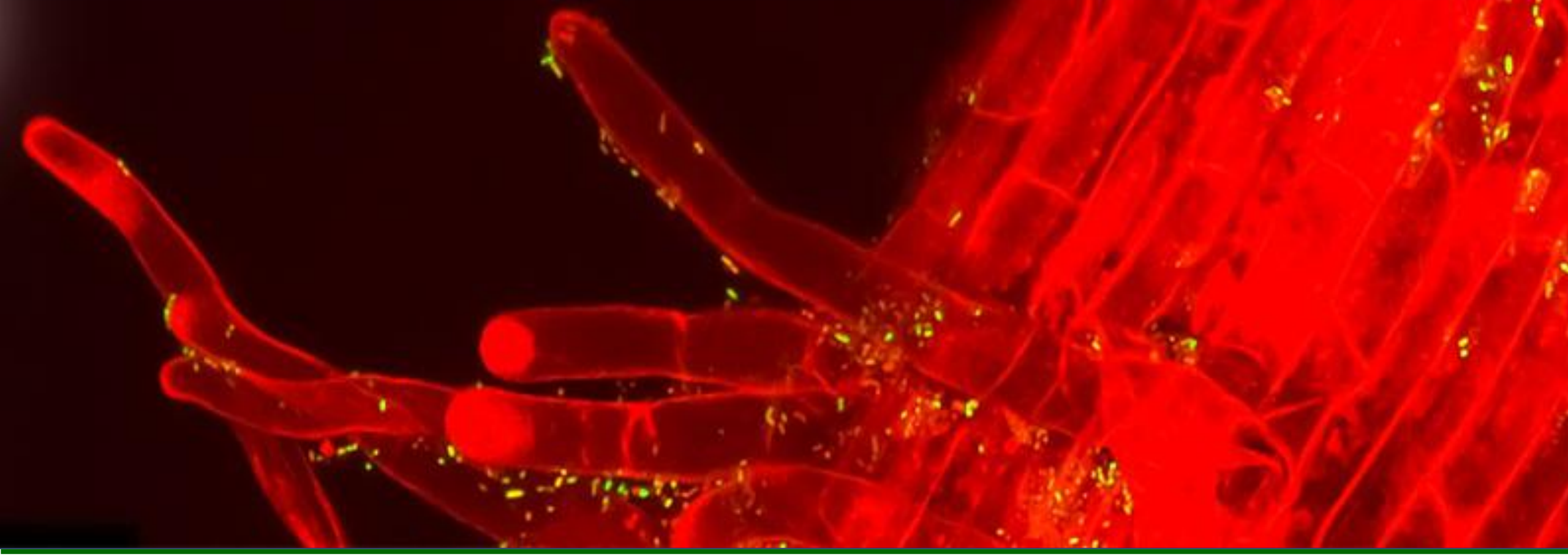
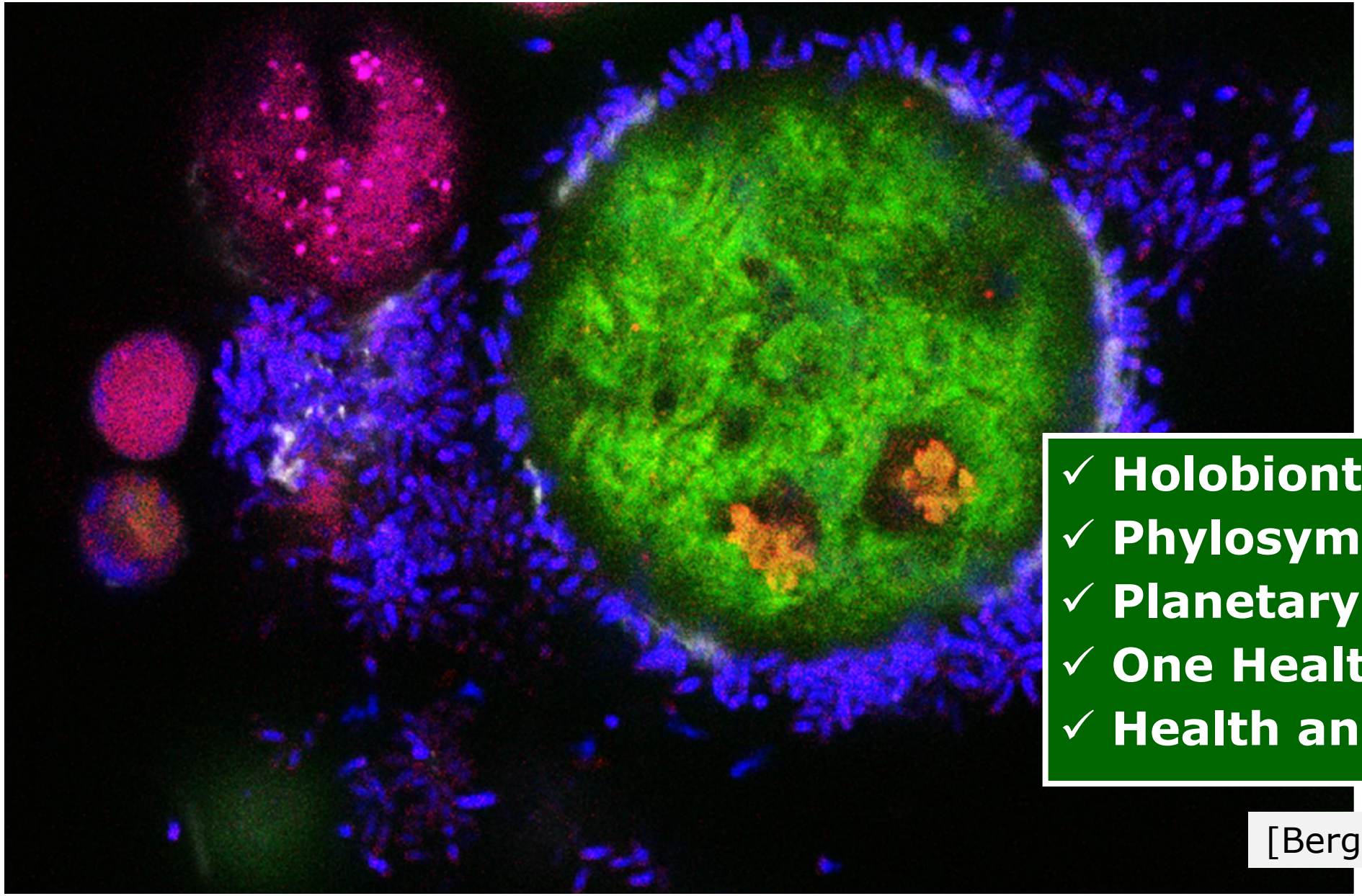


The potential and risk of engineering microbiomes for One health

Gabriele Berg & Team

AUSTRIA / GERMANY

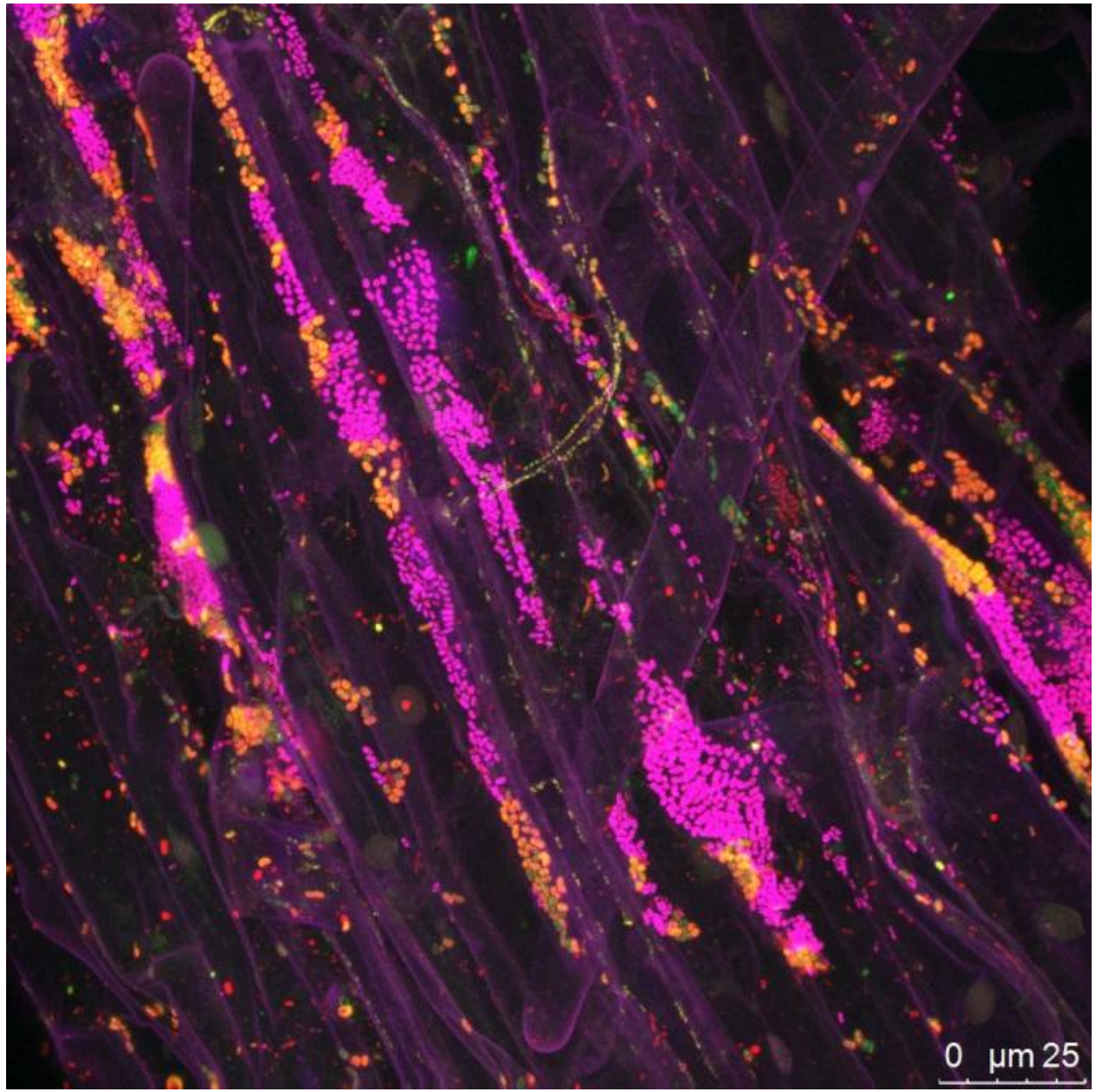
1. Microbiome research has revealed new fundamental concepts



- ✓ **Holobiont concept**
- ✓ **Phylosymbiosis concept**
- ✓ **Planetary Health concept**
- ✓ **One Health concept**
- ✓ **Health and Disease**

[Berg *et al.* Microbiome 2020]

2. A new understanding of microbiomes has been discovered



A paradigm shift: the diverse microbiome is key to health and resilience

A healthy microbiome is:

- ✓ **Highly diverse, rich and evenly structured with members known for beneficial as well as for pathogenic interaction and different lifestyles**
- ✓ **Crucial for health and resilience of the hosts**

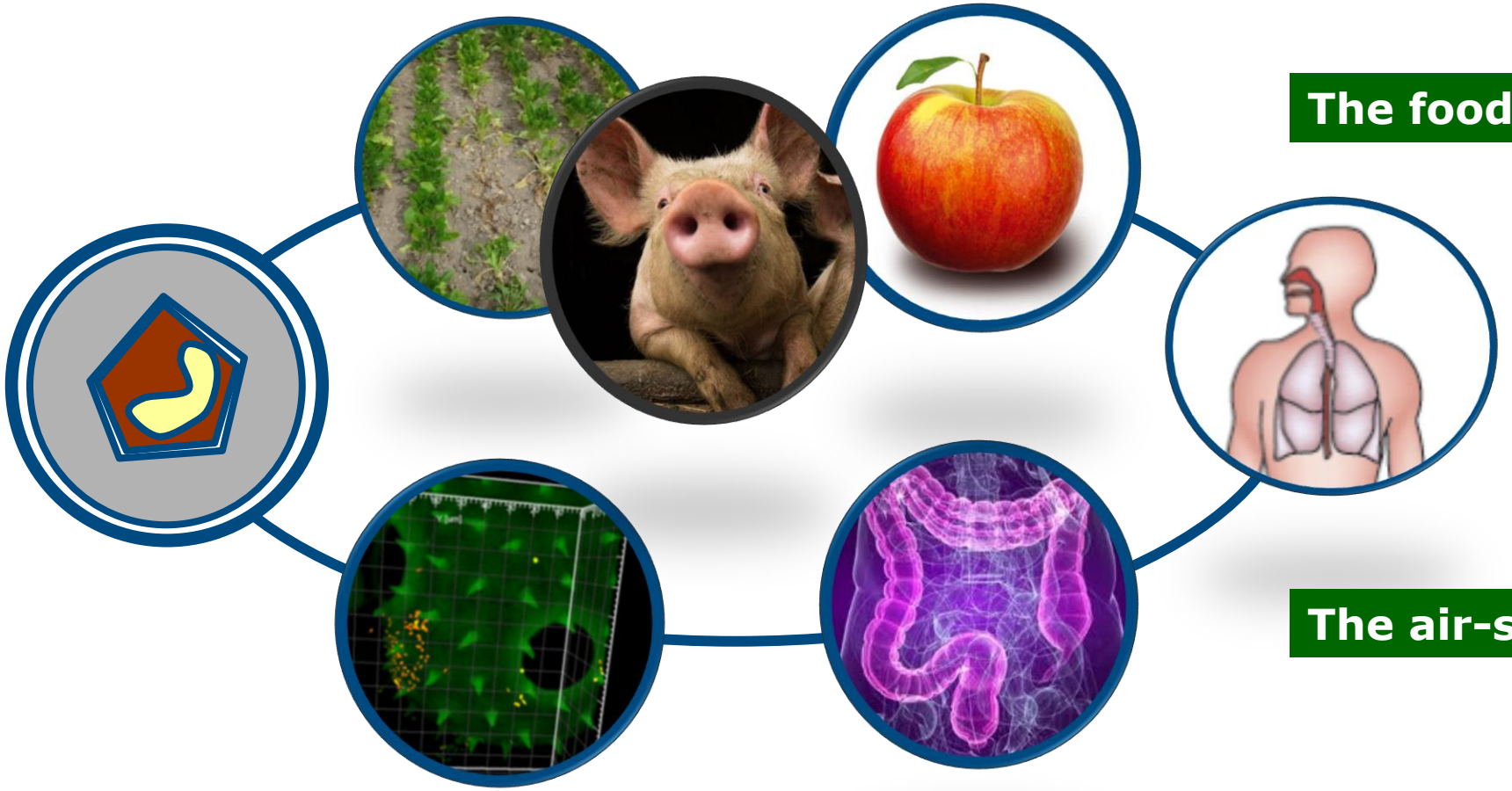
Host-specific microbiomes have co-evolved for 480 million years

Potential pathogens are everywhere; emerging pathogens are man-made

[Berg & Raaijmakers ISME J 2018]

3. The environmental microbiome is connected with human health

The interconnected plant microbiome



The food-gut interface

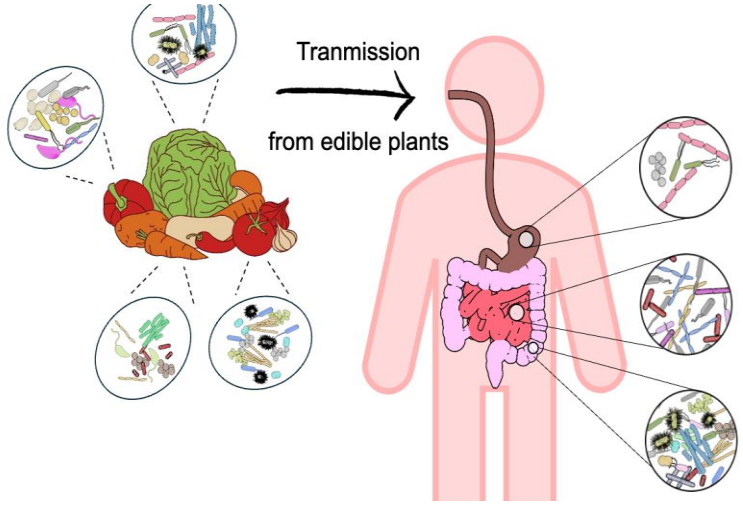
The air-skin interface

[Sessitsch *et al.* Microbiol Mol Biol Rev. 2025]

4. The evidence for the food – gut microbiome connection is novel

Significant overlap, e.g. for *Enterobacteriales, Burkholderiales,* and *Lactobacillales*

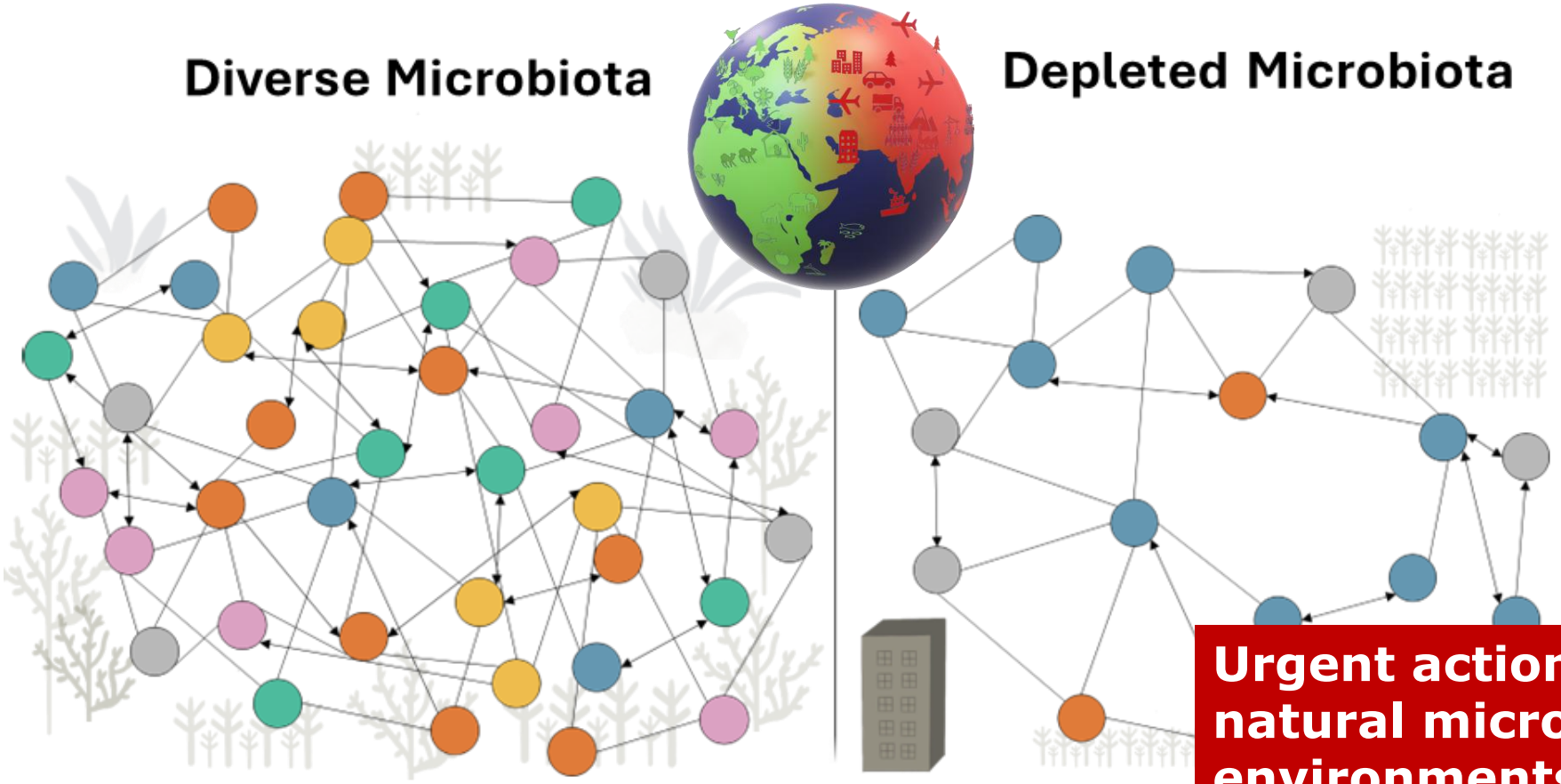
The first and last year of life are crucial



A highly diverse gut microbiome promotes HEALTH

[Wicaksono et al. Gut Microbe 2023, 2025]

5. The loss of microbial diversity and health



Biodiversity hypothesis of health by Hanski et al. (2012)

Loss of plant microbial diversity by Berg et al. (2017, 2022)

The theory of disappearing microbiota by Blaser (2017)

- Half of the diversity is already lost

Urgent action is needed to restore natural microbiota across diverse environments

Taxonomic **diversity** and **functional redundancy** in microbiomes is associated with an increased **stress tolerance** and **resilience**.

A **loss of microbial diversity** in different habitats has been linked to **modern lifestyle** and is often associated with **dysbiosis**.

- **Increase of chronic diseases (metabolic and immune-associated diseases)**
- **Increase of health-care associated infections and antimicrobial resistances**

6. We need microbiome management & protection

Abiotic management

Broad-band applications

Dietary change

Fecal microbiota transplantation

Pro/pre/syn-biotics

Precision medicine

Soil management

Complex communities

Single inocula

Precision agriculture

Bioeconomy

ONE HEALTH

Medicine

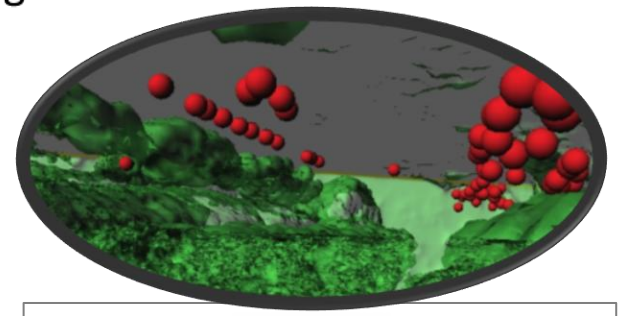
Agriculture

Biotic management

Probiotics
Synbiotics
Prebiotics

Precision treatments

Bioprotectans
Biostimulants
Biopesticides
Biofertilizers



Single strains
SynComs
Defined microbial consortia
Native transplants

[Berg *et al.*, Microbiome 2020]

7. The native microbiome has an huge, yet untapped, potential

First successful European Product on the basis of a defined microbial consortia from the native microbiota for stress protection

[BFC Technology: Berg & Müller 2018, PCT/EP2018/075760]

The benefits of vermicompost:

Extraordinary microbial richness

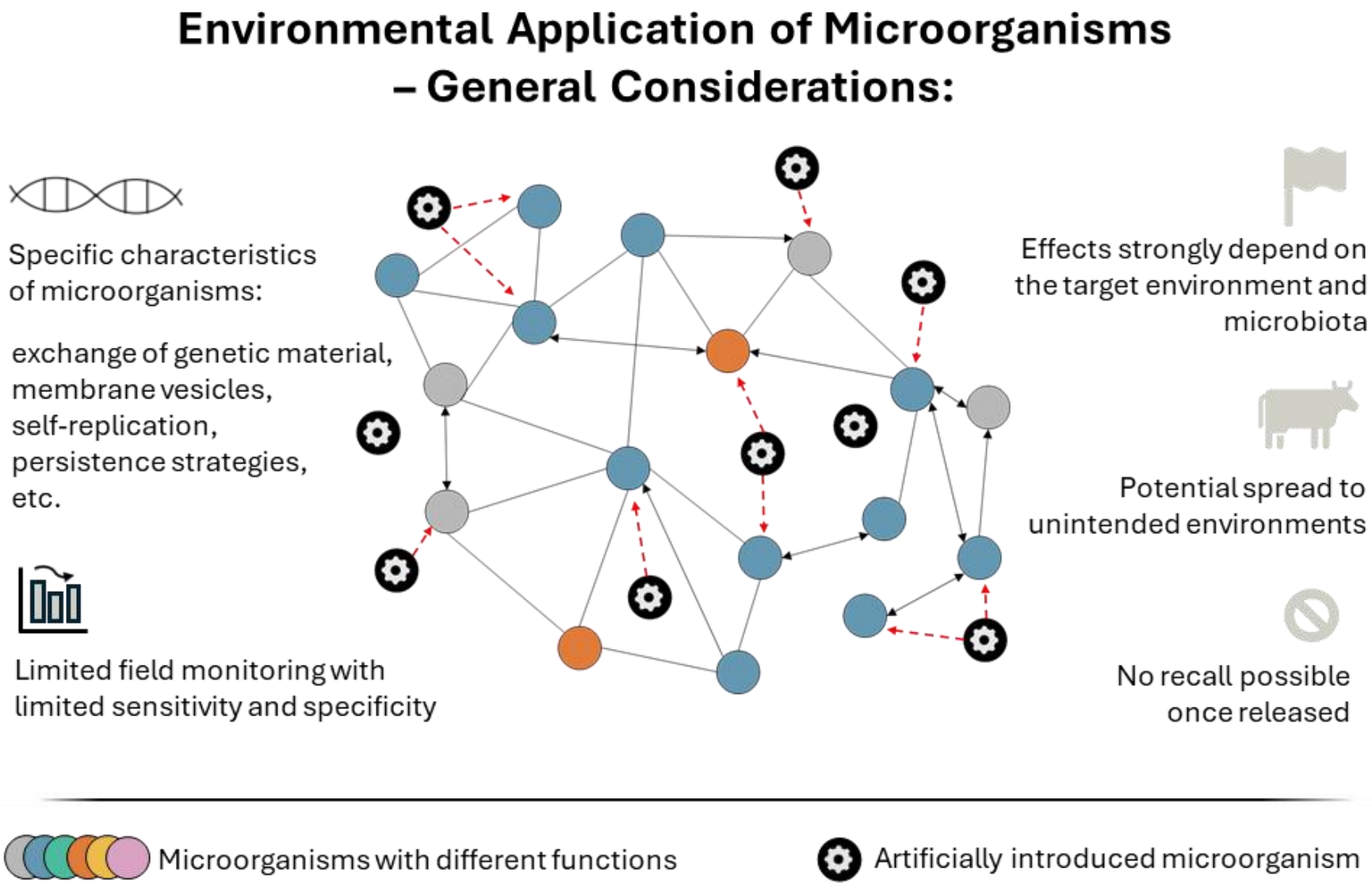
Can be produced locally

Improve soil microbial diversity and structure

Yield increase vegetables 15-40%

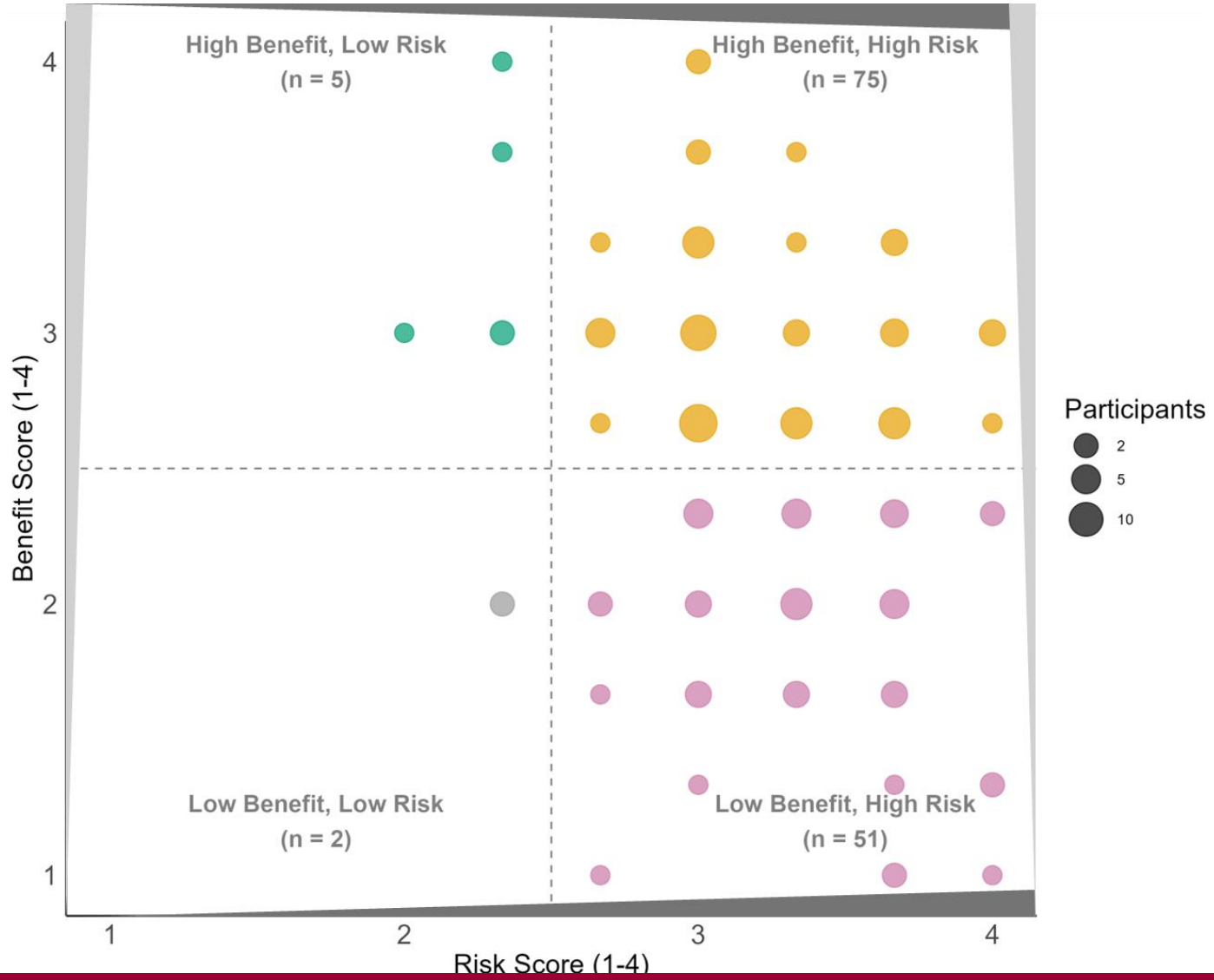
[Meta study: Fangfei Li *et al.* 2026]

8. We need a holistic assessment of benefits and risks



Once released into the environment, microorganisms may persist, mutate, disperse, exchange genes, affect organisms, and integrate into ecological networks in ways that cannot be forecasted or monitored; making their release irreversible.

9. Risk-Benefit Assessment of GMMs showed high risk

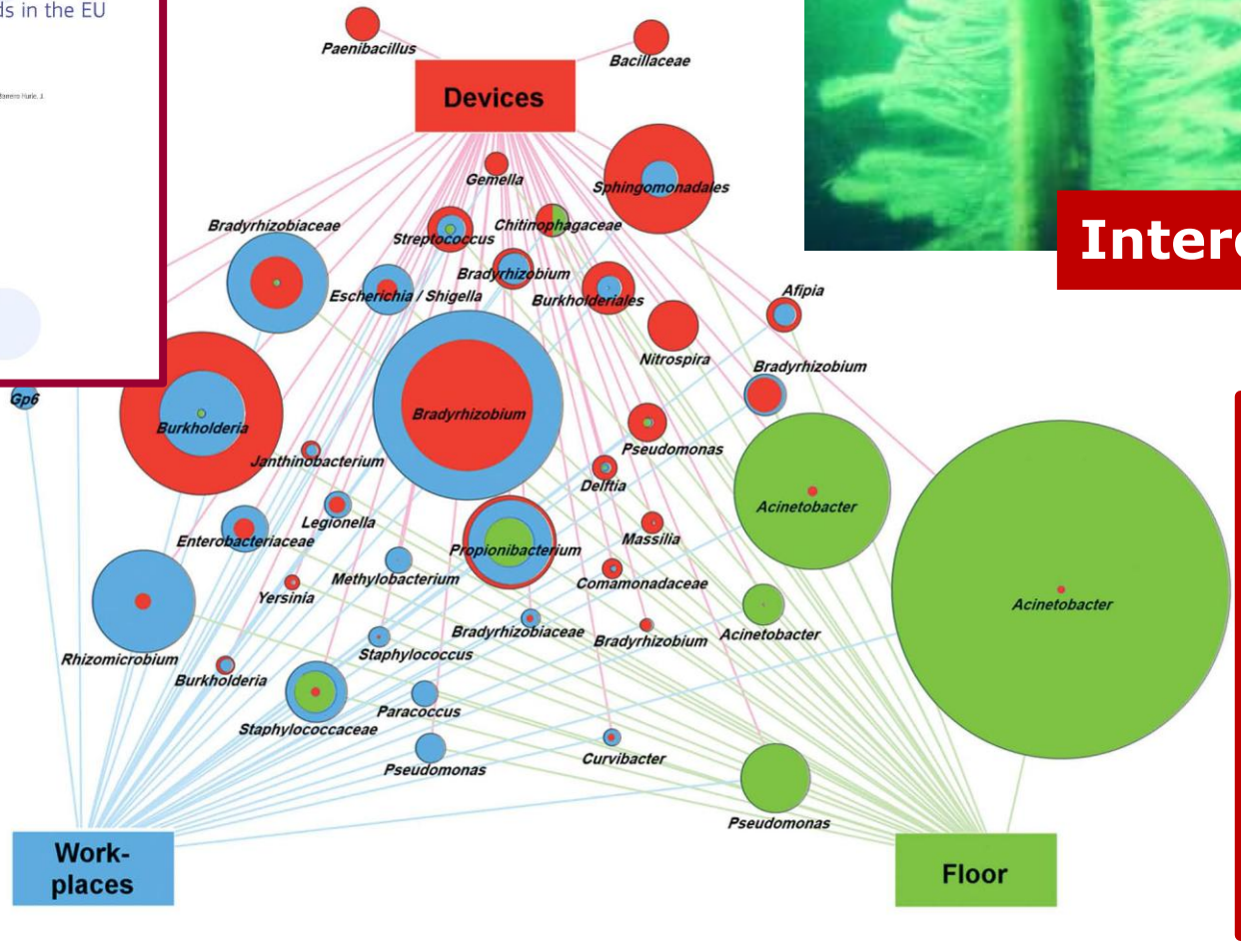


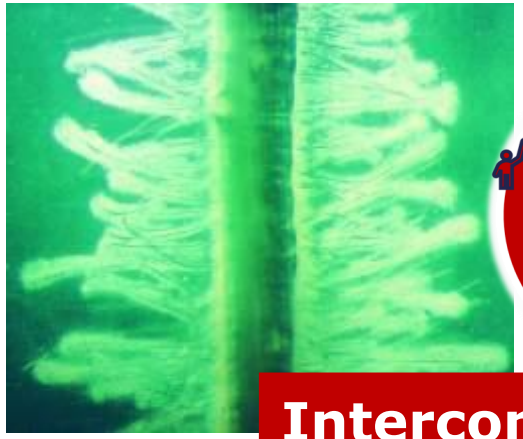
Here we asked 200 microbiome and environmental science professionals (universities, research center, industry)

- **While 60% of the participants acknowledged potential benefits, 94% expressed high concerns about ecological risks and uncertainties**
- **the complexity of microbial communities and potential unintended consequences warrant precaution**

Whether the potential release of GMMs is fundamentally riskier than that of unmodified inoculants remains a subject of active debate and defies generalization.

10. Example GMMs - need for holistic assessment

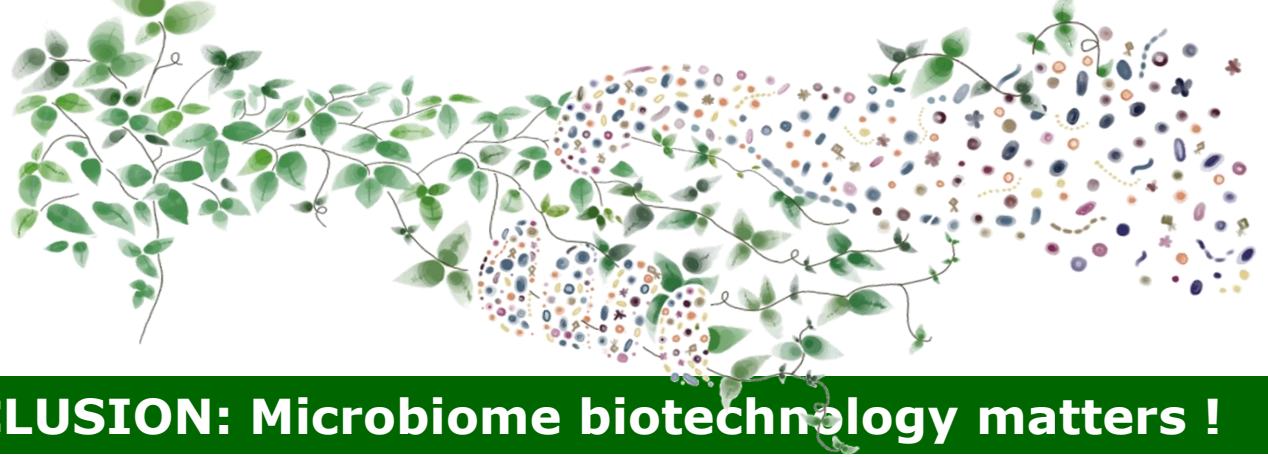




Interconnected microbiomes

- The **One Health** aspect is completely missing
- Nitrogen-fixing bacteria provide the basis of **health-care associated biofilms**
- ***Bradyrhizobium, Rhizobium*** and ***Klebsiella*** are opportuntistic pathogens that can cause **severe hospital-accquired infections** and death
- **EU: 8 million cases, 90.000 death per year**

[Berg et al. 2005; Oberauner *et al.* Sci Rep 2013 Mahnert *et al*., Nat Communication 2020]



CONCLUSION: Microbiome biotechnology matters !

1. Microbiome research is developing rapidly and is radically changing our existing understanding; examples include the enormous loss of microbial biodiversity, which goes hand in hand with the rise in chronic diseases and antimicrobial resistance.
2. It is important to take action here, as One, planetary and public health is already severely affected.
3. The acceleration of biotechnological development and interventions is a suitable means to this end.
4. Neither the current nor the proposed regulation reflects the current state of scientific knowledge.
5. Any product development based on microorganisms and microbiomes should be assessed on a case-by-case basis. Currently, it would be difficult to monitor the effect of GMMs.