and function) in long-standing co-evolved systems
Microbial dynamics (distribution and function) in long-standing co-evolved systems

*C. echinospermum*  
*C. reticulatum*
Soil types vary significantly by collection site

- C. echinospermum
- C. reticulatum

The graph shows the variation in soil types across different collection sites, with variables such as N, S, P, Cu, Mn, Na, pH, PC1, PC2, X, Y, Z, and organic matter.
What is the structure microbial communities associated with wild chickpea?

Has domestication impacted the structure and function of chickpea’s microbiome?

Can we harness components of the native chickpea microbiome for purposes of agriculture?
16S r DNA

Amplification Library - PCR amplification of V4

Nature Reviews Microbiology 12,635-645(2014) doi:10.1038/nrmicro3330

Ashelford K E et al. Appl. Environ. Microbiol. 2005;71:7724-7736
Biogeography of the microbiome

10 cores, 40 compartments per site
21 sites, 840 communities sequenced

1 = bulk soil away
2 = bulk soil in root zone
3 = residual soil at root surface
4 = residual soil at nodule surface
5 = integral root microbes
6 = integral nodule microbes
7 = leaf microbes
8 = cultured nodule microbes
Microbiomes of Wild Chickpea
16S rDNA Profiling

Nodule
Nodule plane
Root
Rhizoplane
Soil
Plants select reproducible microbial communities

Unweighted Unifrac
What drives local structure of the microbiome?
Reciprocal soils in a common garden
5 soils, 12 genotypes, 7-fold replication, 4 compartments = 1,640 communities
Reciprocal Soils: Roots
A few generalizations

1. Plants select

2. Alpha diversity decreases as communities approach the plant surface and enter the plant, and do so in reproducible ways (as determined by 16S sequencing).

3. Beta diversity distinguishes communities on the plant surface.

4. Differences in soil substrate are correlated with local microbial communities.

5. Plant genetic/physiological process exert selection.
Generate living culture collections for the predominant microbiome taxa

- ~700 isolates for a range of soils and plant compartments
- Sequenced genomes for first set of 182 strains
- Testing individual strains and simple consortia of strains for “function”

**Function?**
- Plant growth promotion.
- Enhancement of nitrogen fixation.
- Stress tolerance.
- Nutrient acquisition.
Phenotyping for potential plant growth promoting traits

Antifungal activity

Growth on ACC

Ca3PO4 solubilization

\( \text{SAM} \rightarrow \text{ACC} \rightarrow \text{C2H4} \)
Chickpea Domestication
PanGenome Diversity

- Bacterial species are considerably more diverse than higher organisms.

- Even within well defined single species, the fraction of conserved genes within a bacterial species is quite low, perhaps < 50% are common to all members of a species (and many fewer at higher taxonomic levels).

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What is the significance of pan-genome diversity?

The pan genome of *Prochlorococcus* is estimated to be 84,872 genes, which >twice that of the human genome. A single genome is ~1,900 genes and 1.8 Mb.

Isolates that occur in similar habitats frequently have similar flexible genome content, even if they are phylogenetically distant within the genus. Where is the baseline for ecologically meaningful diversity?

Biller et al., Nature Reviews Microbiology. 13:13-27.
6 core marker genes

- 32 genomes
- ~4000 core genes
16S rDNA Profiling

Nodule	Nodule plane	Root	Rhizoplane	Soil