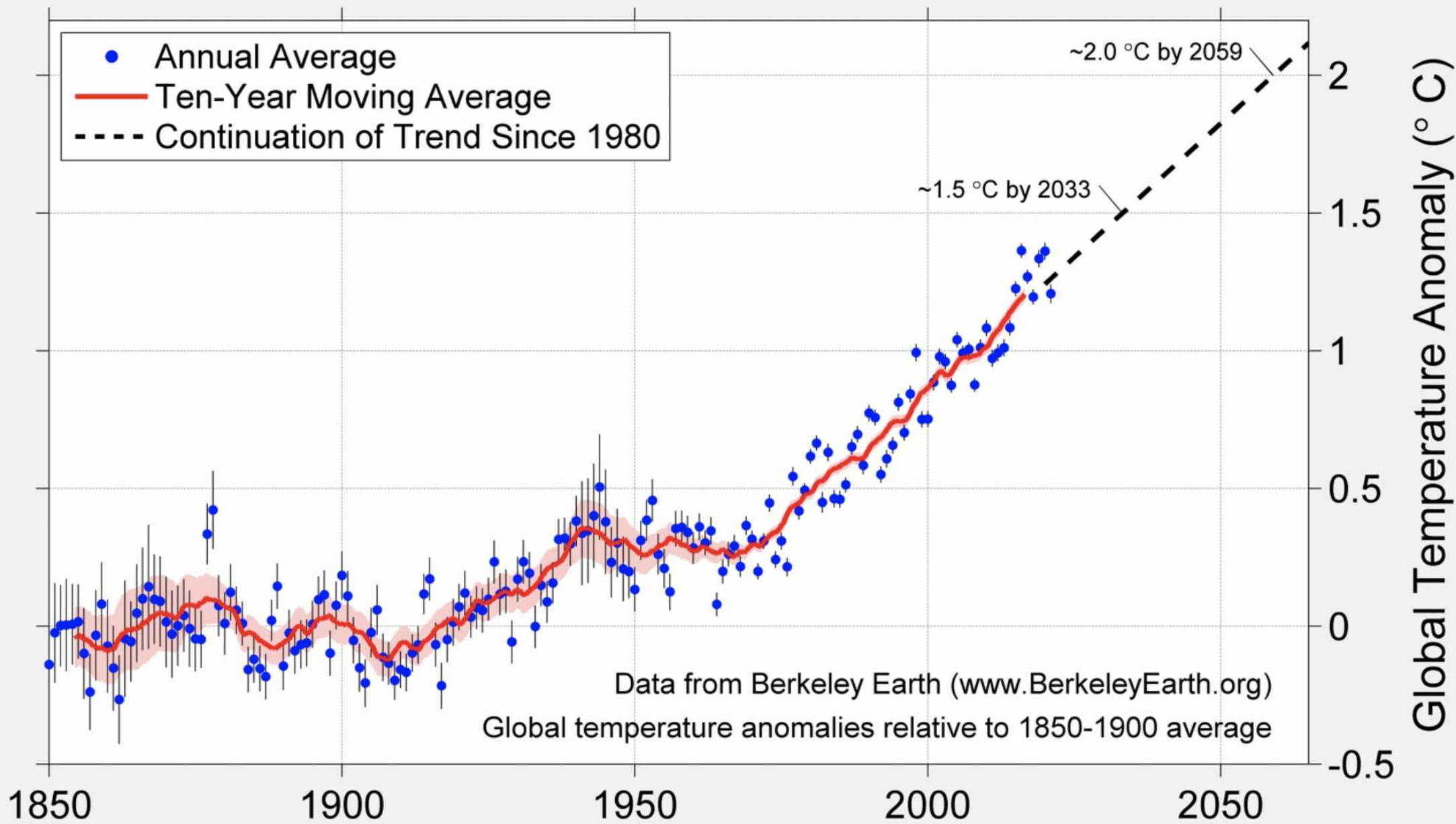


Uncovering the *Pinus radiata* microbiome: A key to resilient forests?

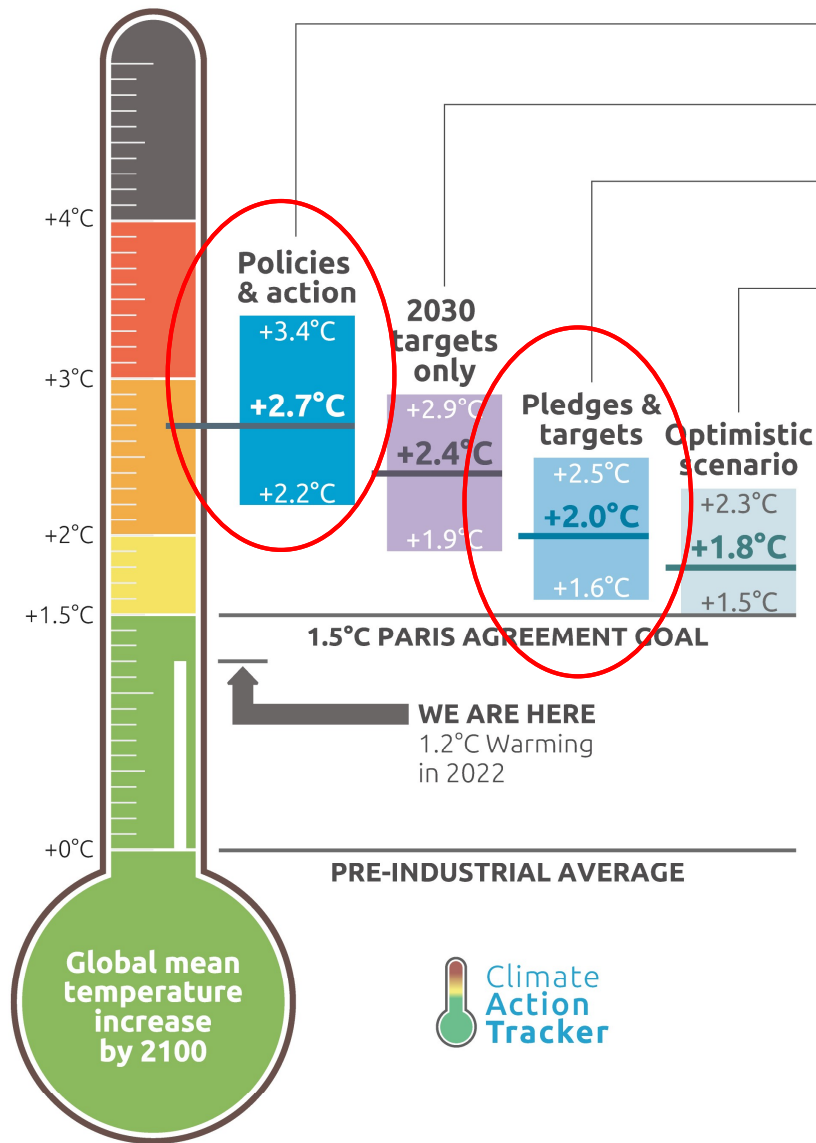
Kathryn Walker, Lottie Armstrong, Mariann Brennan, Katie Daley, and Steve A Wakelin





Data from Berkeley Earth (www.BerkeleyEarth.org)

Global temperature anomalies relative to 1850-1900 average



Policies & action

Real world action based on current policies †

2030 targets only

Based on 2030 NDC targets* †

Pledges & targets

Based on 2030 NDC targets* and submitted and binding long-term targets

Optimistic scenario

Best case scenario and assumes full implementation of all **announced** targets including net zero targets, LTSs and NDCs*

† Temperatures continue to rise after 2100

* If 2030 NDC targets are weaker than projected emissions levels under policies & action, we use levels from policy & action

CAT warming projections Global temperature increase by 2100

November 2022 Update

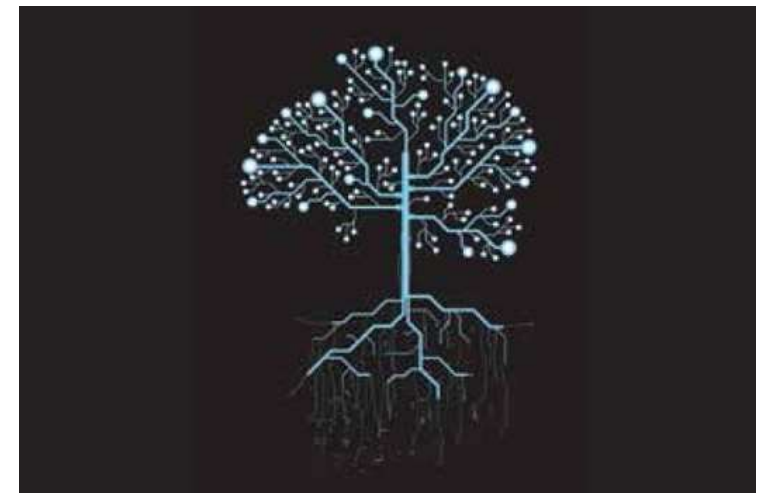
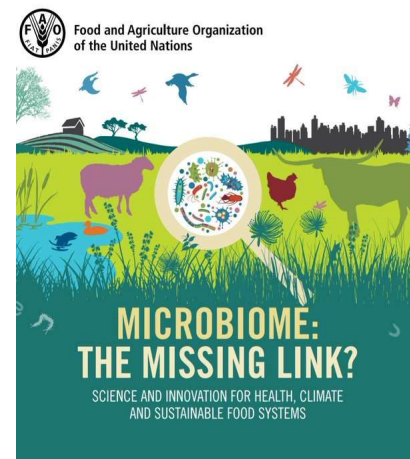
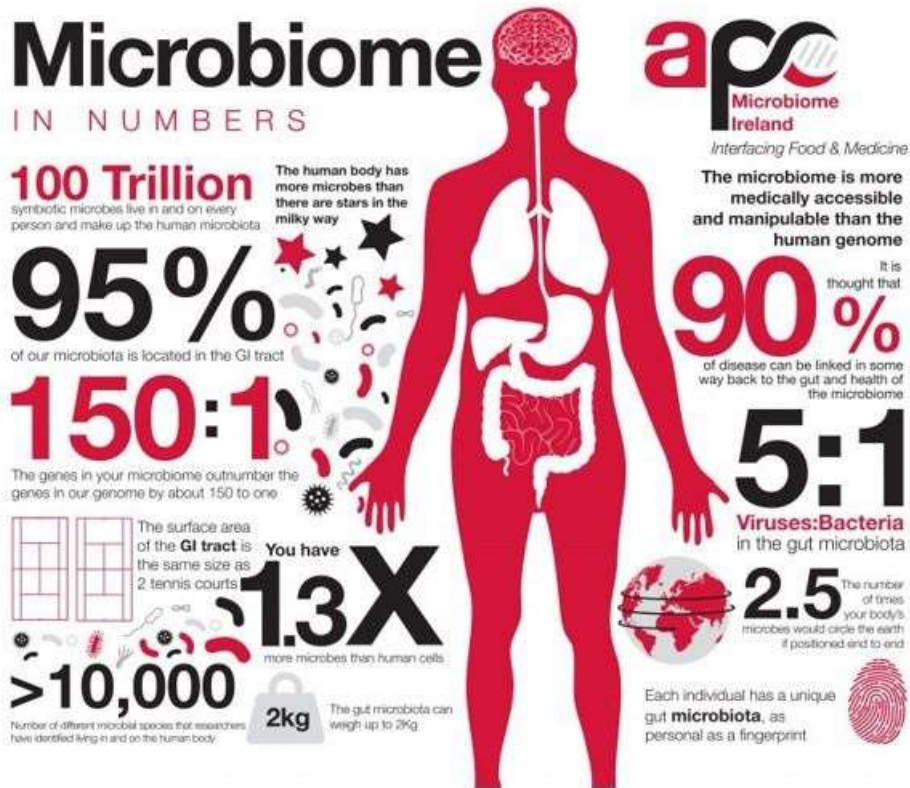
Most trees alive today wont be able to survive in the climate expected in 40 years



- Trees and forest ecosystems are at elevated risk from ecological change brought about by climate change
- Strategies that trees have honed for millions of years are failing to keep pace with **rate of change**
- New strategies are needed ASAP
- **Could the tree microbiome be the key to more resilient forests?**

Tree Microbiome Programme: Background

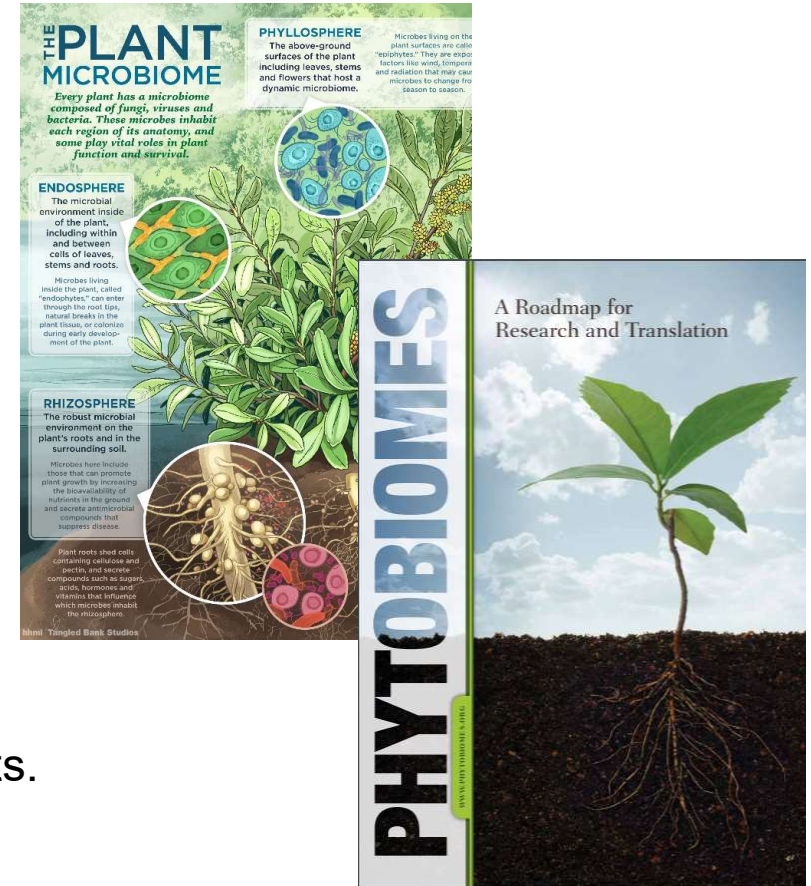
- Microbiomes profoundly alter systems they are in: fitness, disease, physiology, etc
- Influences all aspects of health and wellbeing
- Offers new solutions in treating disease



Plant microbiome

The plant microbiome is “intricately involved in plant health, and serves as reservoirs of new genes that the plants may access, to improve fitness, survival and therein ecosystem stability and function”

- Marnie Rout



Opportunity to protect our forests from abiotic and biotic threats.

The tree and its microbiome = The holobiome



- Fundamentally changes our picture of what a tree is. From a single entity (tree), to a large collection of organisms that act and have evolved together.
- Holobiome contains not only the host genome but also the genomes of all the microbes in the microbiome.
- New opportunities to increase resilience and productivity.
- Tree microbiome model based on *Pinus radiata*.

Uncovering the *Pinus radiata* microbiome

Indexing the microorganisms living on and in different tissues of *Pinus radiata*

- What are there? What could be there? How are these ecosystems structured? Role of deterministic v stochastic processes in assembly. Extent of sharing of taxa among tissues and exchanges with the environment.
- Method development.
- Needles, pollen and wood.

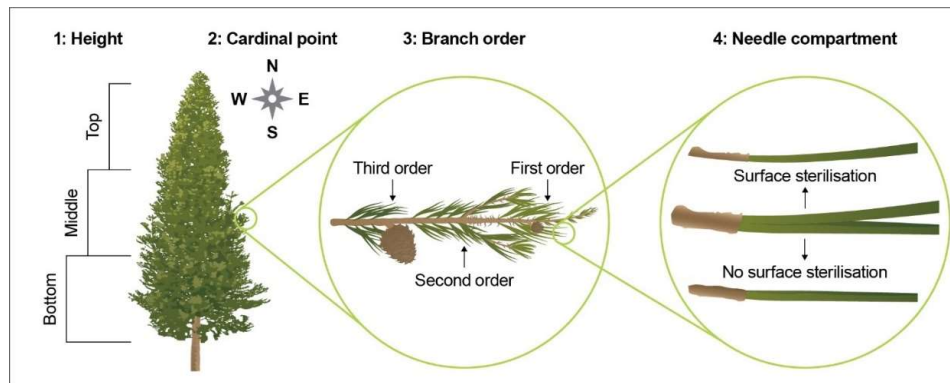
Needle Microbiome

- Solar panels for the tree. Energy collection system directly linked to tree growth & forest productivity.
- Trees above-ground environmental sensor network; detects changes and initiates whole/tree responses.
- Microbiome in/on needles, important for needle health, function, environmental sensing, tree signalling.



Needle Microbiome

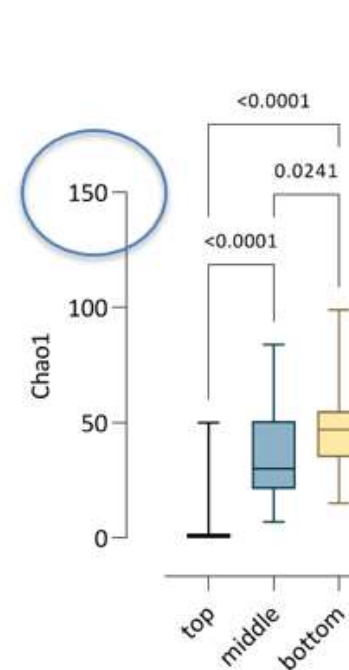
- Sampling method established



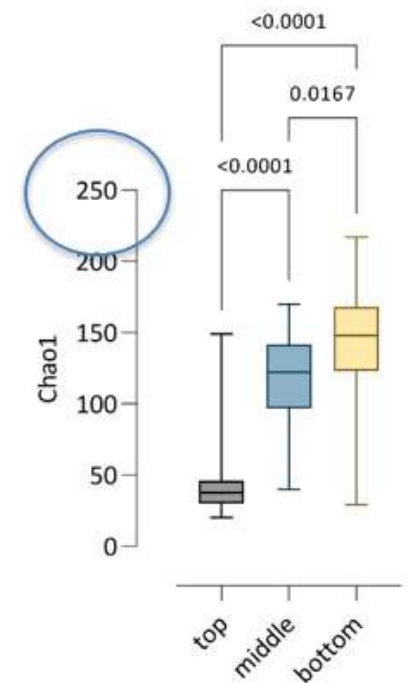
- Pine needles are a fungal rich ecosystem
- Tree height influenced community composition and richness

Richness

Bacteria

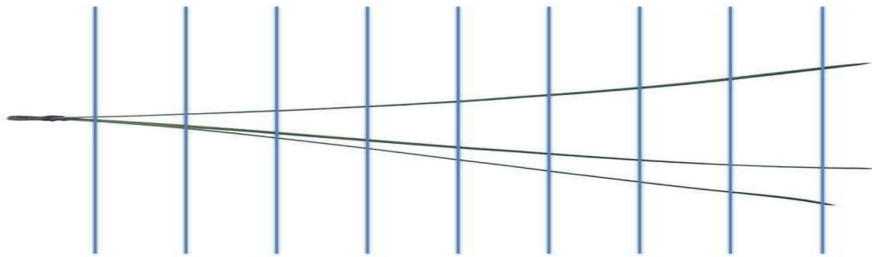


Fungi

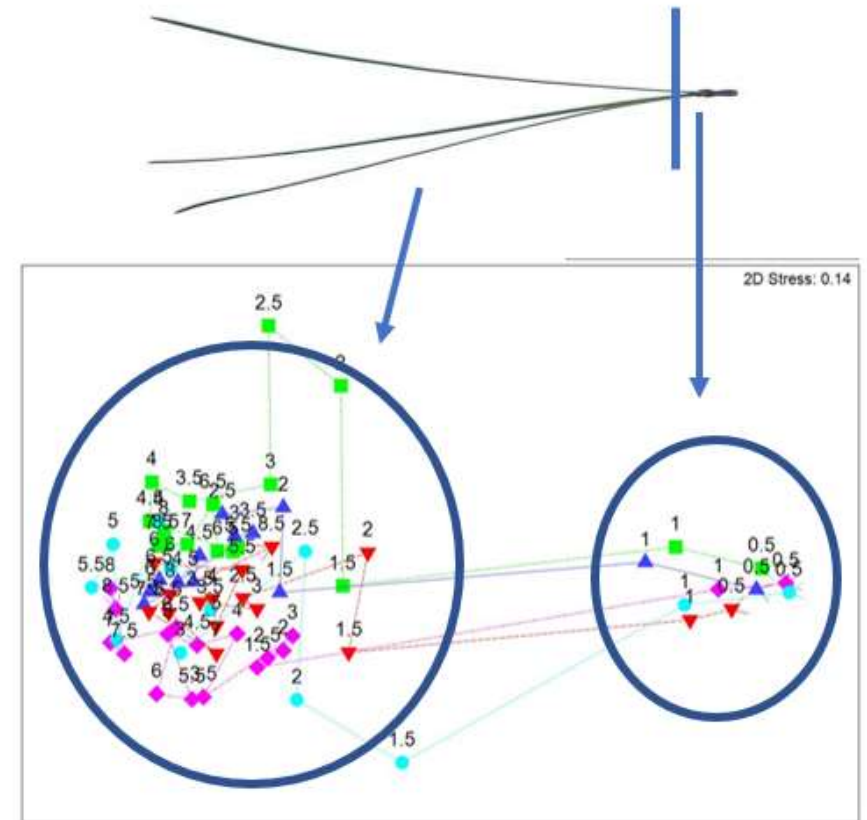


Needle Microbiome

- Sampling method established



- Fungal community different at the sheath compared to the rest of the needle.
- Comparisons among trees in different environments and with different genetics can now be made.



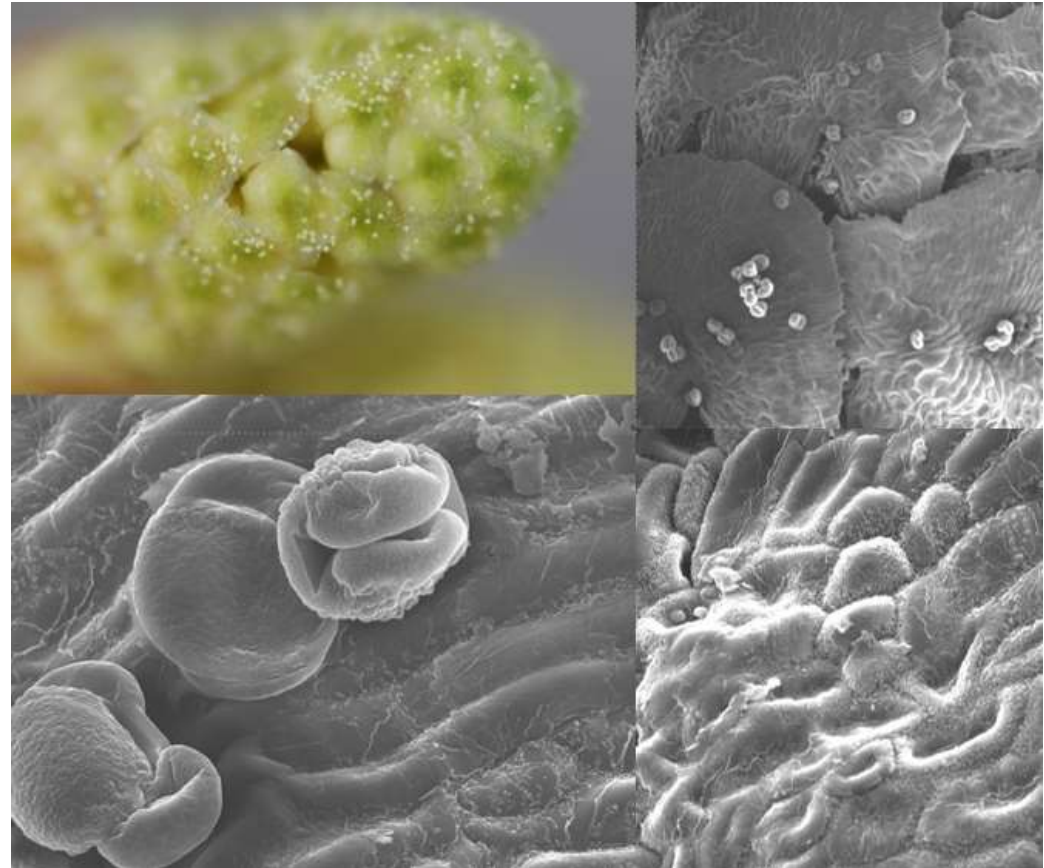
Pollen Microbiome

- Does pine pollen also host complex bacterial and fungal communities?
- Could pollen be a vector for distributing beneficial microbes or pathogens to a pine forest?
- Is there a common core of microbes which are found on all pine pollen?
- Or is the microbiome dominated by a secondary microbiome, obtained from the environment?

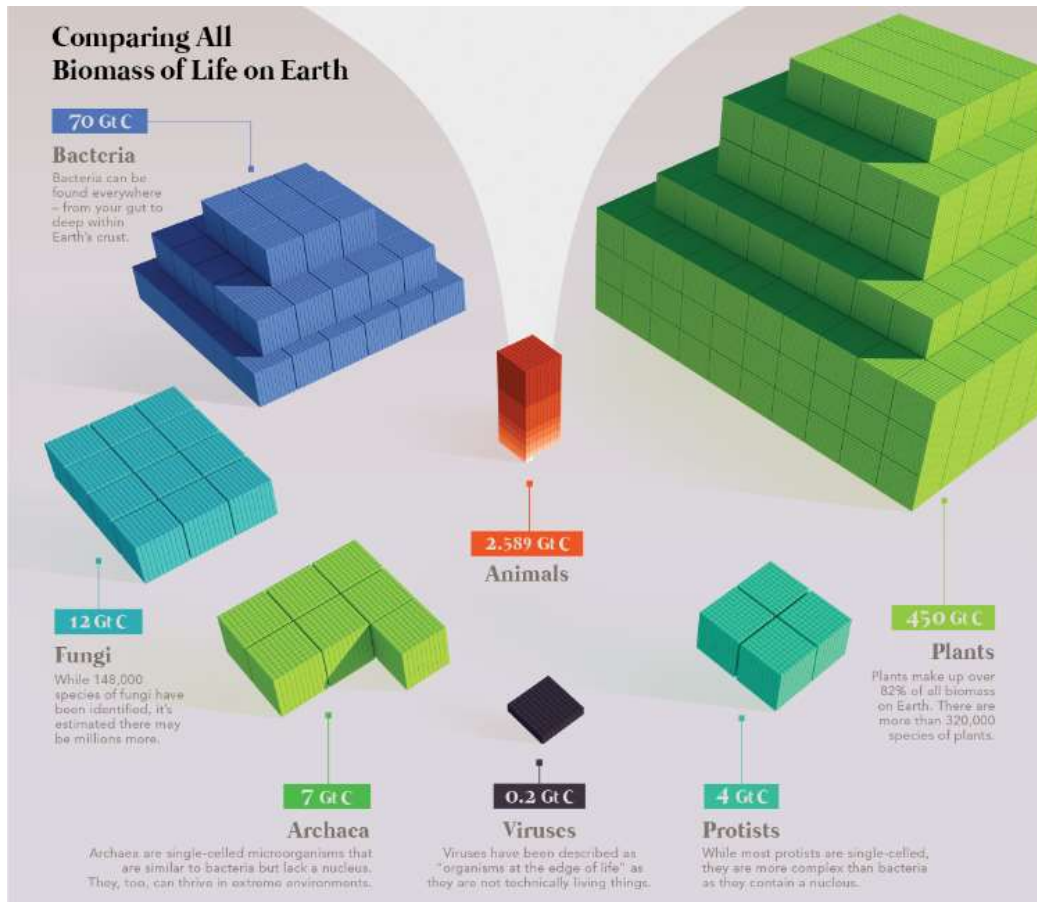


Pollen is *unlikely* to be supporting much microbiome for vertical transfer (deterministically)

- Looking for a conserved/core community amongst the variable biome.
- Most pollen is visibly absent of microbes.
- Microbes hitch-hike from the catkin structures.
- *Possible* catkin microbiome is important to inoculate pollen and 'seed' microbiomes to next generation.
- We don't have evidence to support this one way or the other.



Why is the wood microbiome of such interest?



Mark Belan visualcapitalist.com

550 Gt C in all Earth's biomass. Plants hold 450 Gt of this (~ 80% all living C)

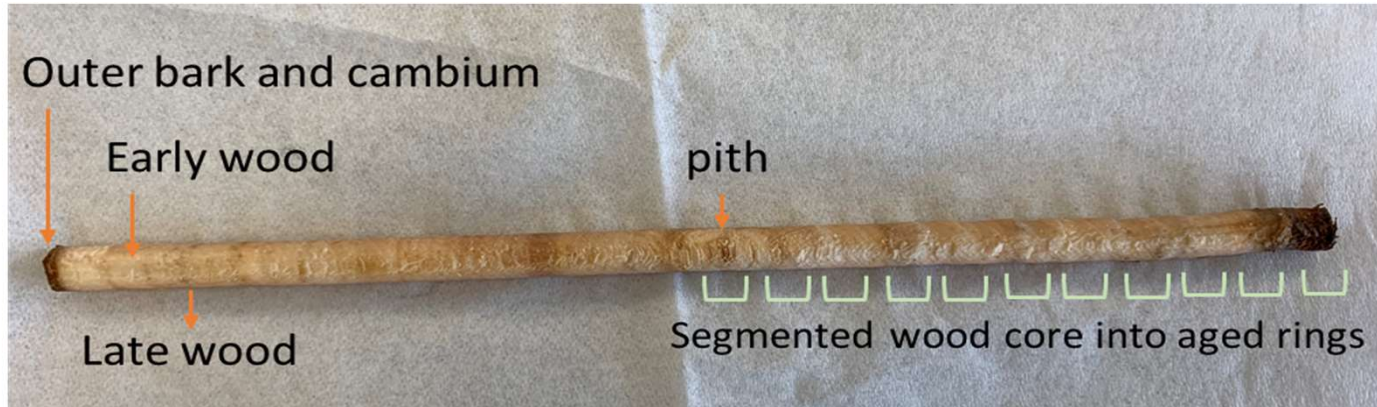
300 Gt of this is held in tree stems¹

- Thus, tree stems – and principally woody tissues – are estimated to hold **in excess of half the total biomass carbon present on Earth.**
 - This is an unimaginably vast organic biome, a massive volume of habitat for microbes.
- Not only is woody tissue the most neglected habitat of phytobiome research, but we posit that this is also one of the **most understudied yet vitally important microbiomes globally per se.**

¹Bar-On et al. 2018. PNAS 115(25): 6506-6511

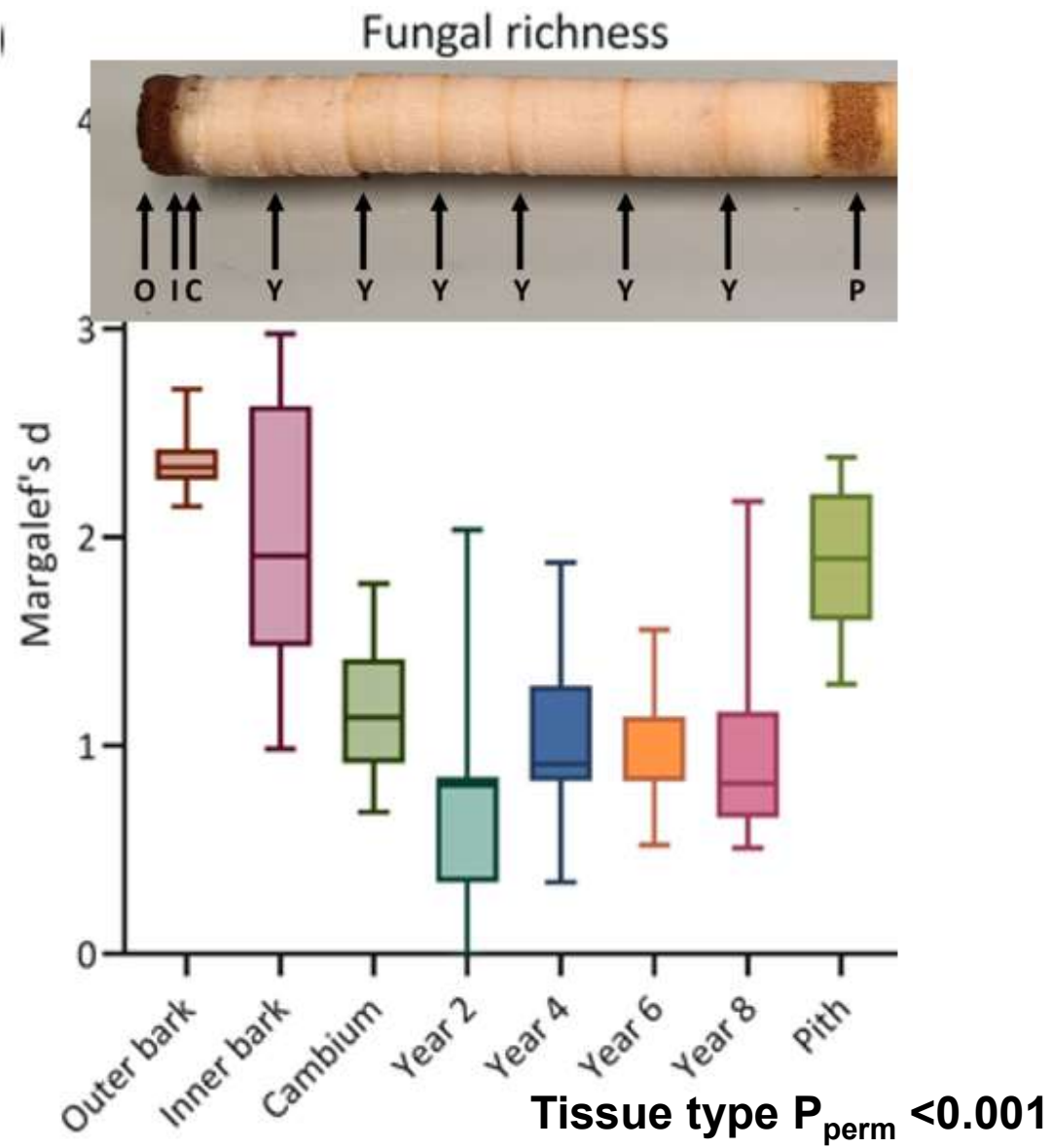
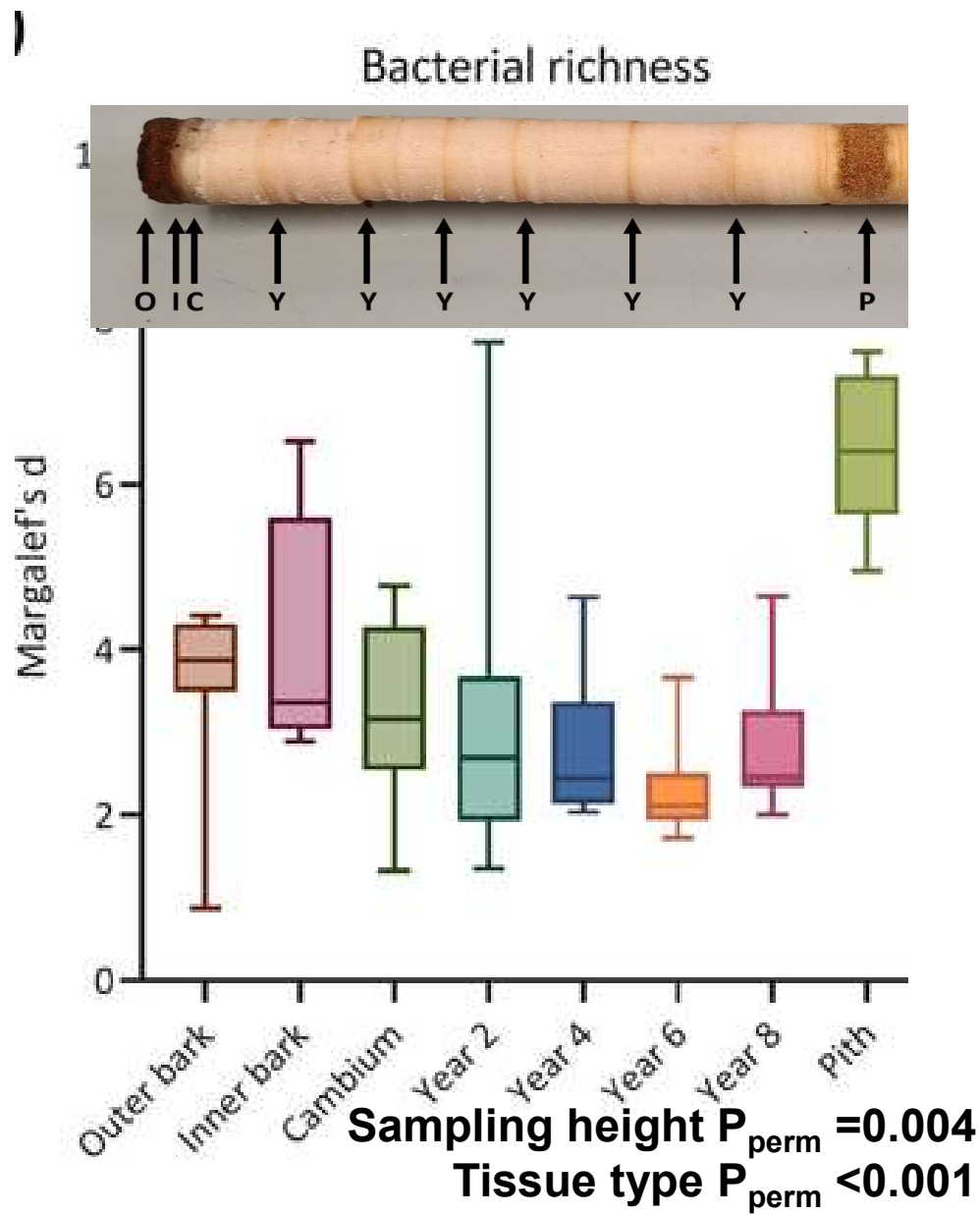
Wood microbiome

Conducted sampling vertically up a tree. Determined if 'height' of trunk influenced microbiome occurrence.



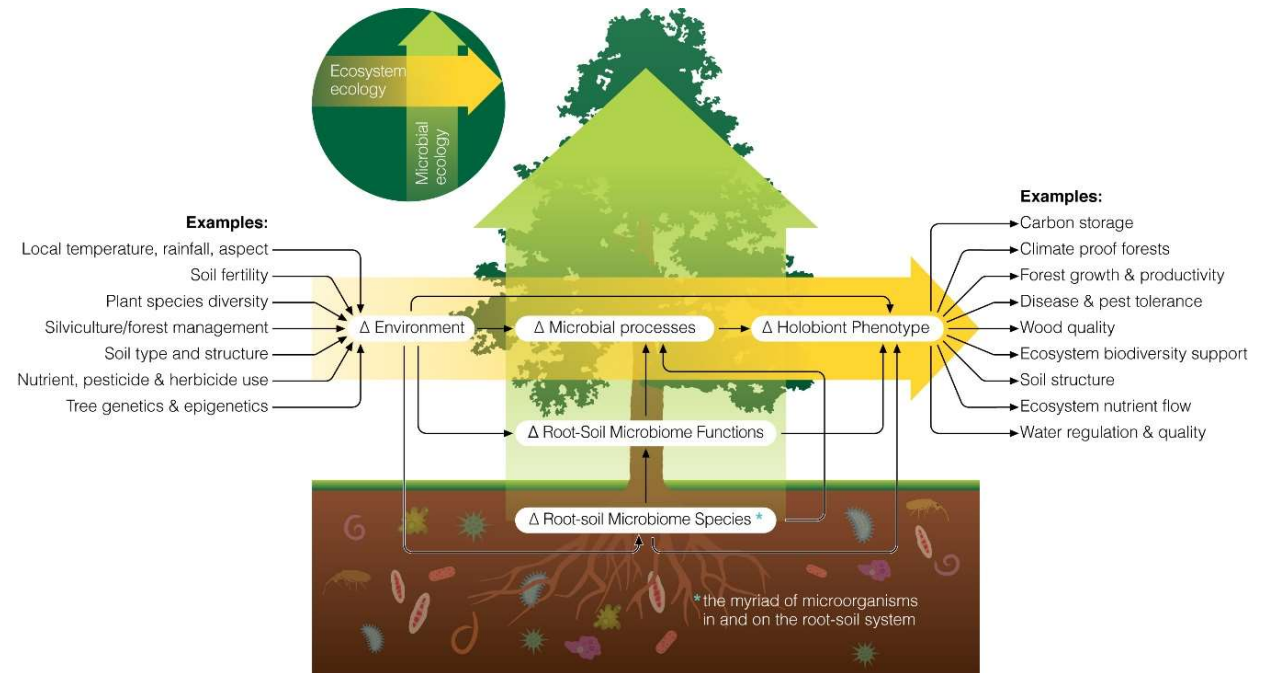
Sampling height far less important ($p > 0.05$) than tissue type.
Work was replicated across several trees at single height





Tying it all together, the holobiome and resilient forests

- Can plants learn to be programmed by the microbiome?
- Can we manipulate and train the microbiome of a pine tree to adapt?
- Can we show/teach a pine forest how to adapt to change?



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