

Introduction to Microbial Ecosystems and Microbiome Engineering

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▶ Microbial Ecosystem

Ecosystem: all the living organisms, combined to the physical and chemical components of their environment

Microbial: unicellular microscopic organisms ($< 100 \mu\text{m}$)



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Prokaryotes

- *Bacteria*
- *Archaea*

Eukaryotes

- Fungi (e.g., yeasts, molds)
- Protists (e.g., microalgae)



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Ecosystem: all the living organisms, combined to the physical and chemical components of their environment

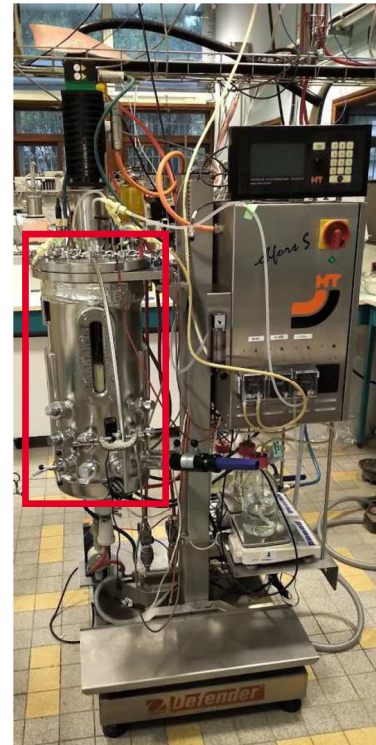
Microbial: unicellular microscopic organisms ($< 100 \mu\text{m}$)

Prokaryotes

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Confined, engineered microbial ecosystem

[Polytech Montpellier]



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Prokaryotes

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2.5×10^{30} cells (*Bacteria*
and *Archaea*)

8×10^9 people

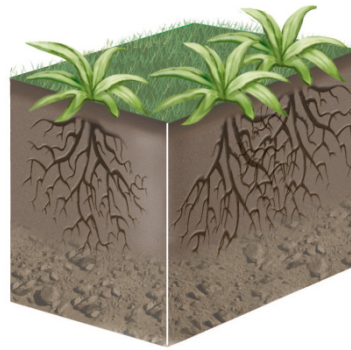
“Every natural ecosystem is firstly a microbial ecosystem”





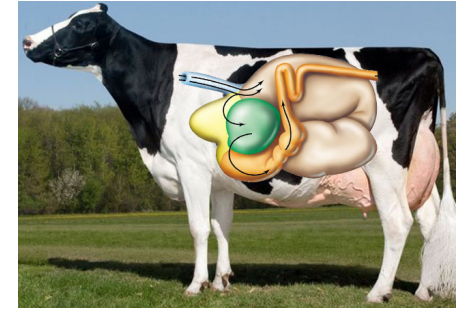
1 gram of cheese rind

10^{10} microbial cells
Low diversity



1 gram of soil

10^8 - 10^{10} microbial cells
 10^4 - 10^5 bacterial species

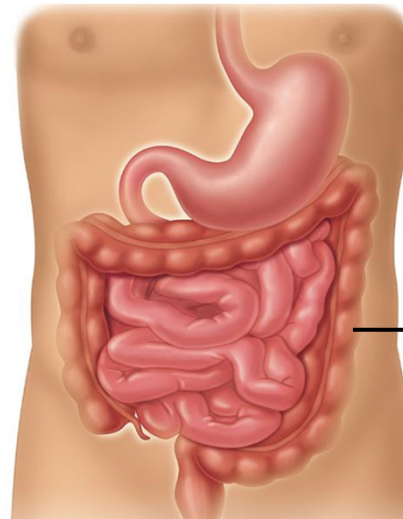


1 gram of rumen content

10^{11} microbial cells
Up to 400 bacterial species



3.0×10^{13} human cells
 3.7×10^{13} bacterial cells



Skin

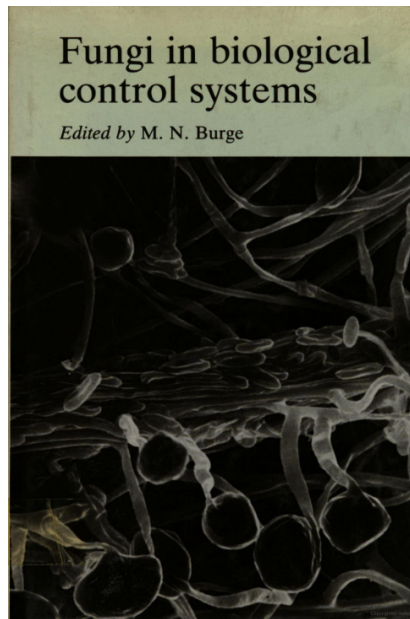
10^{12} microbial cells

1 gram of colon content

10^{11} microbial cells
 10^3 - 10^4 bacterial species

[©2019 Pearson Education Ltd.]

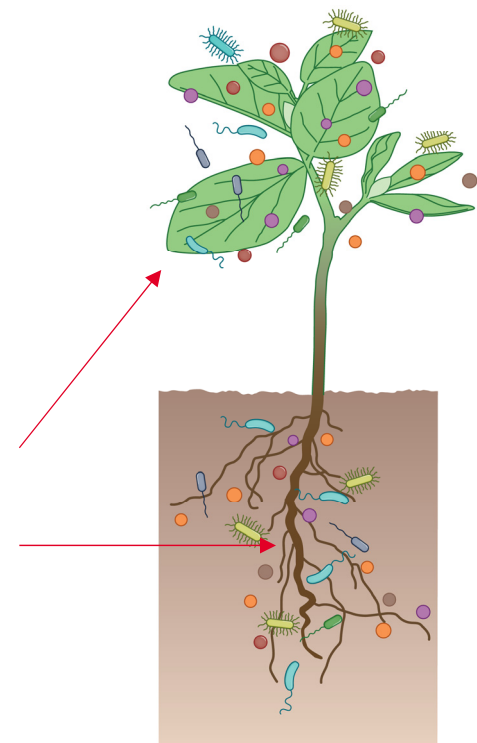




Whipps, J.M., Lewis, K. & Cooke, R.C. (1988)

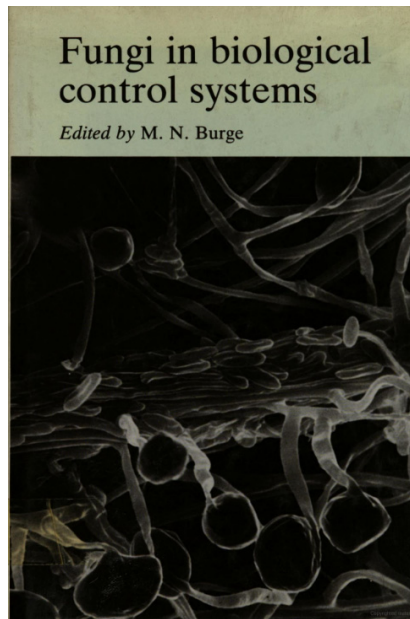
Chapter 9. Mycoparasitism and plant disease control

Microbiomes of the phyllosphere and the rhizosphere



[Banerjee and van der Heijden, 2023]

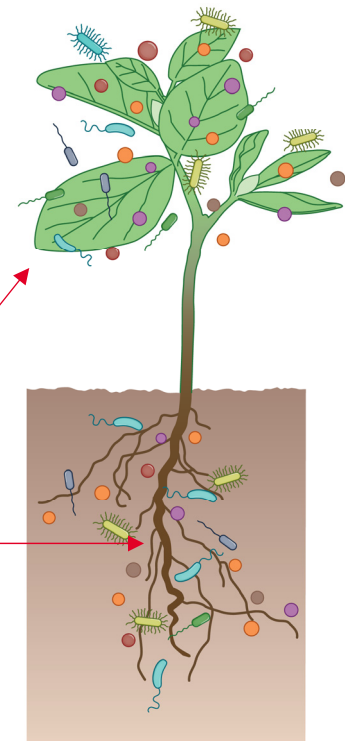




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Chapter 9. Mycoparasitism and plant disease control

Microbiomes of the phyllosphere and the rhizosphere



[Banerjee and van der Heijden, 2023]

► Microbiome

“characteristic microbial community in a reasonably well-defined habitat which has distinct physico-chemical properties as their theatre of activity”

“It is nothing else than a microbial ecosystem”



▶ **Micro-biome**

Micro: microbial communities living on, in and around people, plants, animals, soil, oceans or the atmosphere

Biome: (*ecosystem*), the biotic and abiotic components of a given environment



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Which microorganisms?

- Microbiome
- Mycobiome
- Bacteriome
- Archaeome
- Protistome



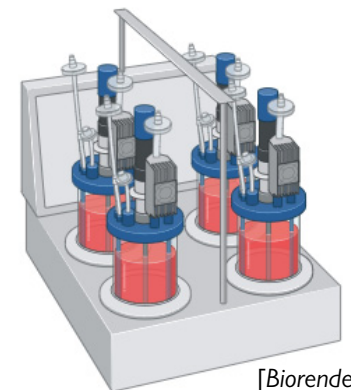
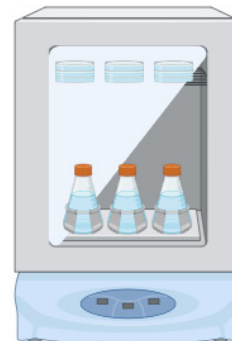
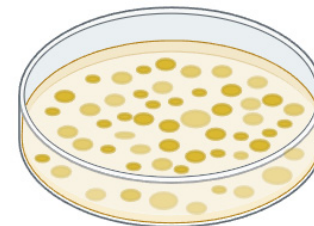
▶ Micro-biome

Micro: microbial communities living on, in and around people, plants, animals, soil, oceans or the atmosphere

Biome: (*ecosystem*), the biotic and abiotic components of a given environment

Which techniques?

- Culture-based



[Biorender]



▶ Micro-biome

Micro: microbial communities living on, in and around people, plants, animals, soil, oceans or the atmosphere

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Which techniques?

- Culture-based

Culturable microbiome

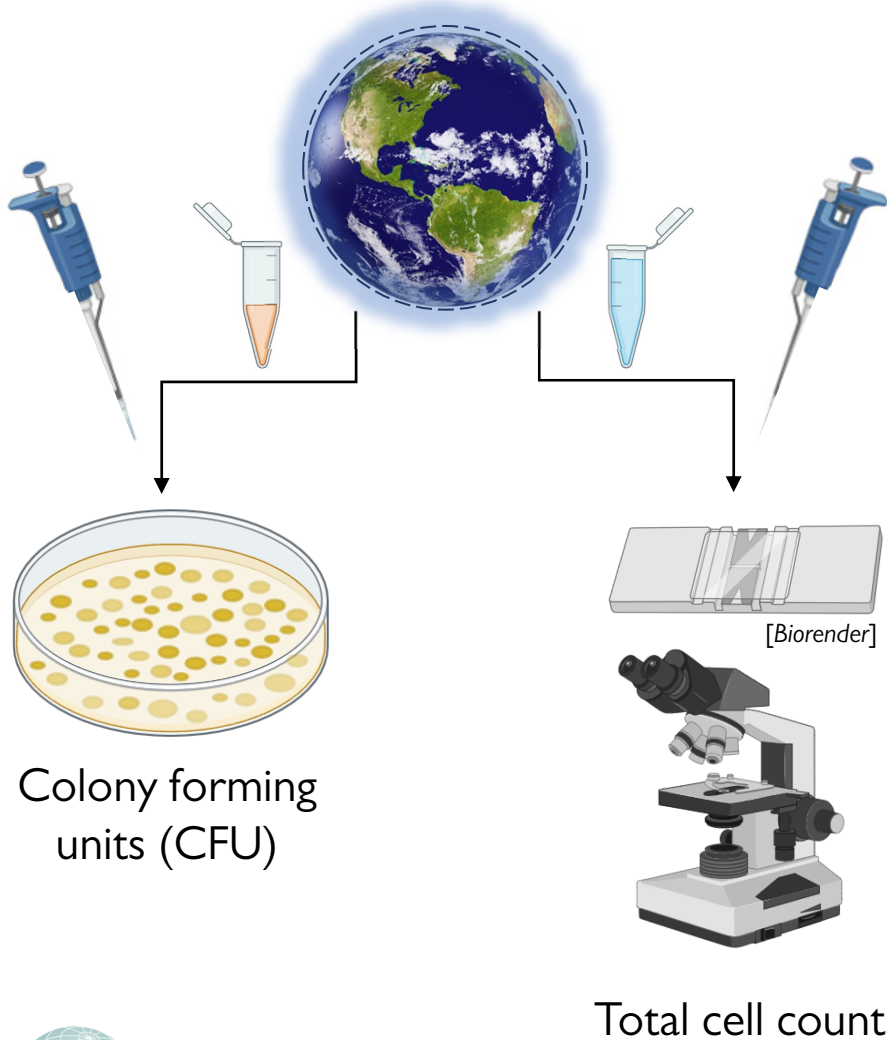


[Prof. Tasha Sturm, Cabrillo College, CA]



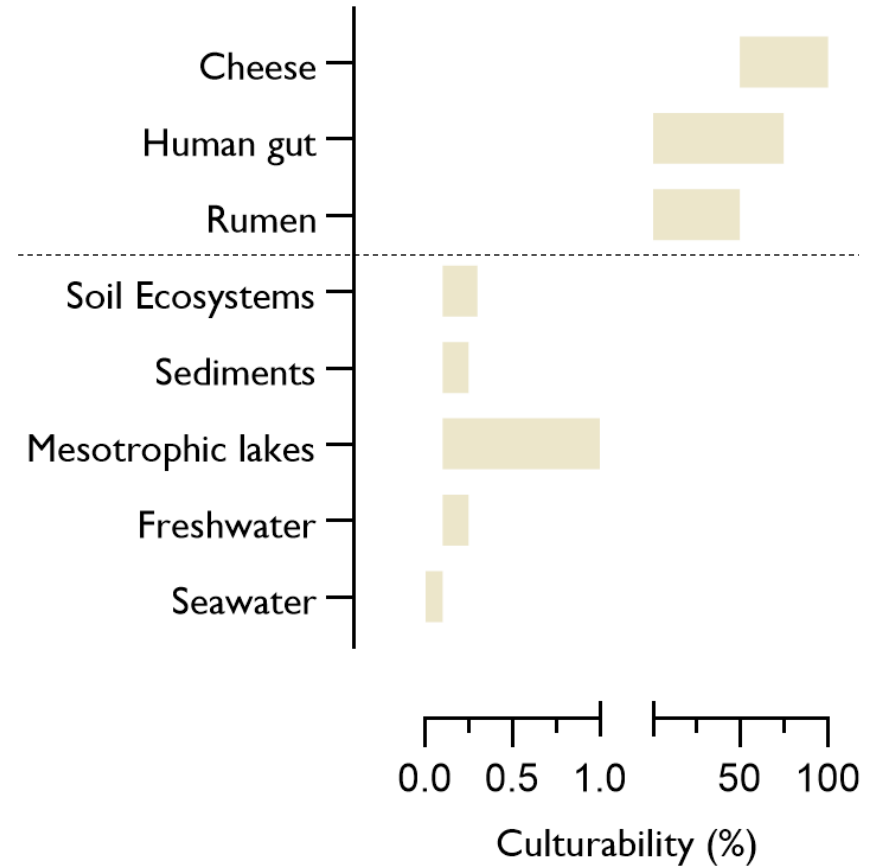
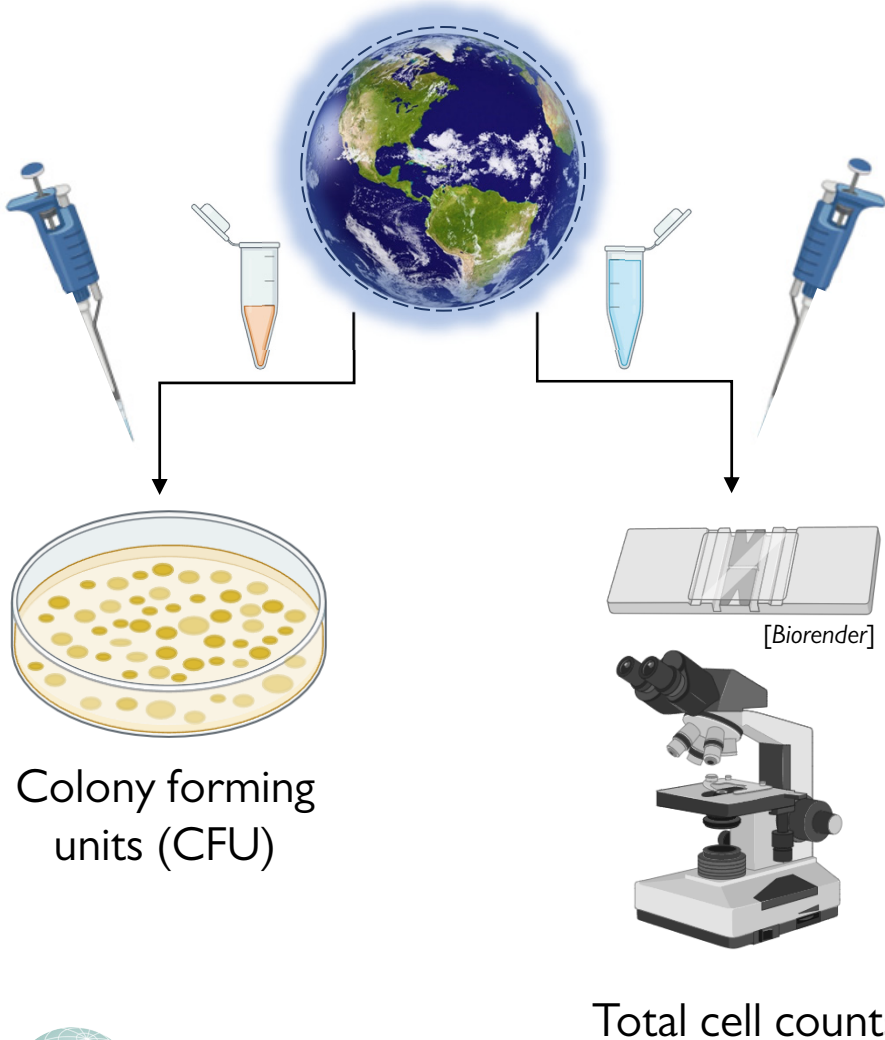
Culturable microbiome and the “great plate count anomaly”

Environmental sample



Culturable microbiome and the “great plate count anomaly”

Environmental sample



▶ Micro-biome

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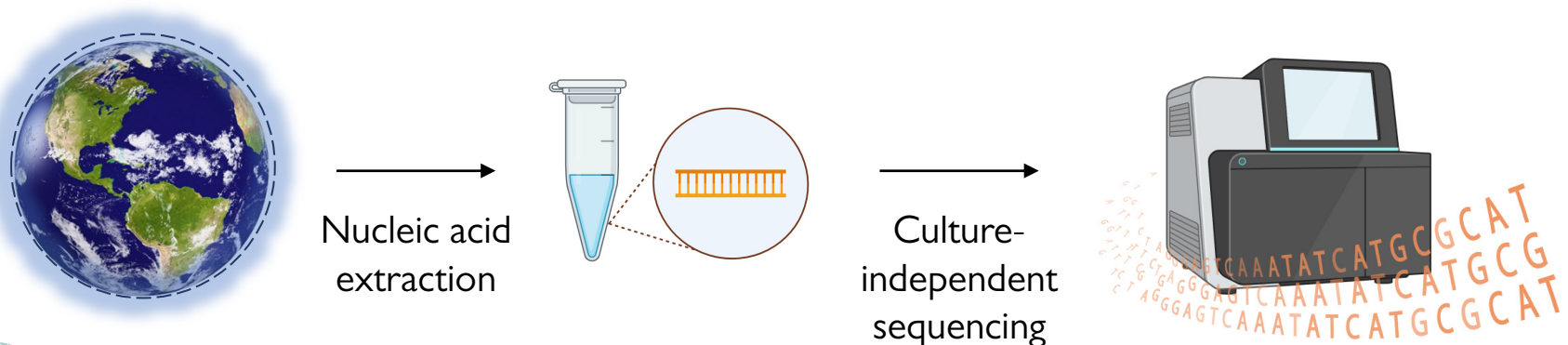
Biome: (*ecosystem*), the biotic and abiotic components of a given environment

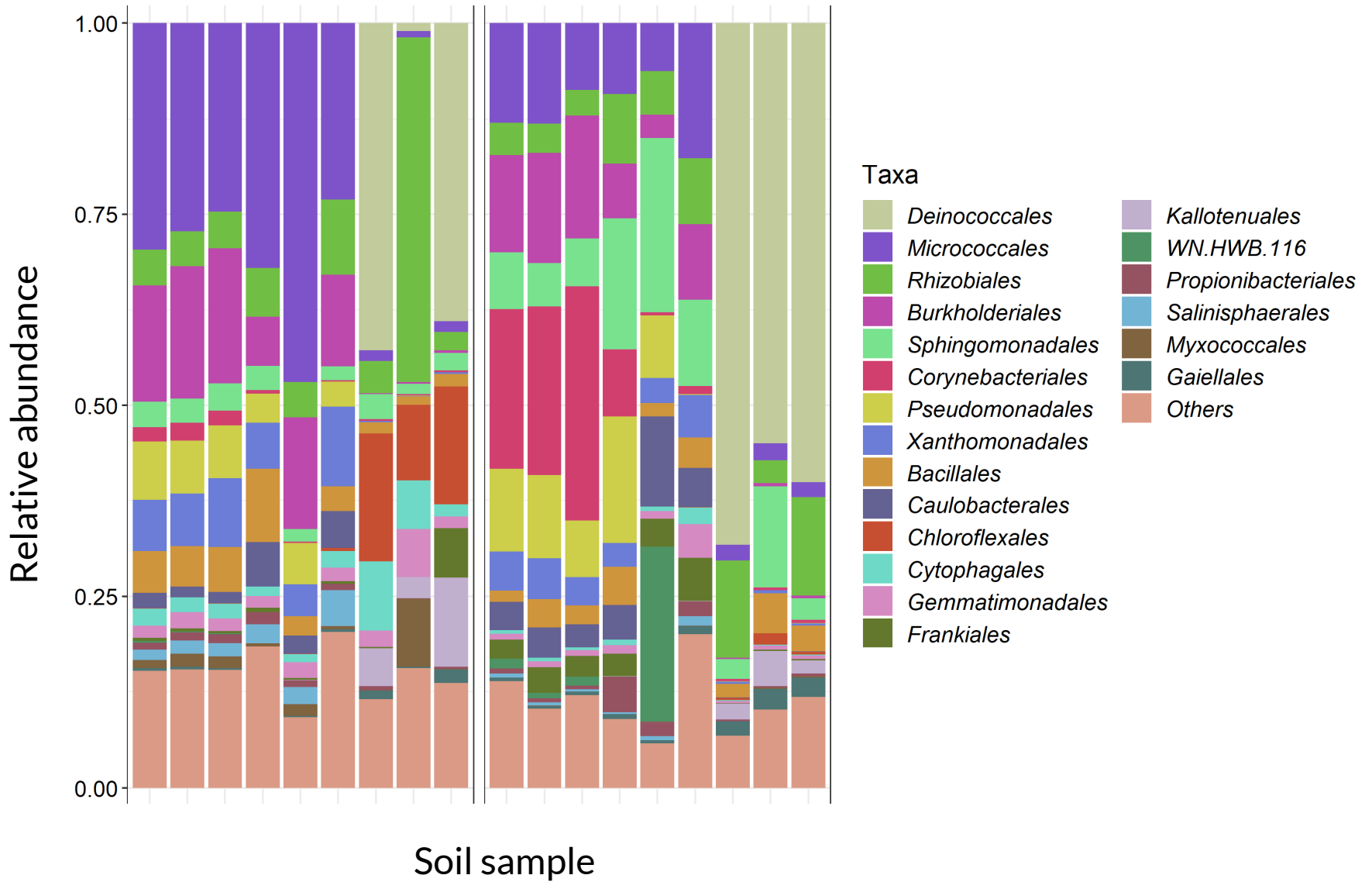
Which techniques?

- Culture-based
- Meta-omics

Metagenome of a microbiome

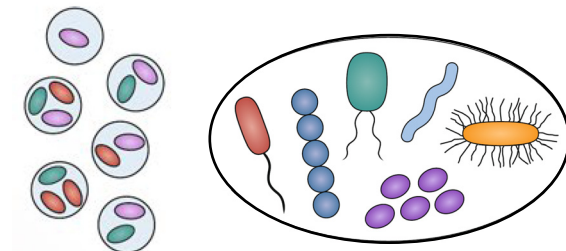
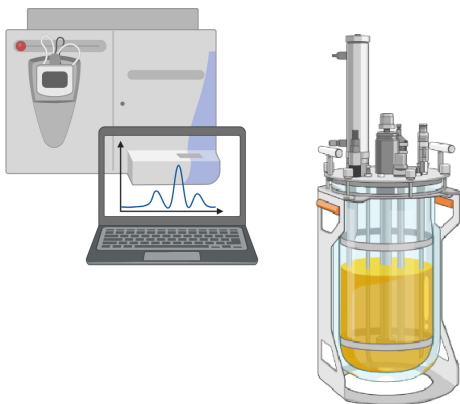
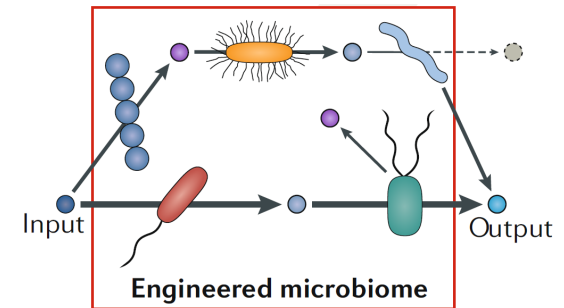
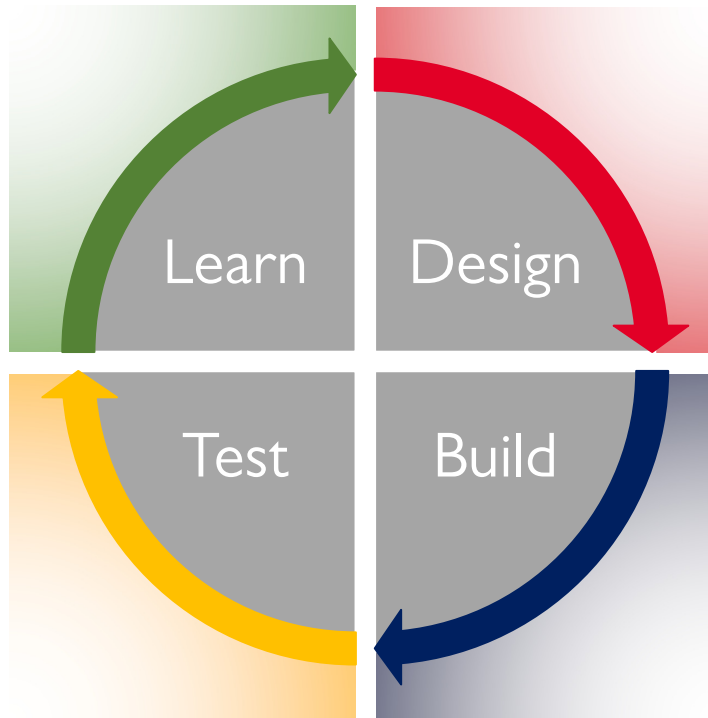
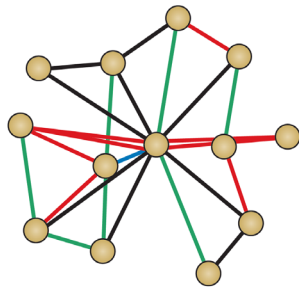
The collection of genes and genomes in any given environmental sample





► Microbiome engineering

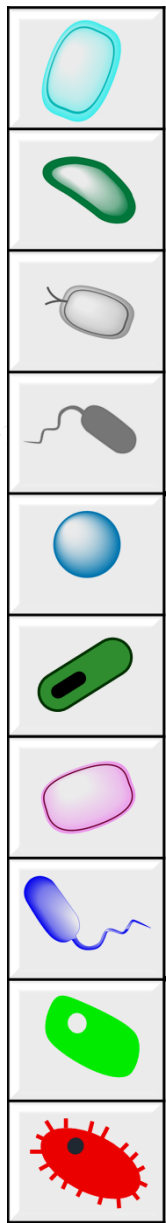
Leveraging fundamental scientific and engineering principles and quantitative design to create synthetic microbiomes or to manipulate natural microbiomes with controllable outputs



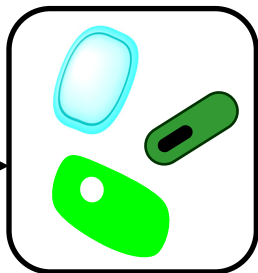
[Lawson et al., 2019, Nat. Rev. Microbiol.]



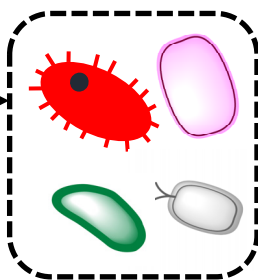
Synthetic ecology



Design A



Design B

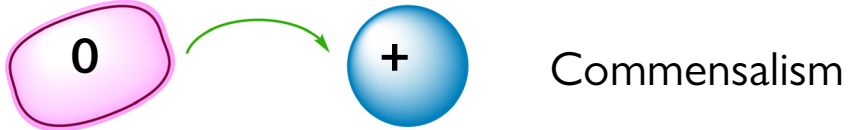
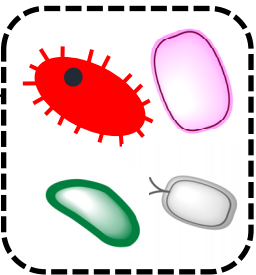


Synthetic ecology

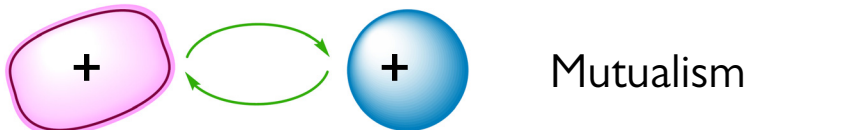
Design A



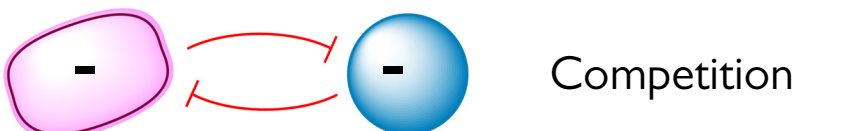
Design B



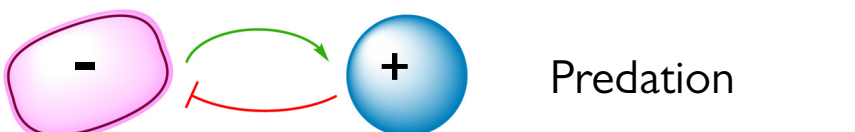
Commensalism



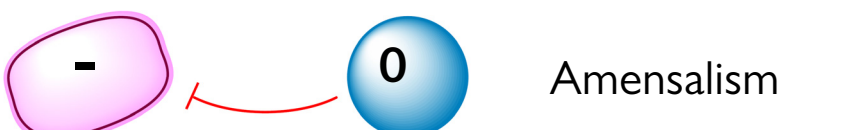
Mutualism



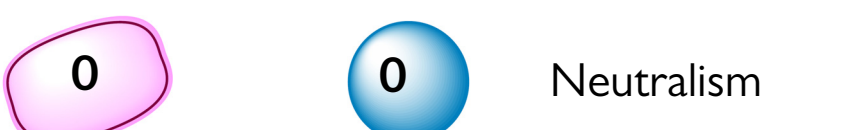
Competition



Predation

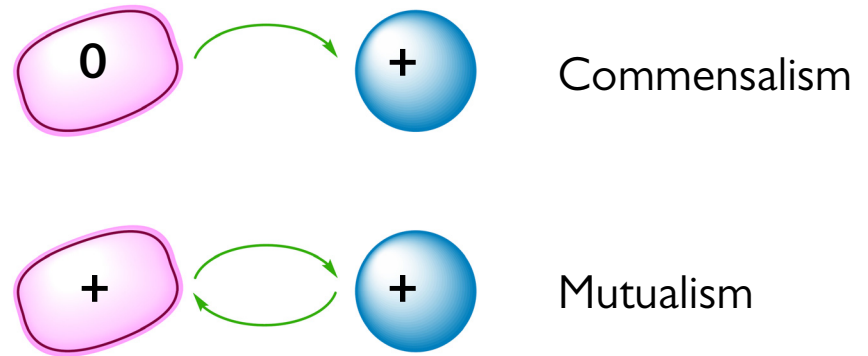
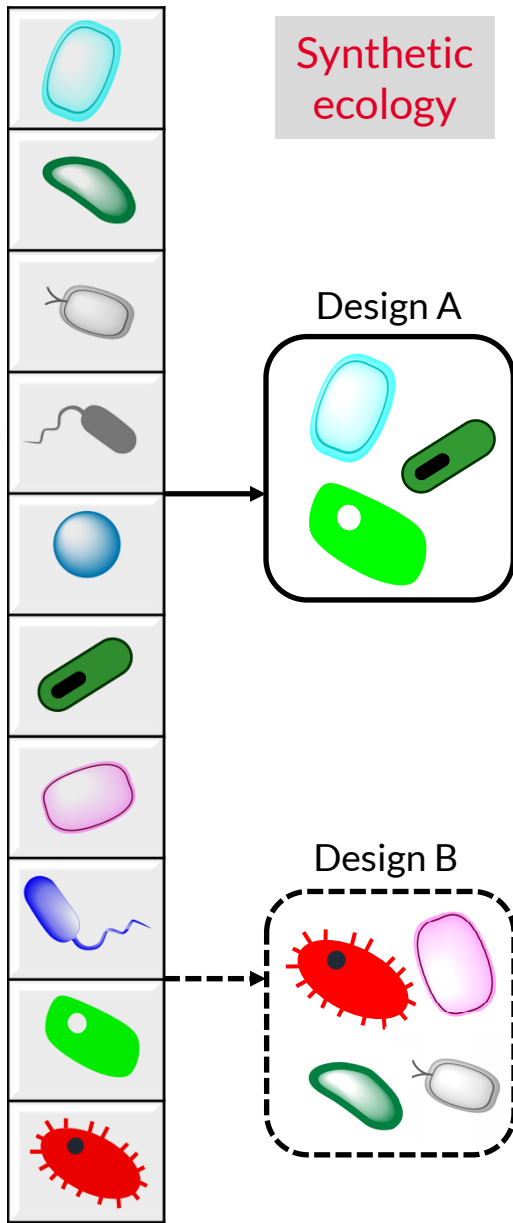


Amensalism



Neutralism



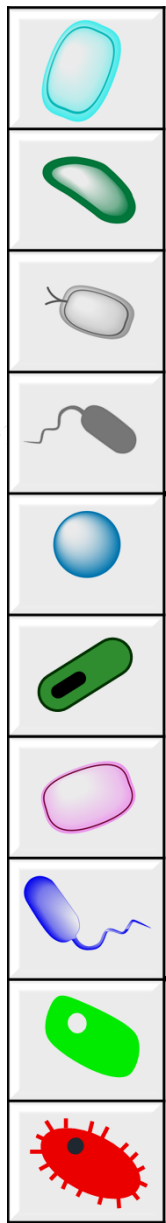


Design of microbial cleaning products

Assembly of polycultures of *Bacillus* sp.

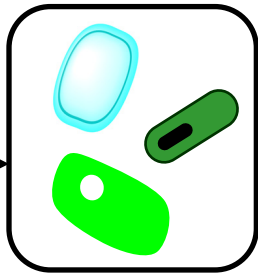
- Biosafety Level I
- Stability in final formulation (sporulation)
- Synergistic interactions to remove recalcitrant materials, such as grease, starch or proteins



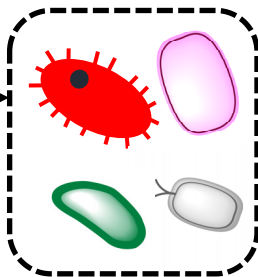


Synthetic ecology

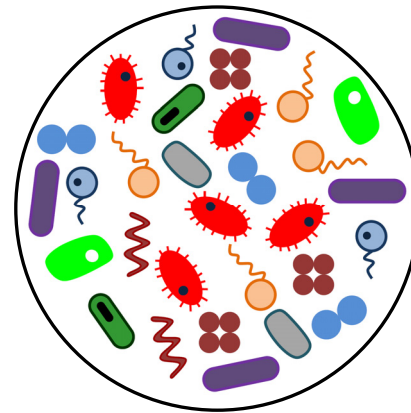
Design A

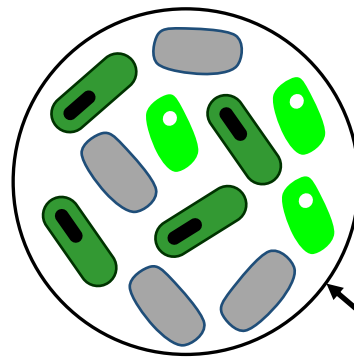
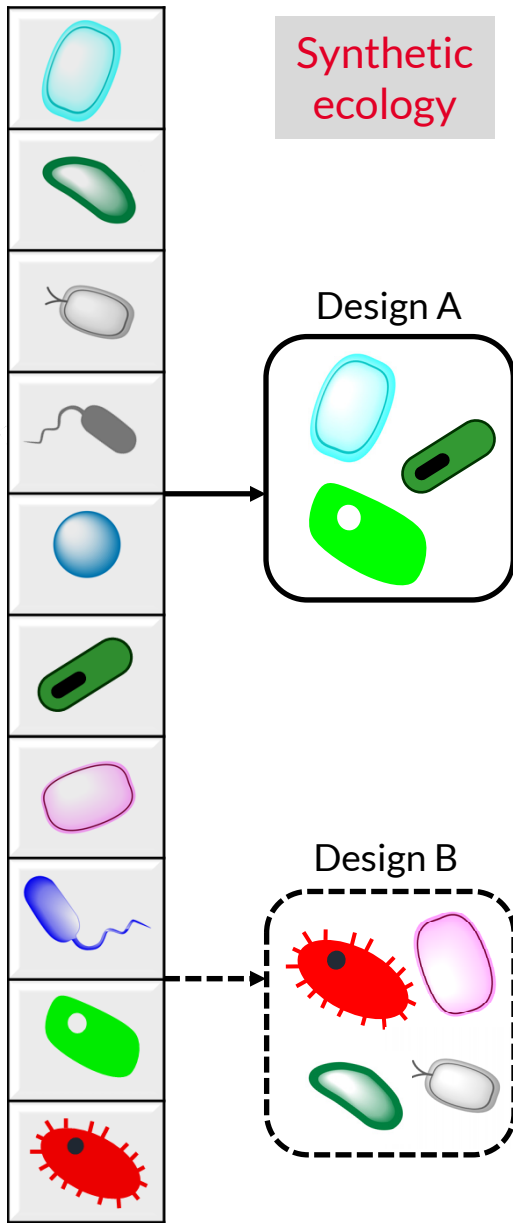


Design B

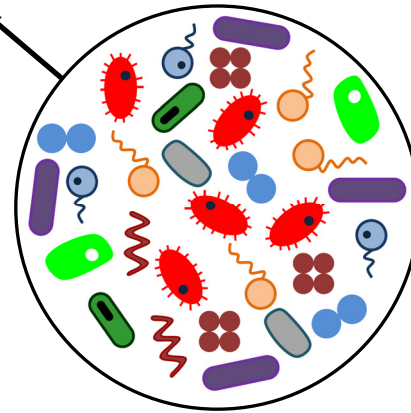


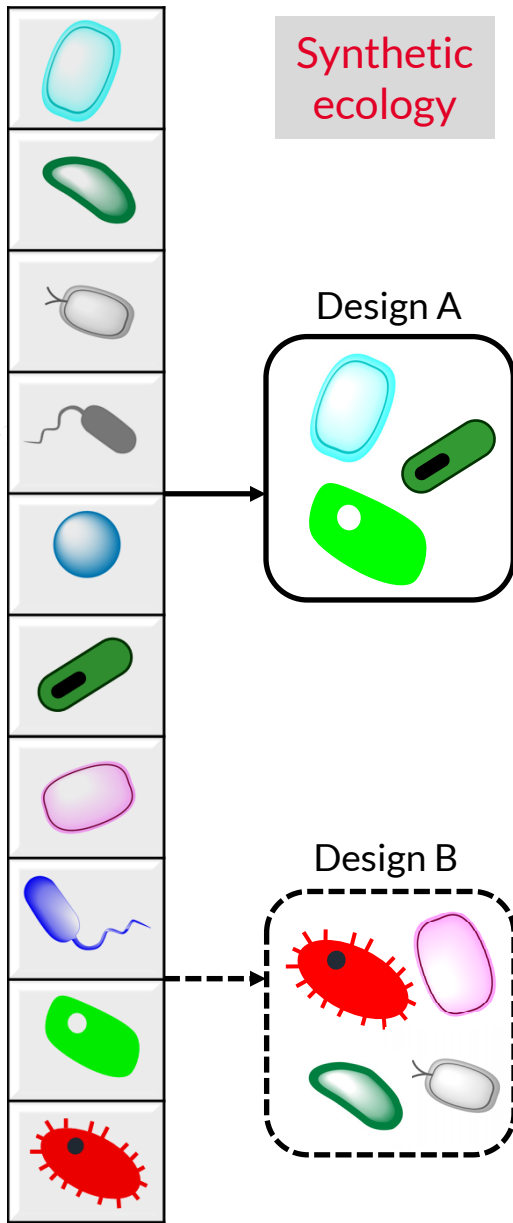
Natural microbiome manipulation





Natural
microbiome
manipulation

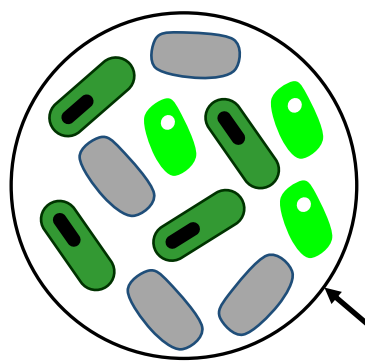




Synthetic ecology

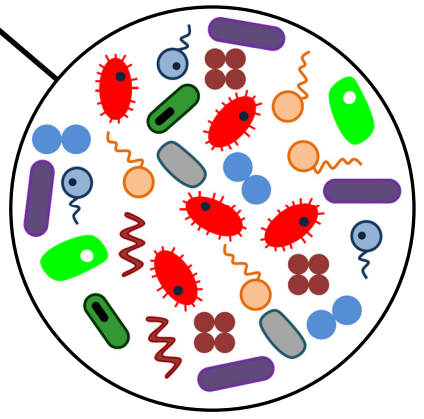
Design A

Design B



Selection

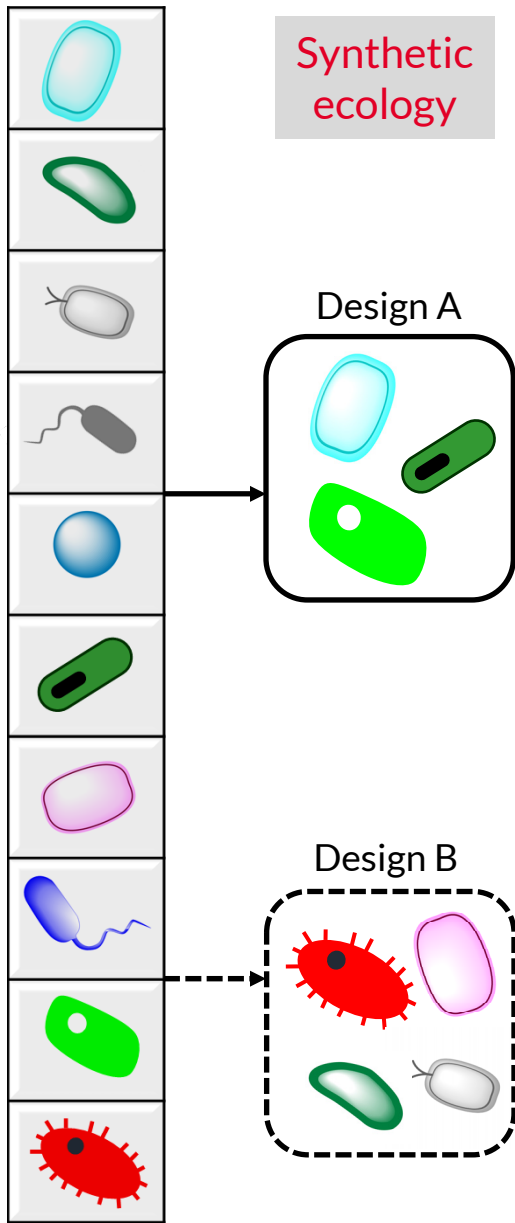
Natural microbiome manipulation



Biostimulation by the addition of prebiotics

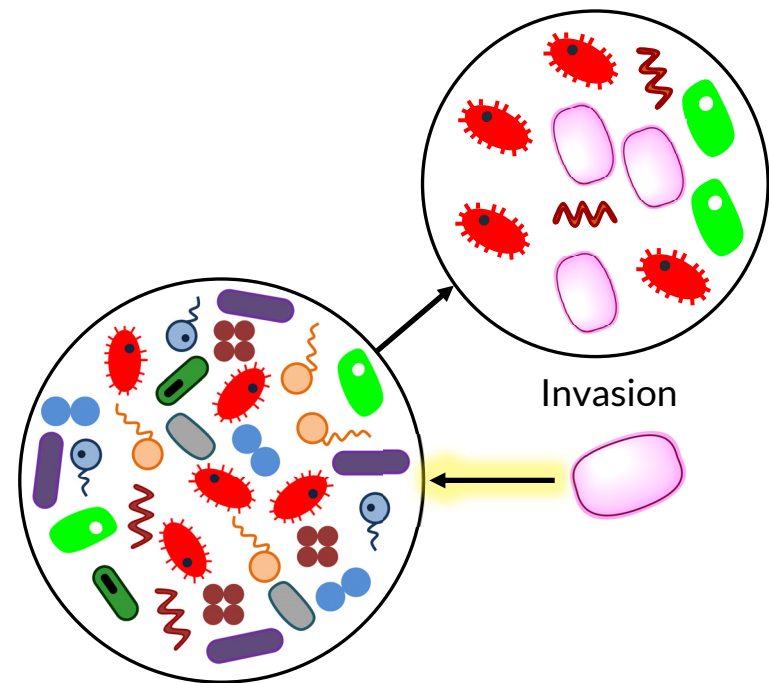
“chemicals, such as dietary fibers, that can promote growth or activity in a community in a selective manner”

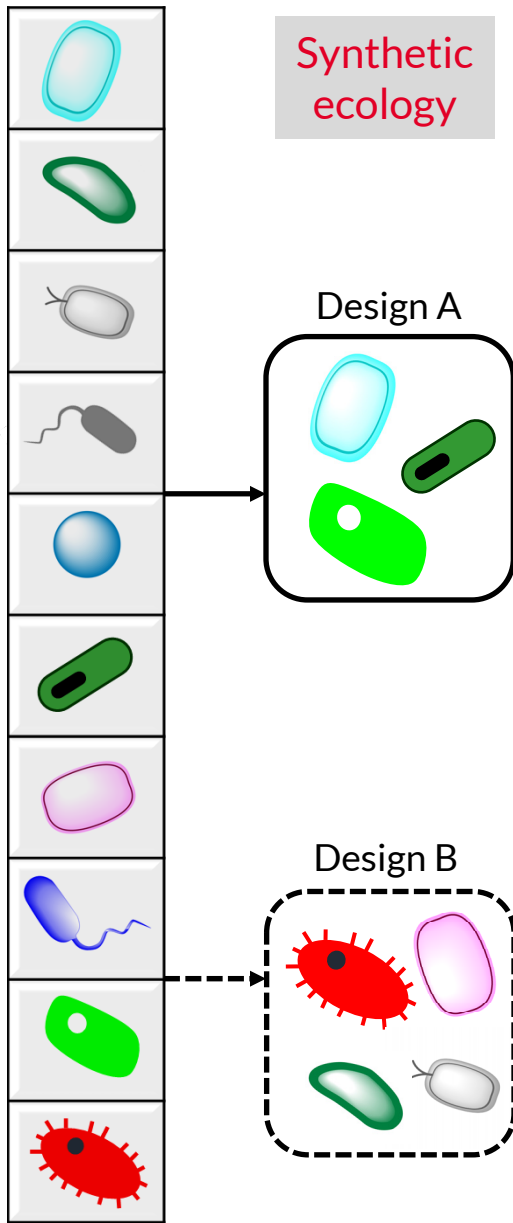




Synthetic ecology

Natural microbiome manipulation



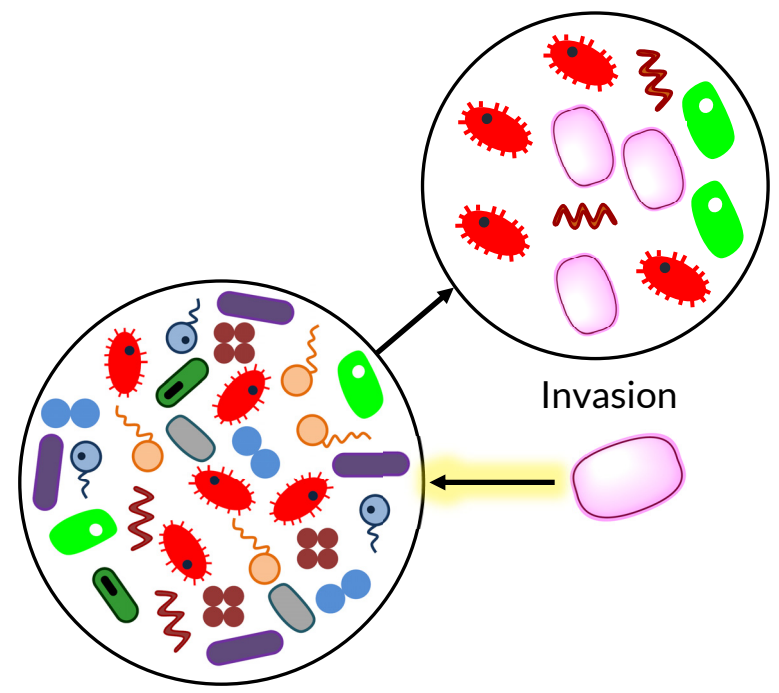


Synthetic ecology

Design A

Design B

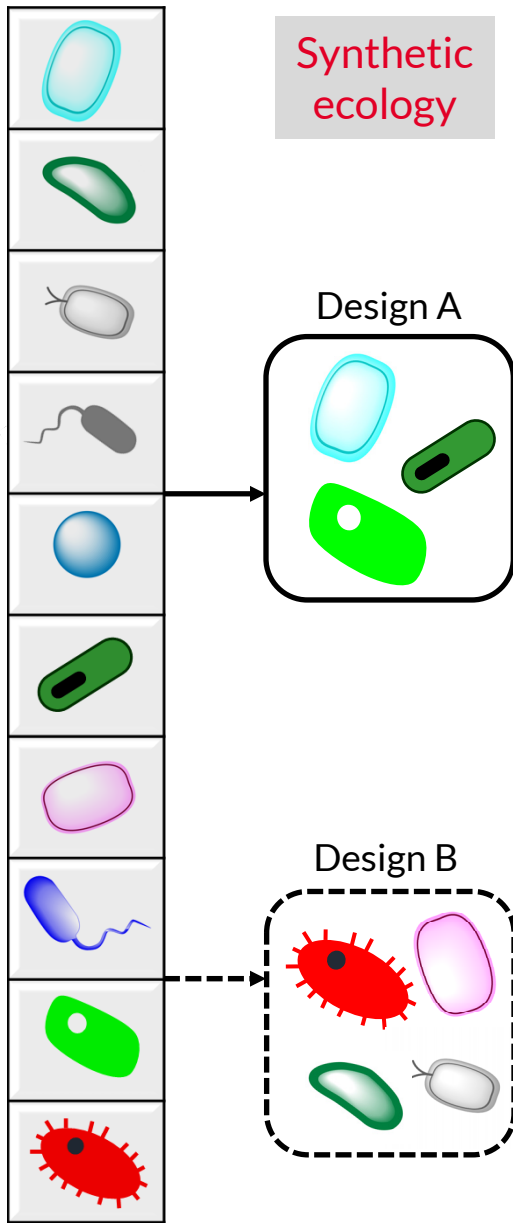
Natural microbiome manipulation



Bioaugmentation by the addition of probiotics

“living microbial inoculants that can confer a benefit to a particular host environment”

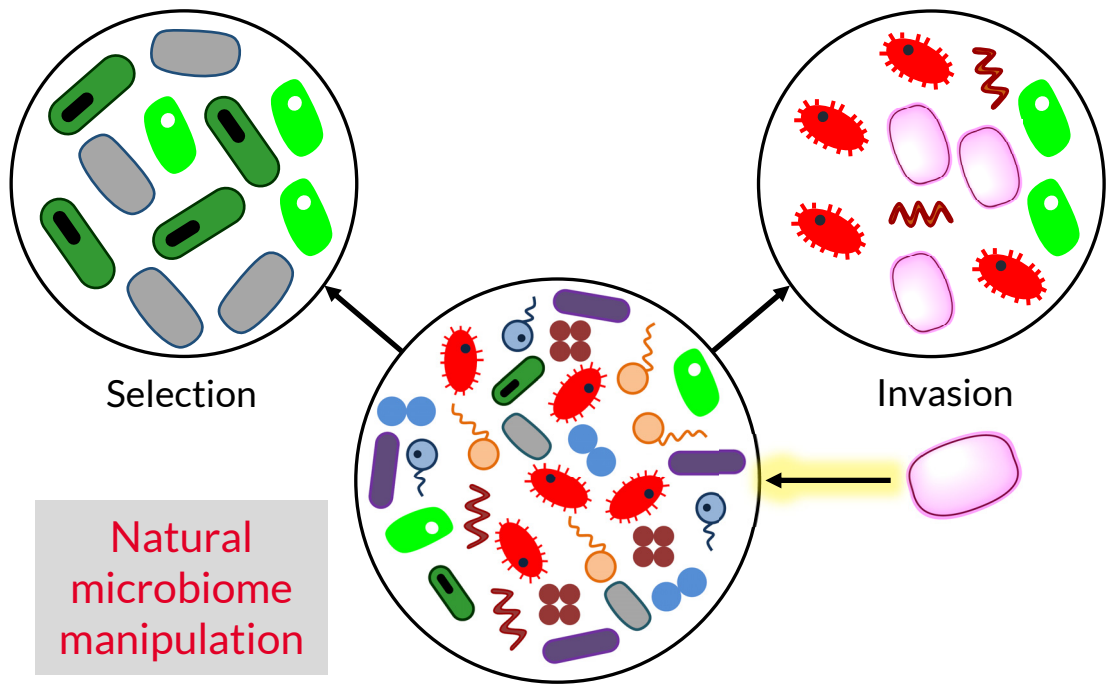




Synthetic ecology

Design A

Design B



Selection

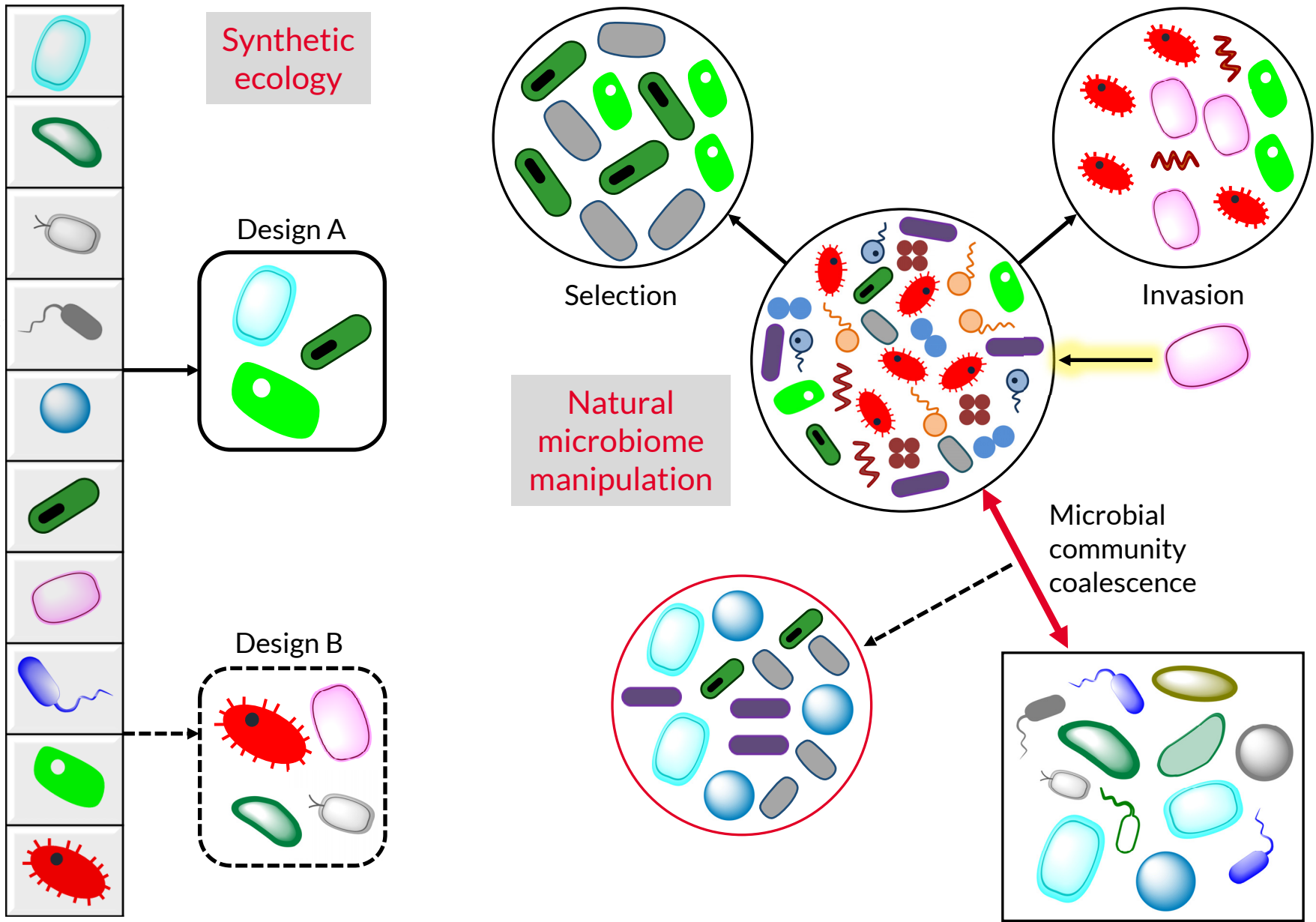
Natural microbiome manipulation

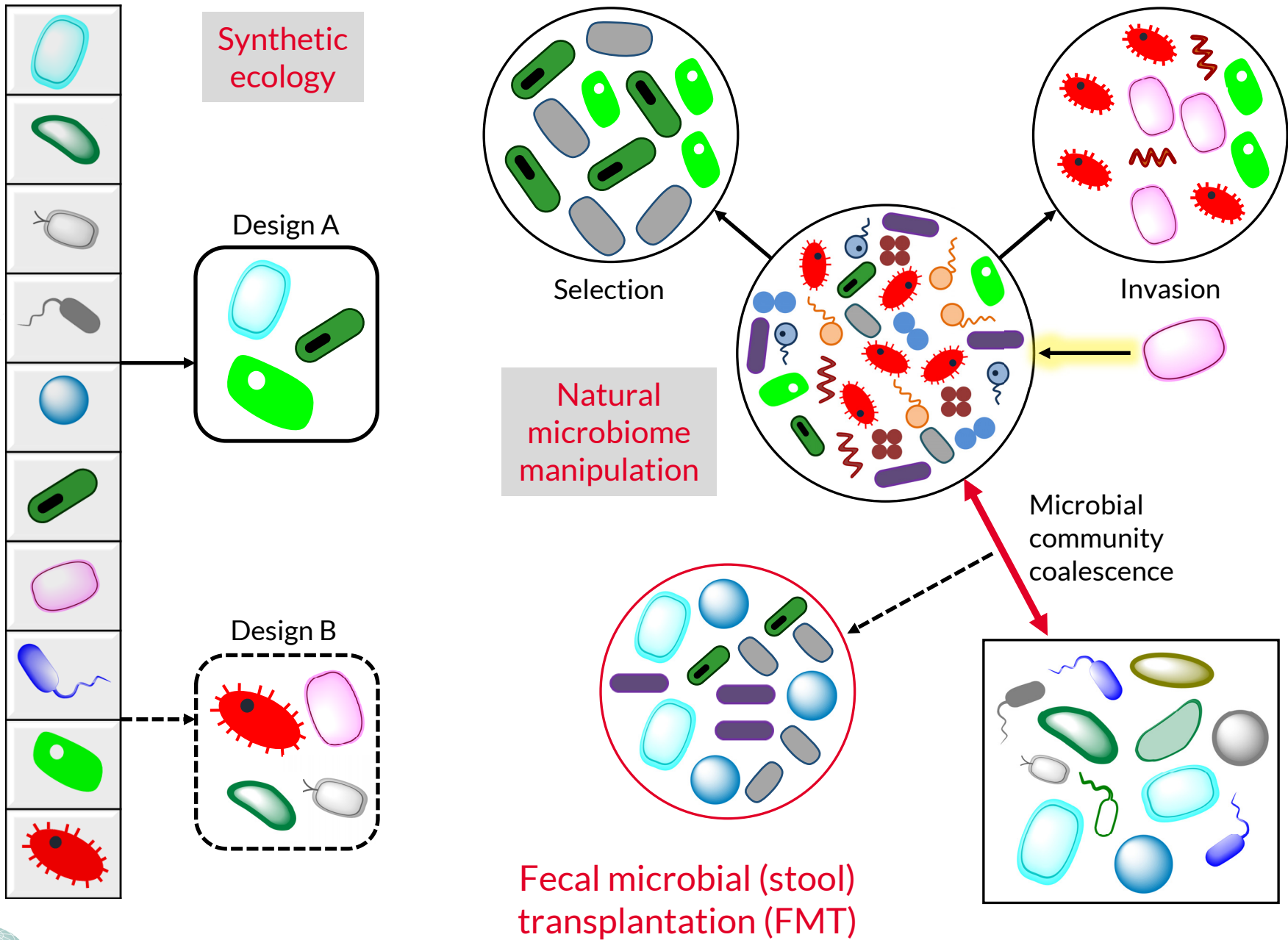
Invasion

Bioaugmentation and biostimulation using synbiotics

“combination of probiotics and prebiotics”







Thank you!

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