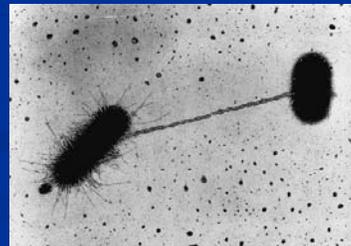


Microbial Diversity in Soil

Mary Stromberger
Matt Wallenstein
Summer Soil Institute
July 21, 2010

How are bacterial species defined?

- Species = An individual belonging to a group of organisms having common characteristics and (usually) are capable of interbreeding
- Problem is that bacteria are capable of horizontal exchange of genetic material
- Organisms with 97% or more genetic similarity
- Operational taxonomic units
- Phylotypes



Bacillus anthracis, *Bacillus cereus*, and *Bacillus thuringiensis*— One Species on the Basis of Genetic Evidence

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HENNING A. JOHANSEN,³ AGNES FOUET,⁴ MICHÉLE MOCK,⁴ IDA HEGNA,^{1,2}
AND ANNE-BRIT KOLSTØ^{1,2*}

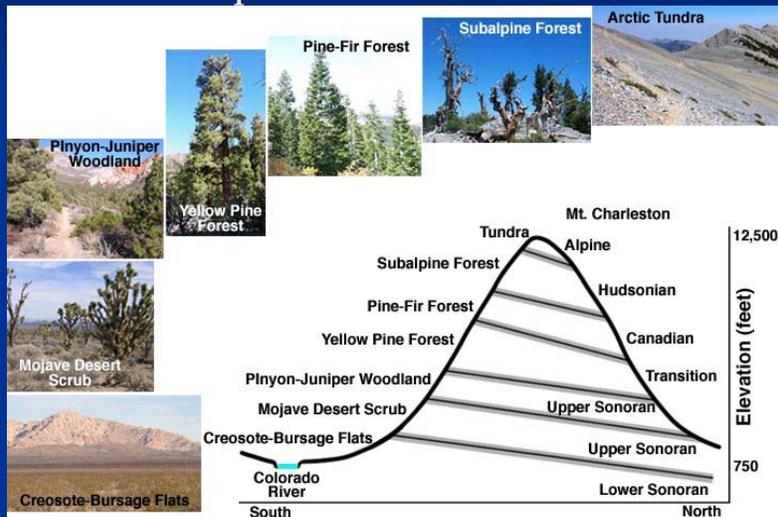
The Biotechnology Centre of Oslo, University of Oslo,¹ and Department of Microbiology, Institute of Pharmacy,² Blindern, 0349 Oslo, and Department of Bacteriology, National Institute of Public Health, Torshov, 0403 Oslo,³ Norway, and Taxines et Pathogénie Bactériennes, URA 2172 CNRS, Institut Pasteur, 75724 Paris Cedex 15, France⁴

Received 28 December 1999/Accepted 19 March 2000

Bacillus anthracis, *Bacillus cereus*, and *Bacillus thuringiensis* are members of the *Bacillus cereus* group of bacteria, demonstrating widely different phenotypes and pathological effects. *B. anthracis* causes the acute fatal disease anthrax and is a potential biological weapon due to its high toxicity. *B. thuringiensis* produces intracellular protein crystals toxic to a wide number of insect larvae and is the most commonly used biological pesticide worldwide. *B. cereus* is a probably ubiquitous soil bacterium and an opportunistic pathogen that is a common cause of food poisoning. In contrast to the differences in phenotypes, we show by multilocus enzyme electrophoresis and by sequence analysis of nine chromosomal genes that *B. anthracis* should be considered a lineage of *B. cereus*. This determination is not only a formal matter of taxonomy but may also have consequences with respect to virulence and the potential of horizontal gene transfer within the *B. cereus* group.

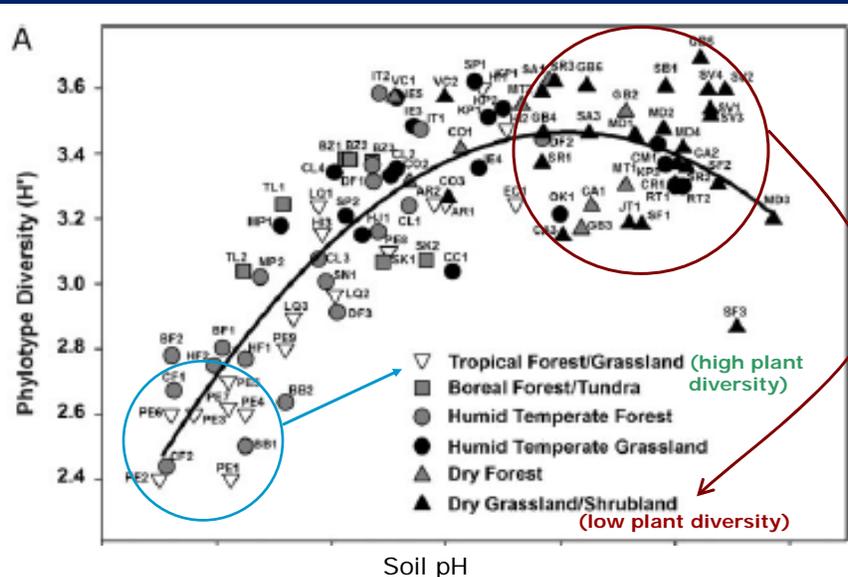
What determines diversity and
community composition?

Are microbes influenced by the same factors (temperature, precipitation, PET) that influence plants and animals?

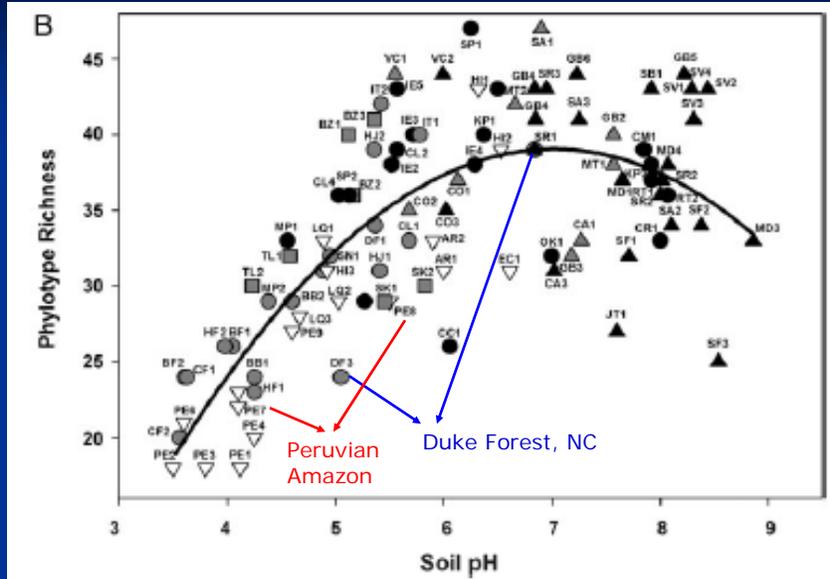


Life zones of Holdridge, 1947

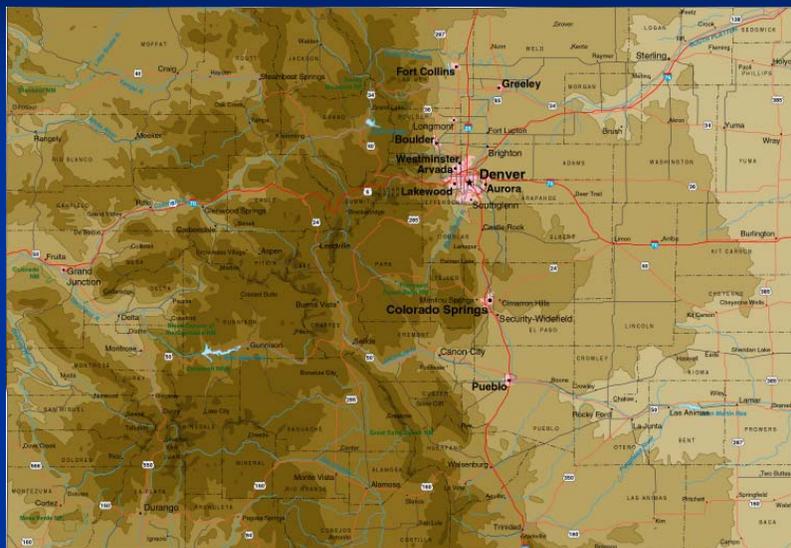
Fierer and Jackson. 2006. The diversity and biogeography of soil bacterial communities. PNAS 103:626-631



For both continental and local scales



Regional scale
(topography, land use type, etc.)



Field scale

(plant communities, management, etc.)



Field scale

(individual plants, burrowing animals, etc.)





Pedon scale

- OM content, microbial biomass and species richness generally decline with depth

Fierer et al. SBB 2003:167-176

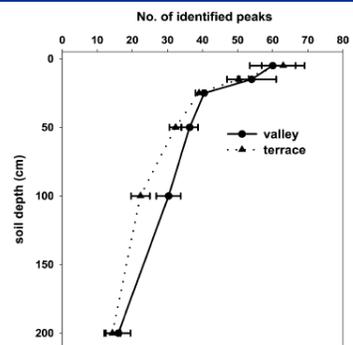
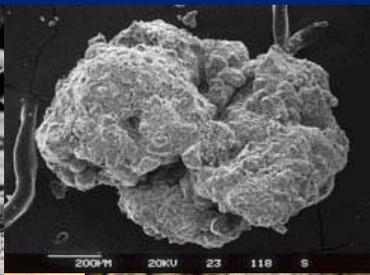


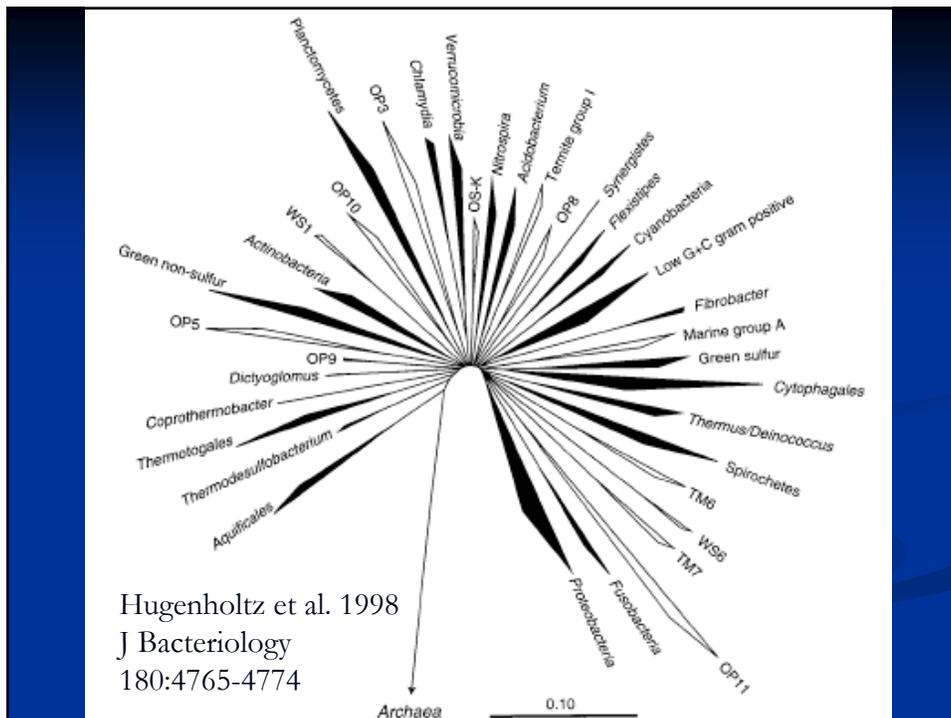
Fig. 2. The number of detectable PLFAs extracted from the soil samples (PLFA richness) with soil depth in the two profiles. Error bars = 1 SE, $N = 3$.

Fine scale (cm or less)

(roots and rhizosphere, aggregates, pores, etc.)



What can genetic information tell us about function?



Toward an Ecological Classification of Soil Bacteria
Fierer et al. 2007. Ecology 88:1354-1364

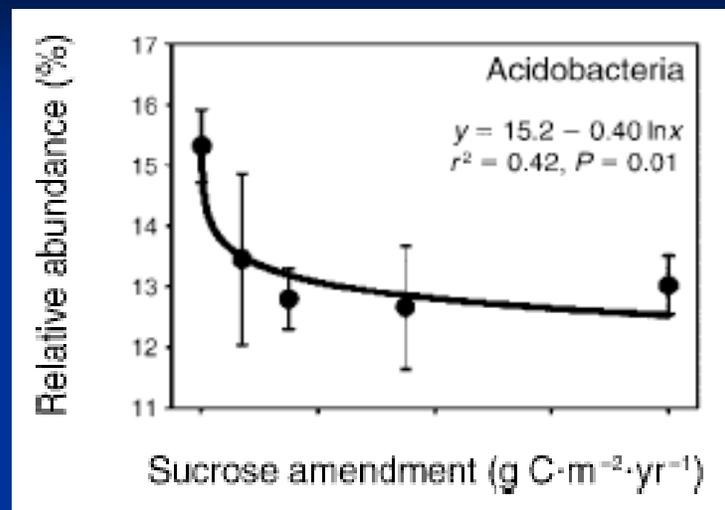
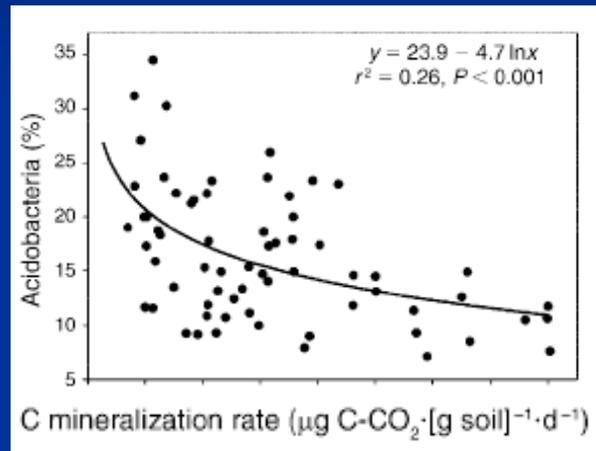


TABLE 2. Ecological attributes that are likely to correspond to copiotrophic and oligotrophic groups of bacteria.

Trait	Copiotrophs	Oligotrophs
Growth rates (μ_{max})	High maximum growth rate (μ_{max}) ¹ when resources are non-limiting, high K_S (substrate concentrations at $1/2 \mu_{max}$). ¹	Low μ_{max} , outcompeted by copiotrophs in high-resource environments, low K_S .
Growth yield ($Y_{X/S}$) ¹	Low $Y_{X/S}$, inefficient conversion of substrate into cell biomass.	High $Y_{X/S}$; high biomass accumulation per unit substrate, efficient resource utilization.
Maintenance requirements (s_{min}) ¹	High s_{min} , substrate supply rates must be sufficiently high to maintain viability.	Low s_{min} , cells remain viable even when substrates are limited.
Substrate uptake systems	Low specific affinity of cells for substrates (a_A or the $\mu_{max}:K_S$ ratio), poor competitors when substrates are limited. ²	High specific affinity (a_A), efficient substrate "scavengers," highly capable of simultaneous uptake of mixed substrates. ²
Responsiveness to substrate additions	Brief lag in growth rates after additions of fresh substrate, large proportion of enzymes are produced constitutively.	Long lag time before growth on fresh substrate is maximized, most enzymes are induced, not constitutive.
Temporal variability in population size	High; substrate availability is pulsed producing "feast and famine conditions," fast rates of population turnover, short mean generation times.	Low; supply of substrates is fairly constant (but low), rates of population turnover are slow, long generation times.
Ease of cultivation	High; grow well in nutrient-rich media, visible colonies appear with incubations of short duration.	Low; visible colonies slow to appear, best isolated with nutrient-poor media.
Cell chemistry and morphology	Low C:N and C:P due to high intracellular nucleic acid and protein content, spherical cells with low surface area: volume ratio. ³	Elongated or filamentous cells with high surface area, volume ratio, ³ presence of prosthecae, ⁴ high capacity for intracellular storage of nutrient reserves. ⁵
rRNA operon copy number	High (>5). ⁶	Low (<2). ⁶
Tolerance to environmental stressors (e.g., pH, temperature, drying-rewetting)	Highly sensitive to environmental stress, spore formation common when exposed to suboptimal environmental conditions.	Individual cells can maintain viability under stressful environmental conditions.

What are the long-term effects
of community change on
ecosystem function?

Microbial Stress-Response Physiology and its Implications for Ecosystem Function

Schimel et al. 2007. *Ecology* 88:1386-1394

- How do stress response physiologies differ among microbial groups?
- Do these differences have ecosystem-level consequences in response to stress?

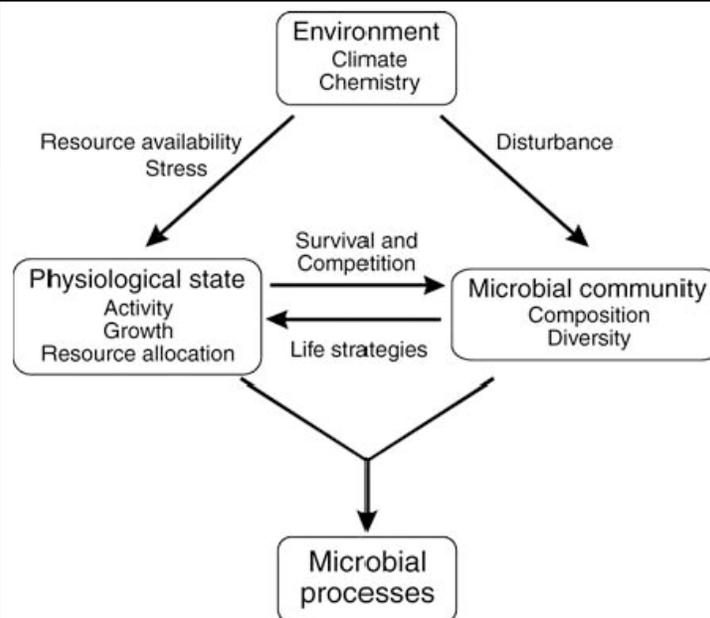
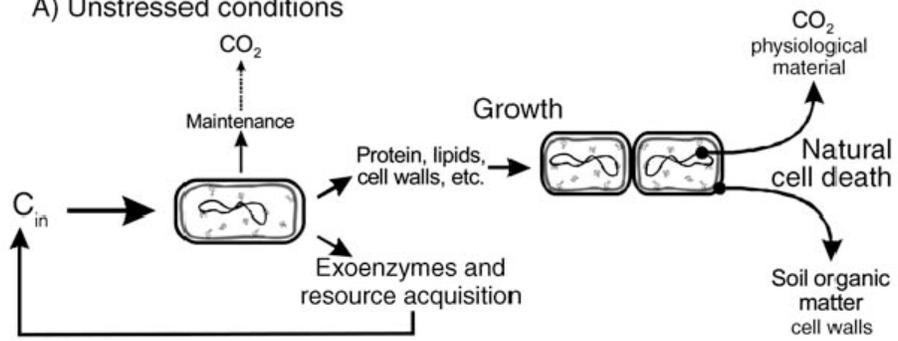
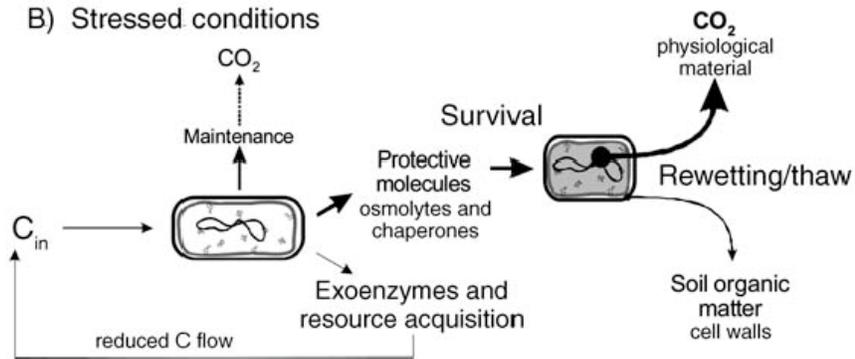


FIG. 1. Links among environmental drivers, microbial physiology, community composition, and ecosystem processes.

A) Unstressed conditions



B) Stressed conditions



How will microbes respond to water stress?

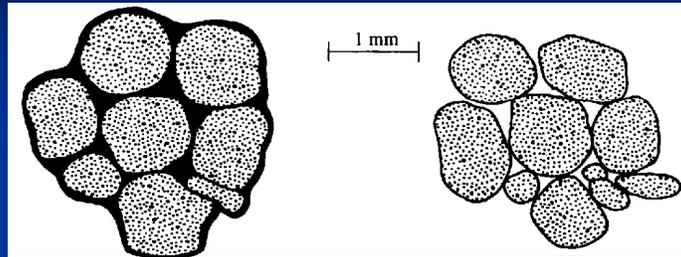
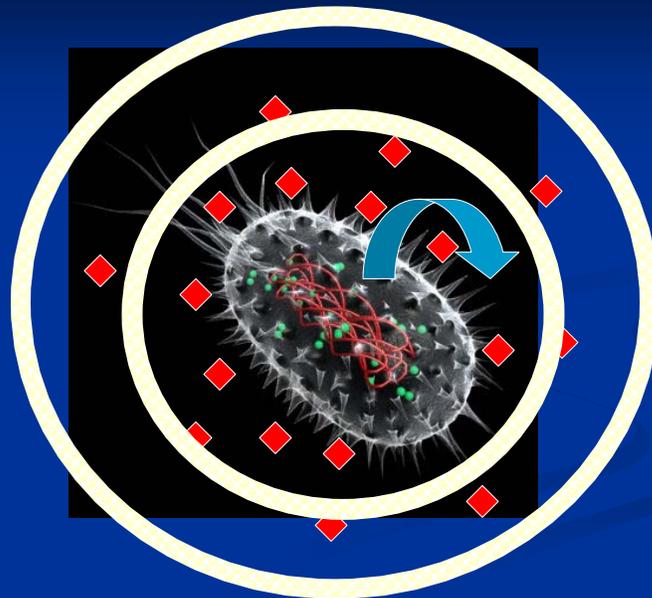


Table 2-3 Microbial tolerance to matrix-controlled (Ψ_m) water stress.

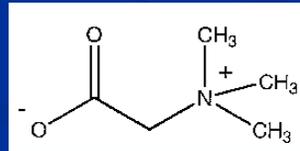
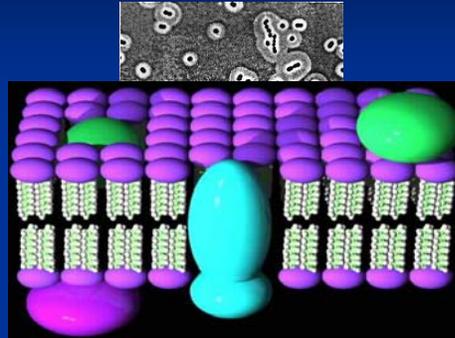
Water potential (MPa)	Water activity (a_w)	Water film thickness	Microbial activity limited (example of genus)
-0.03	0.999	4.0 μm	movement of protozoa, zoospores, and bacteria
-0.1	0.999	1.5 μm	
-0.5	0.996	0.5 μm	
-1.5	0.990	3.0 nm	nitrification; sulfur oxidation
-4.0	0.97	<3.0 nm	bacterial growth (<i>Bacillus</i>)
-10.0	0.93	<1.5 nm	fungal growth (<i>Fusarium</i>)
-40.0	0.75	<0.9 nm	fungal growth (<i>Penicillium</i>)

Adapted from Harris (1981).



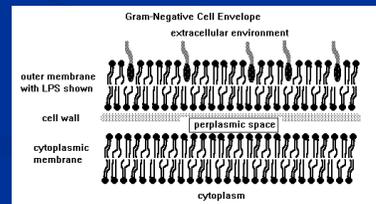
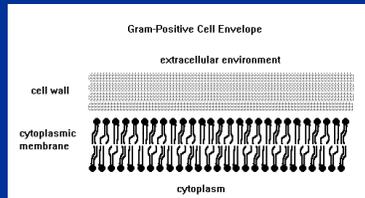
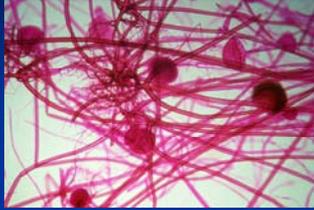
Microbial Osmoregulation

- Synthesize capsules and EPS
- Alter cell wall and membranes
- Manufacture and accumulate compatible solutes within cytoplasm



Organism	Cytoplasmic potentials	Comments
Gram negative bacteria	-7 bar	
Gram positive bacteria	-27 bar	Capable of concentrating more compatible solutes; thicker cells can withstand greater turgor pressures
Fungi	-60 bars	Polyhydric alcohols as compatible solutes; thickest cell walls; can span air gaps

How will community composition change?

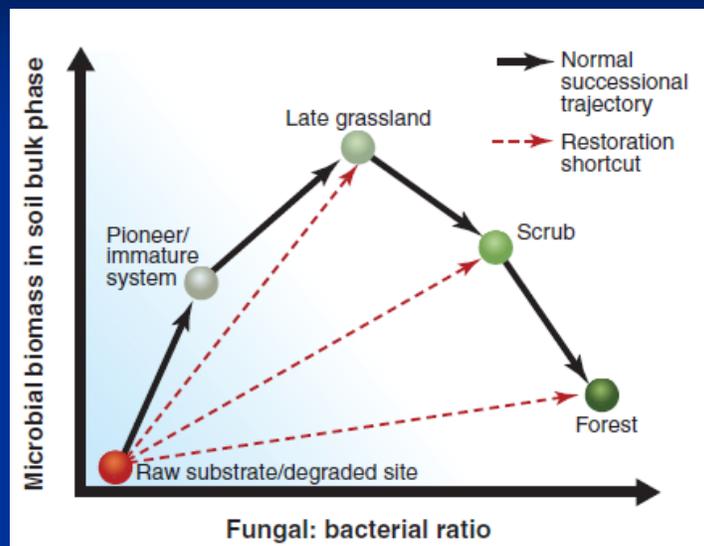


Can we manage microbial diversity
and community composition to
promote ecosystem services?

Soil Microbial Communities and Restoration Ecology: Facilitators or Followers?
Harris 2009. Nature 325:573-574

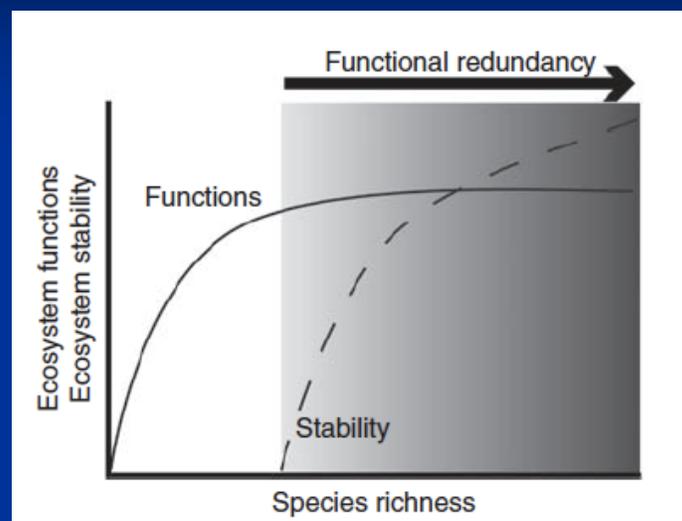
- Are microorganisms key players in restoring degraded lands?
Soil microorganisms = Facilitators of restoration
- Or, do microorganisms simply reflect what is happening to plant communities?
Soil microorganisms = Followers of restoration

Microbial communities change during plant community succession (Followers)



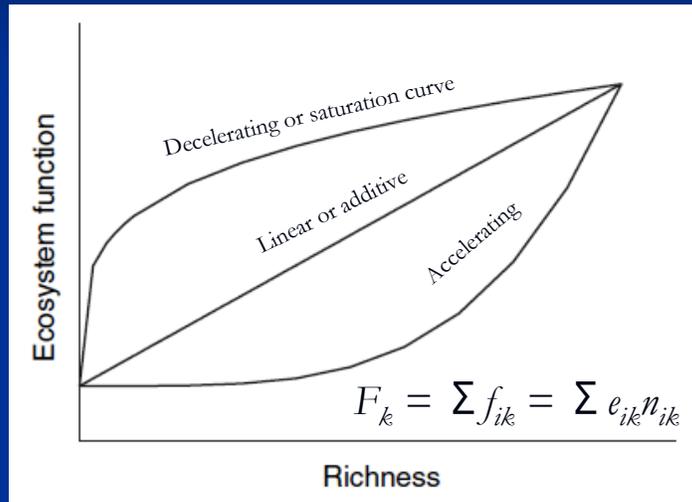
What is the functional significance of the microbial diversity in soil?

What is Microbial Community Ecology? Konopka 2009. ISME J 3:1223-1230



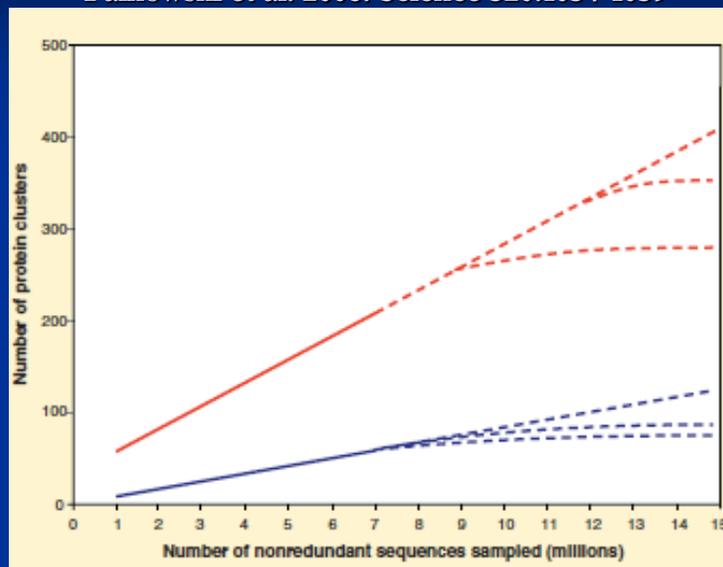
Managing Ecosystem Services: What do we need to know about their ecology?

Kremen 2005. Ecology Letters 8:468-479

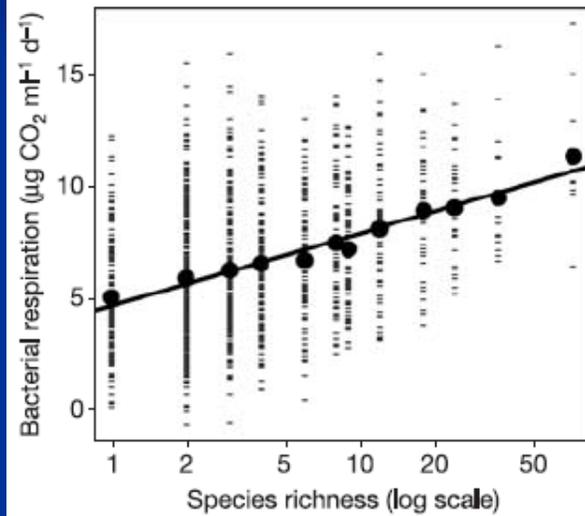


The Microbial Engine's that Drive Earth's Biogeochemical Cycles

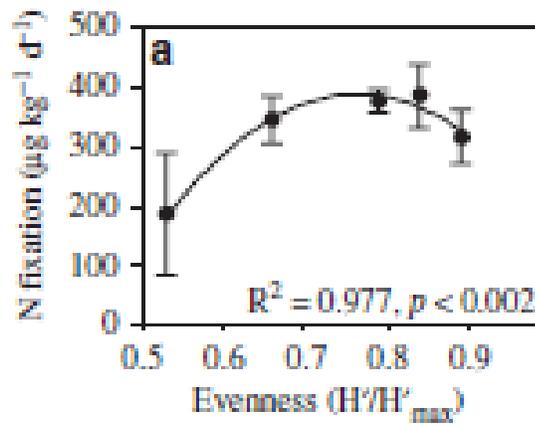
Falkowski et al. 2008. Science 320:1034-1039



The Contribution of Species Richness and Composition to Bacterial Services
Bell et al. 2005. Nature 436:1157-1160



Evidence for the Functional Significance of Diazotroph Community Structure in Soil
Hsu and Buckley 2009. ISME J 3:124-136



Relationship between community *nifH* composition and N fixation