EXPLORING THE DIVERSITY OF HOLOBIONTS AS A KEY IN CONNECTING ANIMALS, PLANTS AND THEIR ENVIRONMENT

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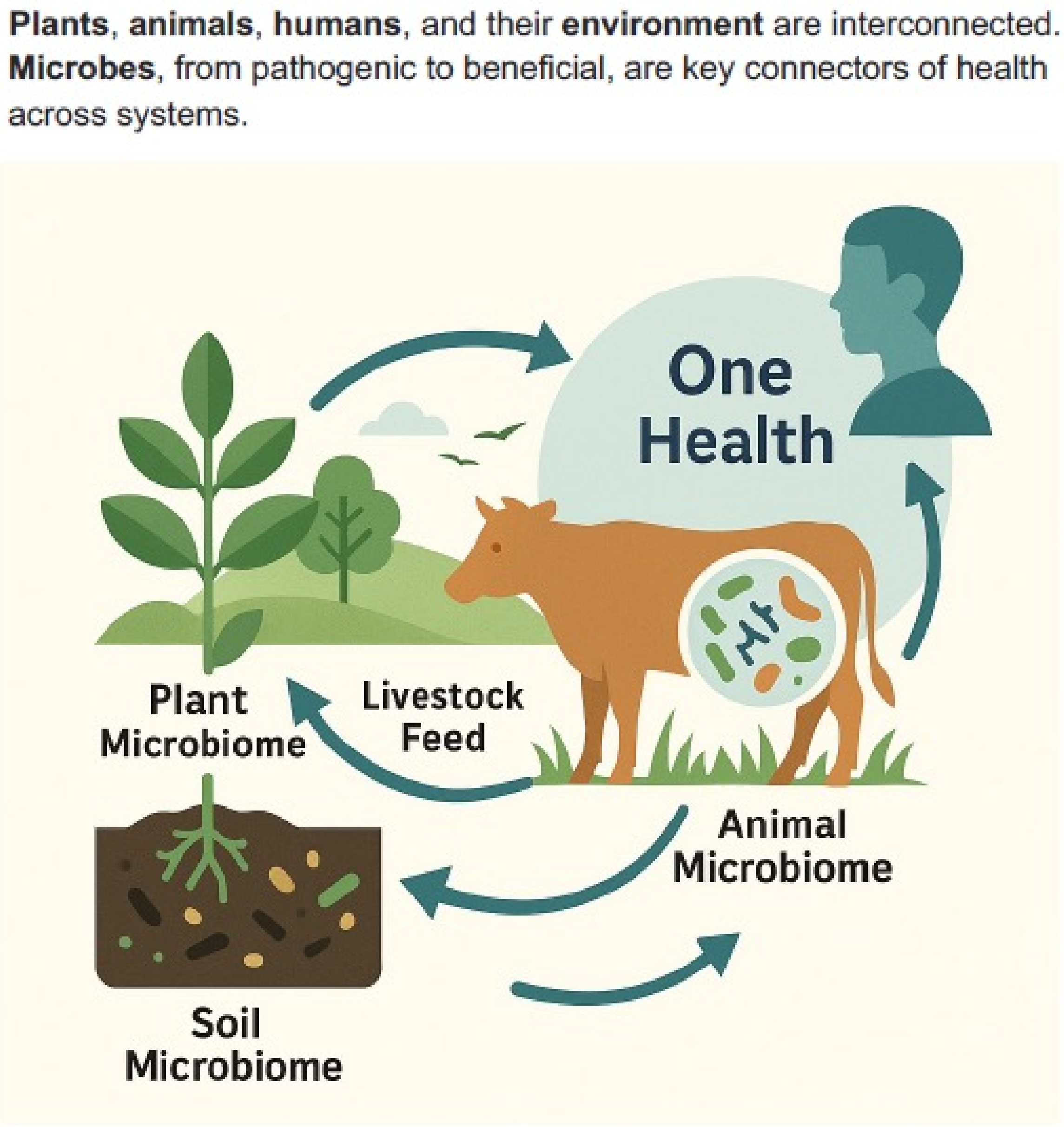
ONE HEALTH: CONNECTING ECOSYSTEMS

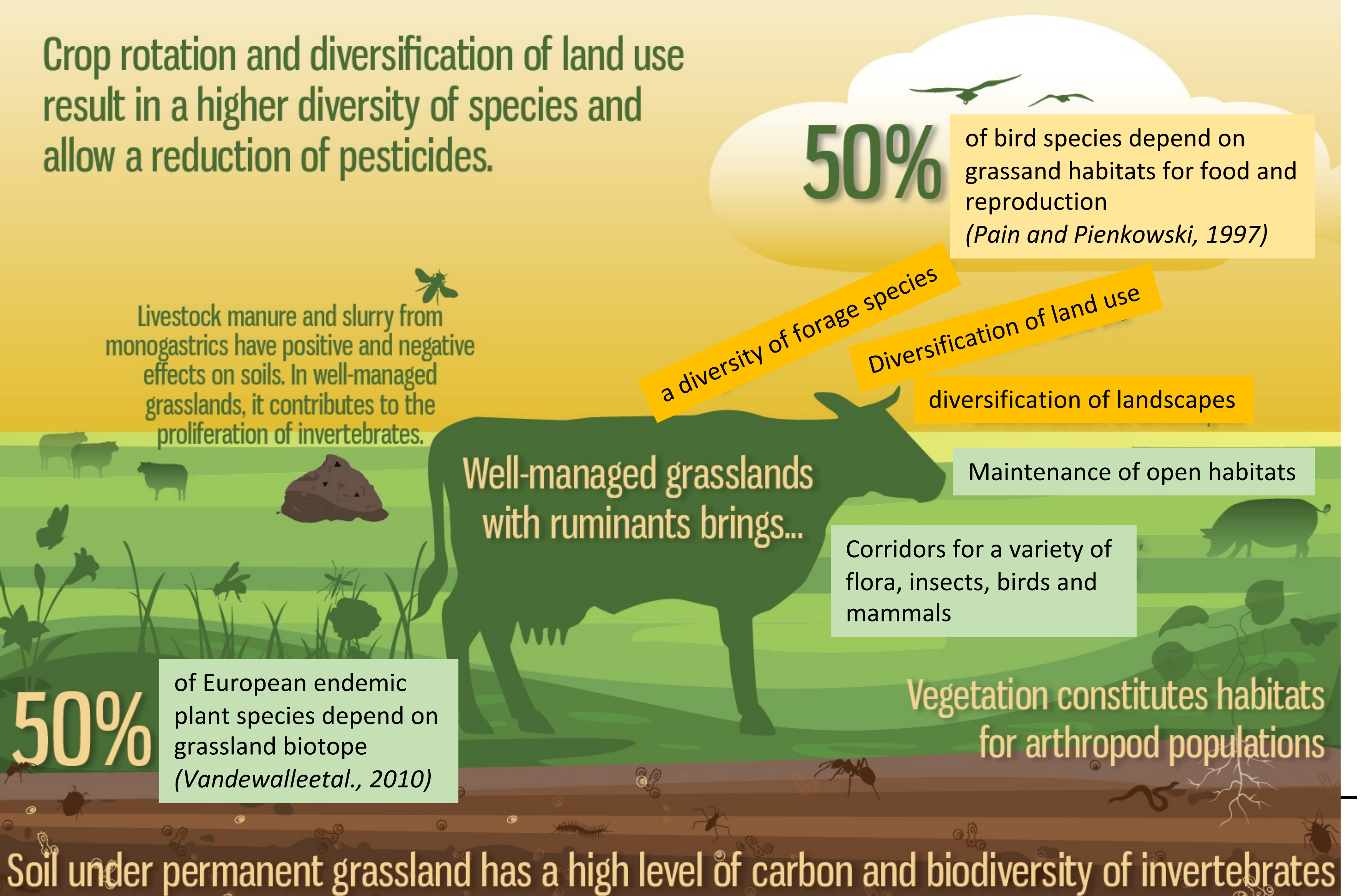


Plants, **animals**, **humans**, and their **environment** are interconnected. **Microbes**, from pathogenic to beneficial, are key connectors of health across systems.

Animal Microbiomes Working Group of the Phytobiomes Alliance - focus areas:

- Characterize the biodiversity and understand the interconnectedness of plants, animals, soil, microbiomes and their environment from a One Health perspective
- Harness microbiomes to optimize the sustainability of livestock systems
- Determine the impact of microbiomes on animal resilience and health

LIVESTOCK: WHAT DO THEY HAVE TO OFFER TO BIODIVERSITY AND HEALTHY SOILS ?



Crop rotation and diversification of land use result in a higher diversity of species and allow a reduction of pesticides.

50% of bird species depend on grassand habitats for food and reproduction
(Pain and Pienkowski, 1997)

Livestock manure and slurry from monogastrics have positive and negative effects on soils. In well-managed grasslands, it contributes to the proliferation of invertebrates.

Well-managed grasslands with ruminants brings...

- a diversity of forage species
- Diversification of land use
- diversification of landscapes
- Maintenance of open habitats
- Corridors for a variety of flora, insects, birds and mammals

Vegetation constitutes habitats for arthropod populations

50% of European endemic plant species depend on grassland biotope
(Vandewalleetal., 2010)

Soil under permanent grassland has a high level of carbon and biodiversity of invertebrates

Examples:

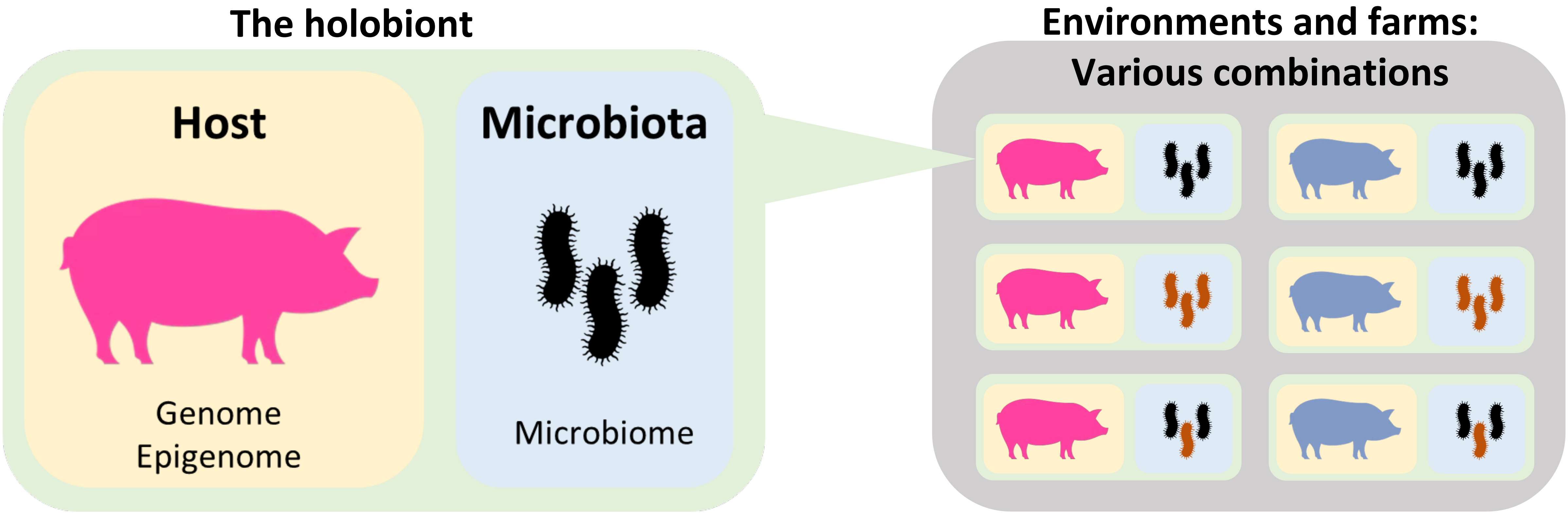
- Impact of reintroducing grassland in cropping systems and diversifying crop rotations
- Well-managed manure production as a natural soil fertilizer

Animal Task Force

https://animaltaskforce.eu/topics/biodiversity-and-soil-health/

THE HOLOBIONT – HOST AND MICROBIOME AS ONE

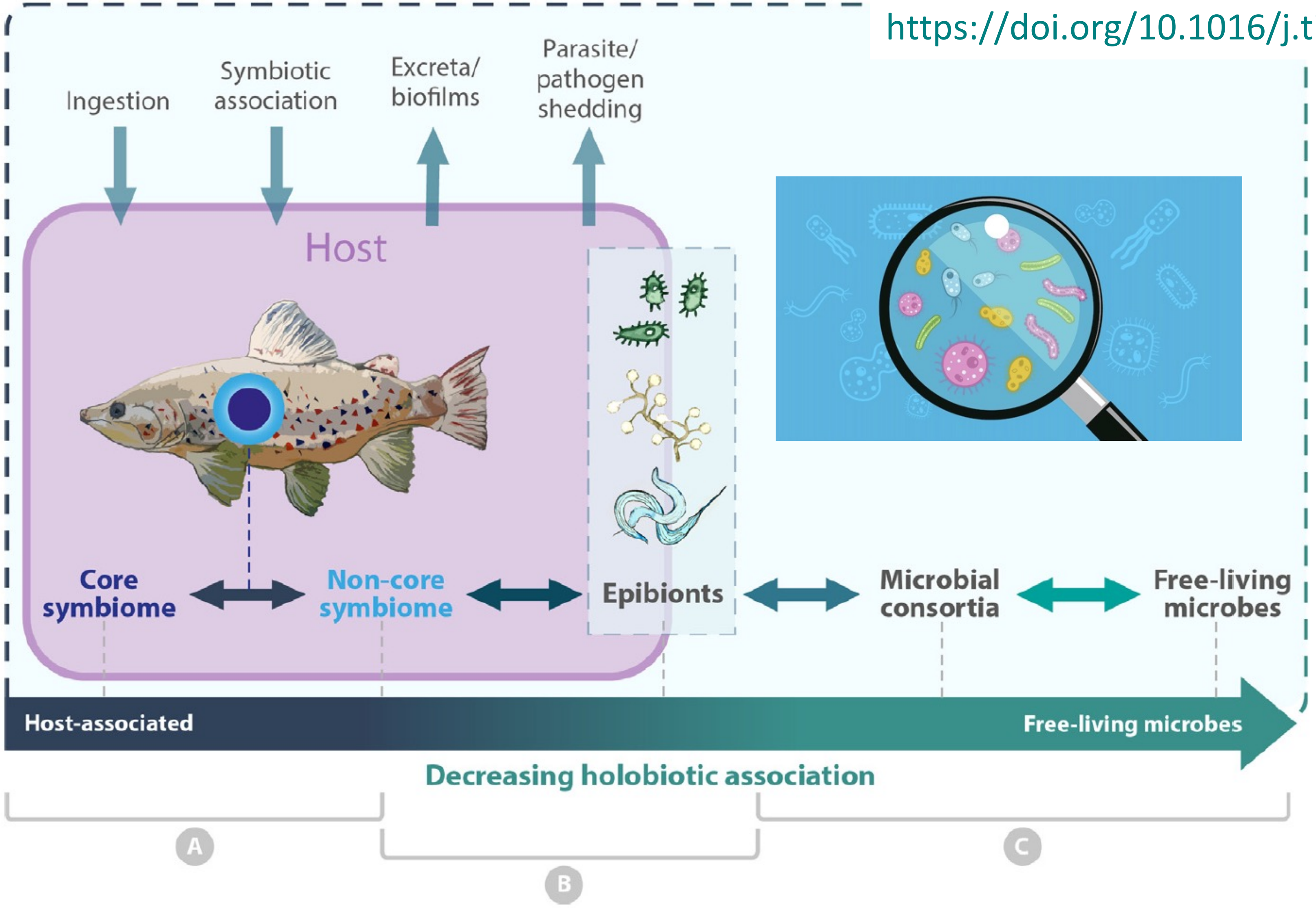
Considering the host and its associated microbiome as a single biological unit – **the holobiont** – reveals the full scope of genetic and functional diversity of a herd member.



Host diversity + microbiota diversity = more adaptable flocks

THE HOLOBIOTIC CONTINUUM

Cook et al., Trends in Microbiology, 2025
https://doi.org/10.1016/j.tim.2024.07.003

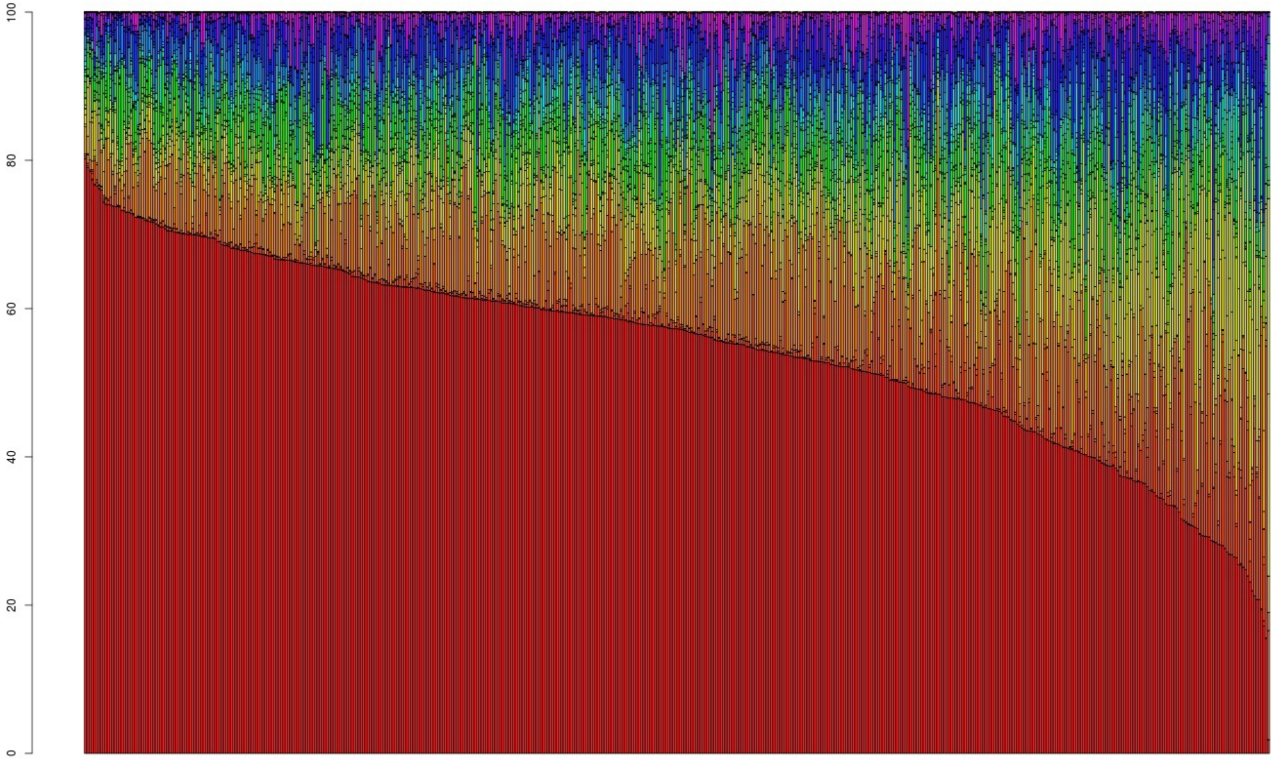


Microbes, from pathogenic to beneficial, are key connectors across systems.

Associations between hosts and their microbiomes exist along a continuum, ranging from core symbionts (e.g., gut microbiota, obligate parasites) to free-living microbes that associate only incidentally.

INDIVIDUAL VARIABILITY OF THE GUT MICROBIOME COMPOSITION

Faecal microbiota - 518 60-day-old Large White piglets – 16S



Dominant genera: *Prevotella*

Ramayo-Caldas et al., 2016, ISME J

THE MICROBIAL COMMUNITIES ARE NOT RANDOMLY ASSEMBLED

Assembly into enterotypes

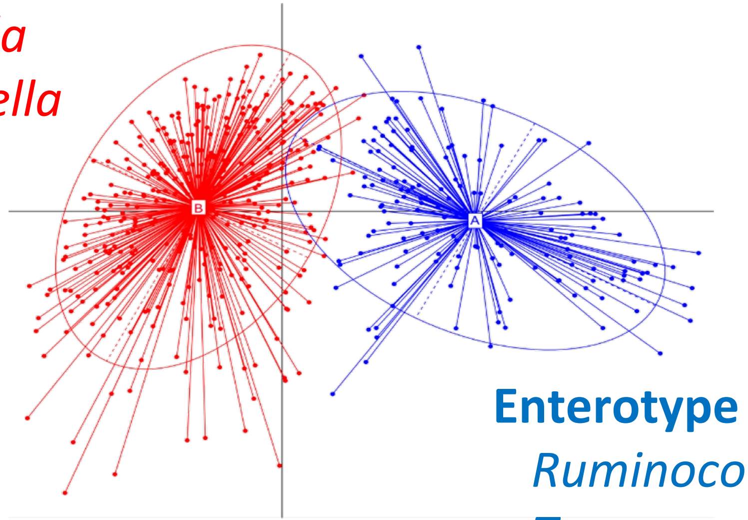
Enterotypes reflect microbial networks (ecosystems)

Enterotype PM

Prevotella

Mitsuokella

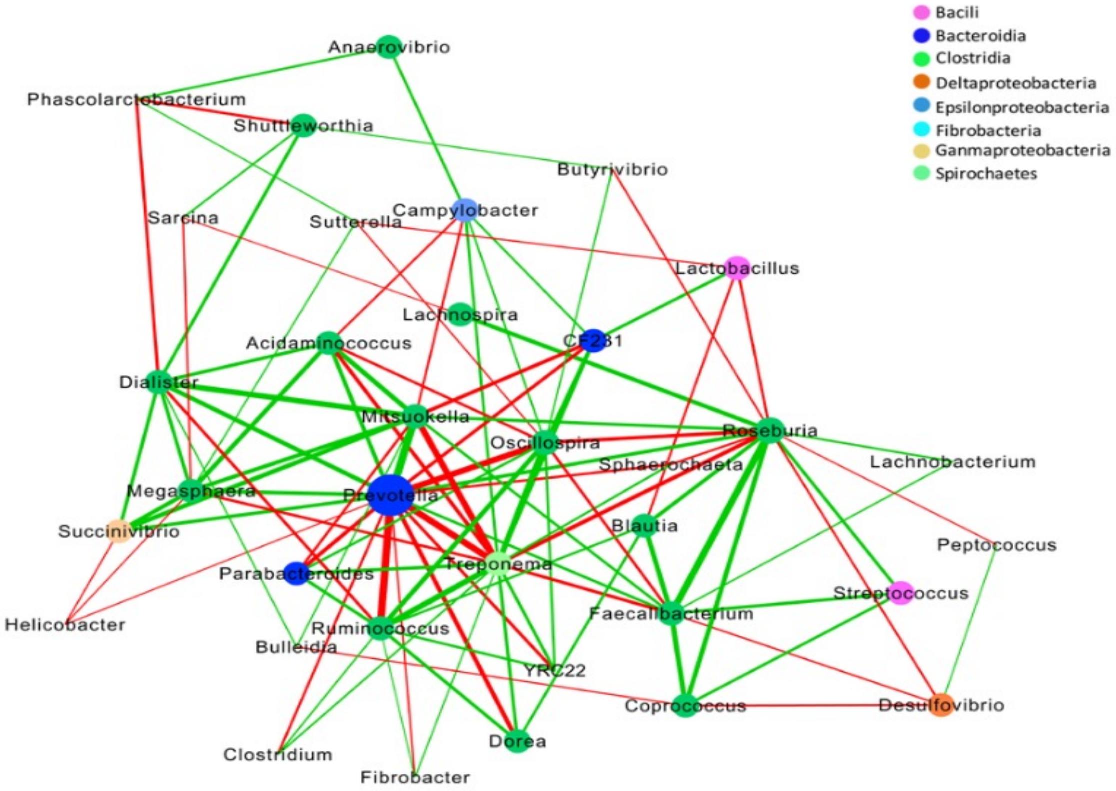
60-day-old LW pigs



Enterotype RT

Ruminococcus

Treponema



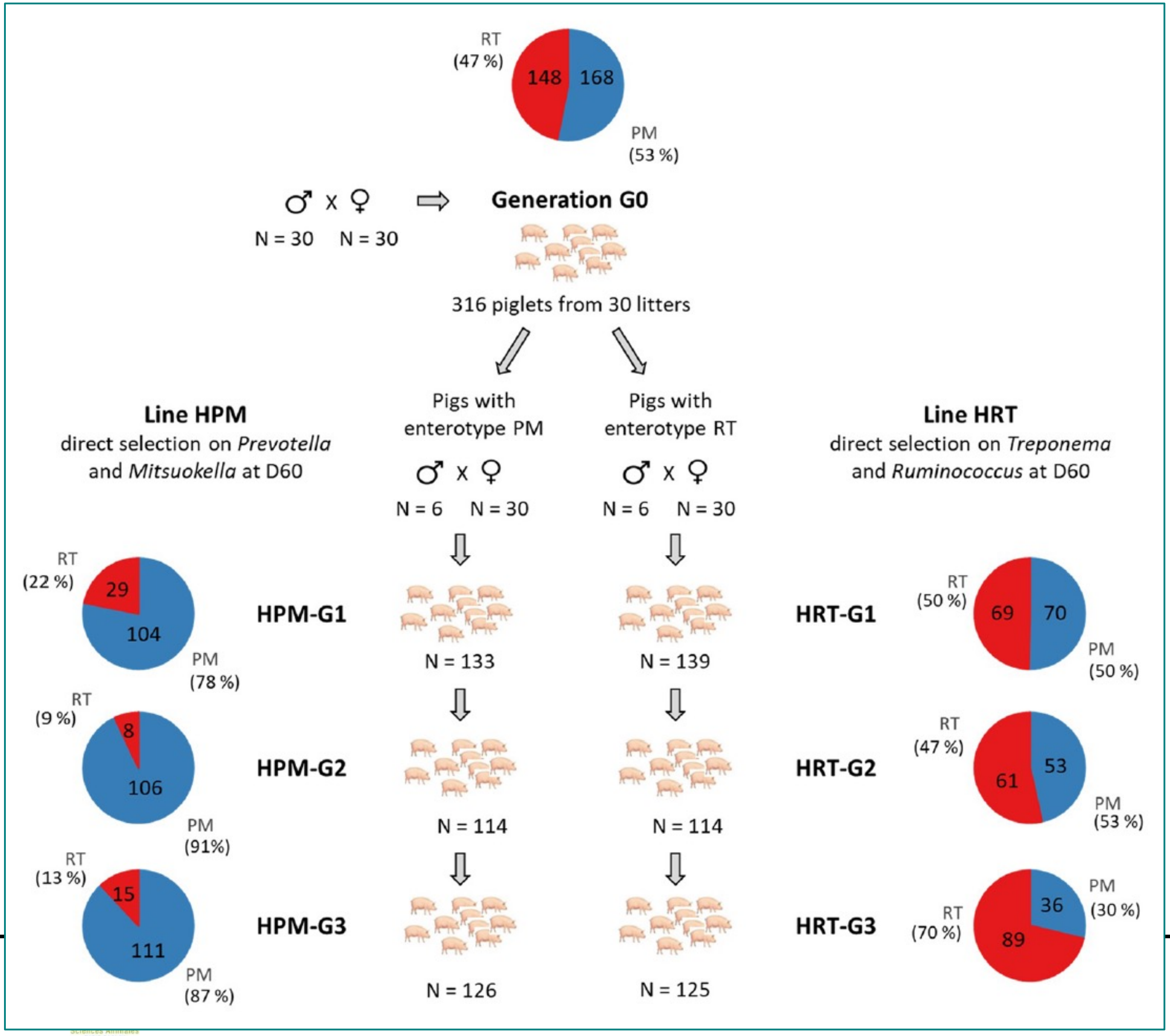
Mach et al., Environ. Microbiol. Rep., 2015
Ramayo-Caldas et al., ISME Journal, 2016
Larzul et al., Microbiome, 2024

THE HOST GENETICS HAS A ROLE IN SHAPING THE GUT MICROBIOME

Heritability

Selection

Larzul et al., Microbiome, 2024



Generation G0

316 piglets from 30 litters

Line HPM
direct selection on *Prevotella* and *Mitsuokella* at D60

Pigs with enterotype PM
♂ x ♀
N = 6 N = 30

Pigs with enterotype RT
♂ x ♀
N = 6 N = 30

Line HRT
direct selection on *Treponema* and *Ruminococcus* at D60

HPM-G1

N = 133
N = 139
HRT-G1

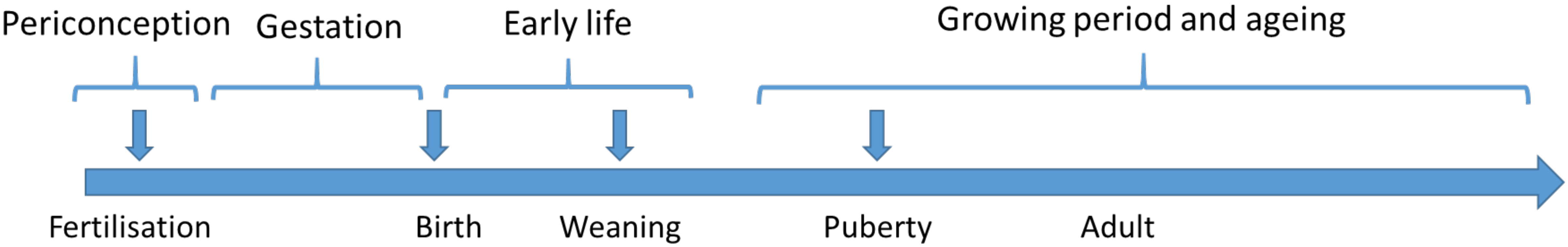
HPM-G2

N = 114
N = 114
HRT-G2

HPM-G3

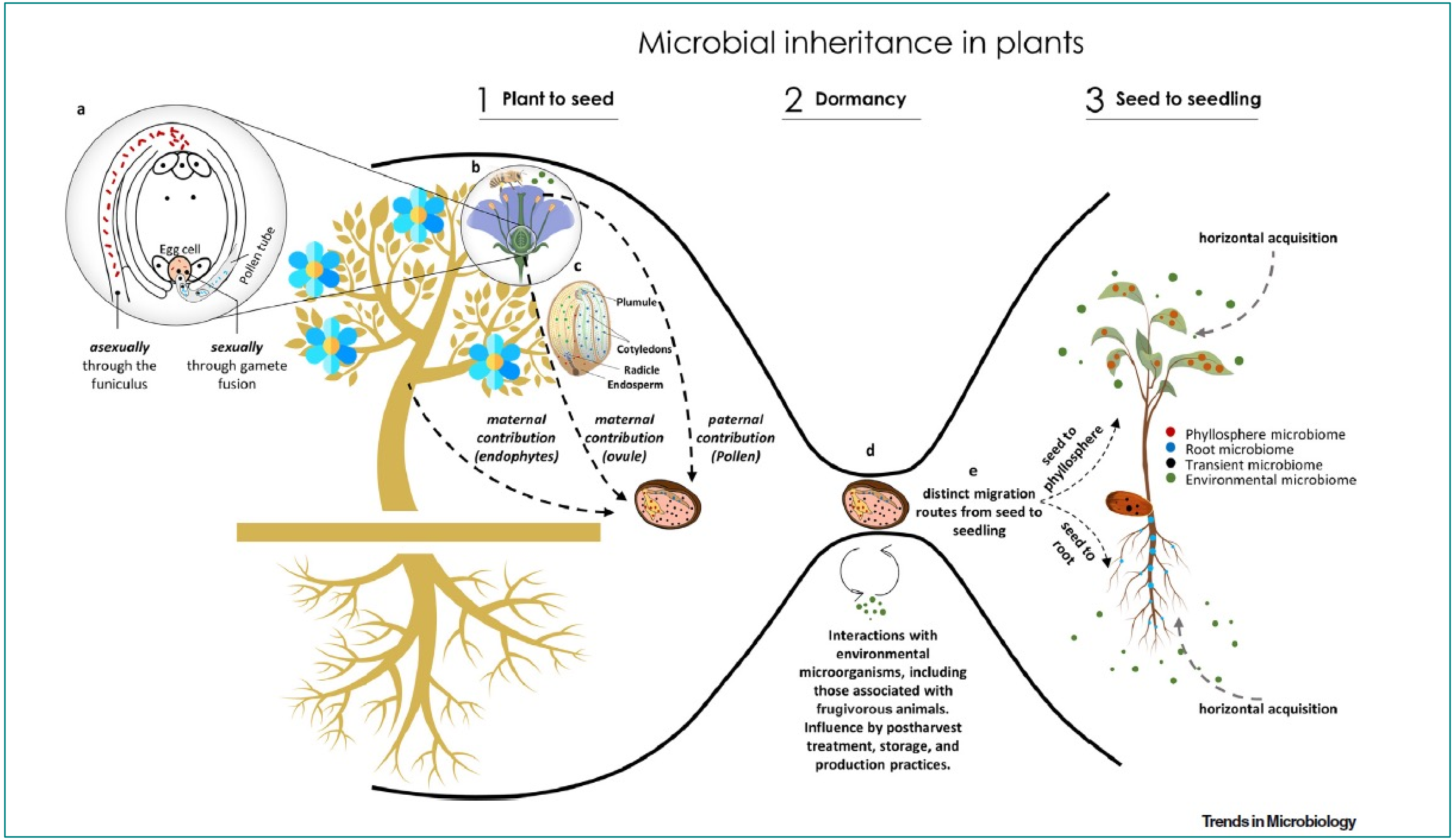
N = 126
N = 125
HRT-G3

HOLOBIONT DIVERSITY – A NEW PARADIGM FOR GENETIC RESOURCES



- The microbiome of the digestive tract provides a flexible, dynamic reservoir of genetic diversity throughout the animal’s lifetime.
- Studies suggest that host and microbiome genomes are non-randomly paired, highlighting the need to study them as a single unit.

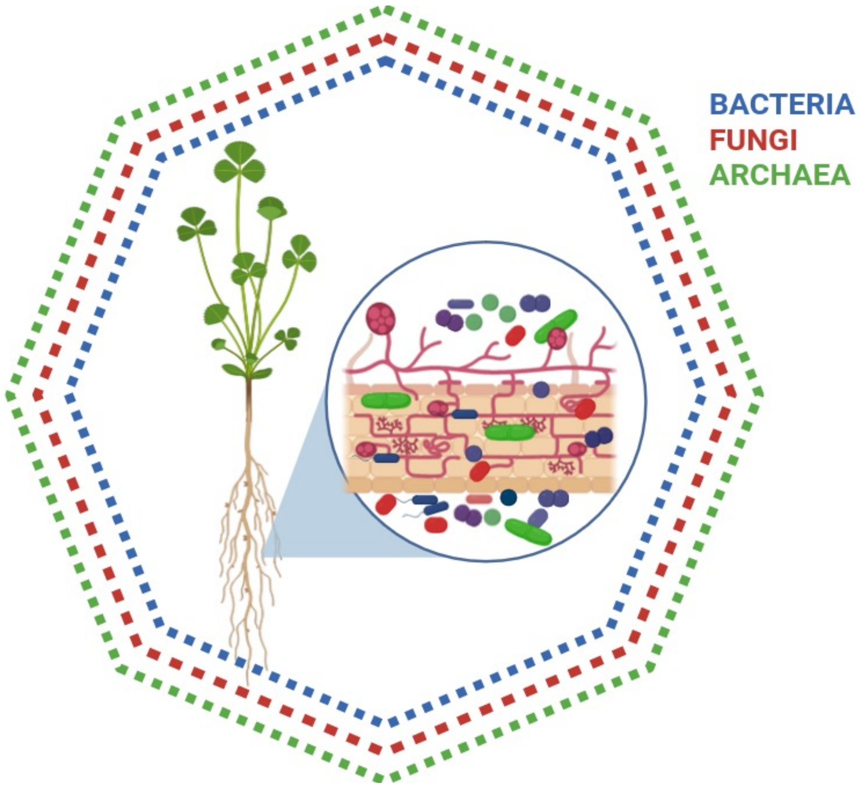
MICROBIAL INHERITANCE IN PLANTS



Abdelfattah et al., 2023, Trends Microbiology

MICROORGANISMS TRANSMISSION ACROSS GENERATIONS IN PLANTS

- Avoids the cost of searching for symbionts
- Ensures habitat quality
- Constitutes a continuity of partnership



- Different inheritance processes:
  - Vertical through seeds
  - Pseudo-vertical (seeds germinating nearby the mother plant)
  - Vertical transmission from mother to daughter ramets in clonal plants

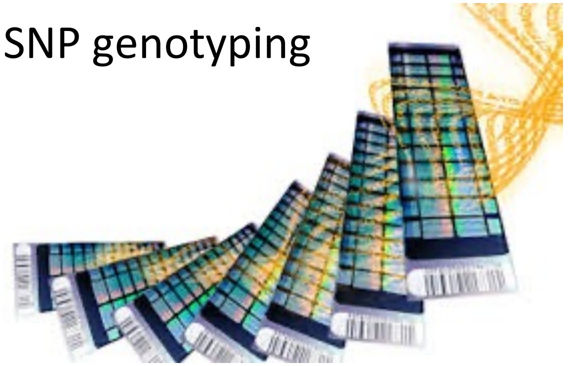
Source: P. Vandenkoornhuyse

TOWARDS AN AGRICULTURE OF HOLOBIONTS - KEY QUESTIONS

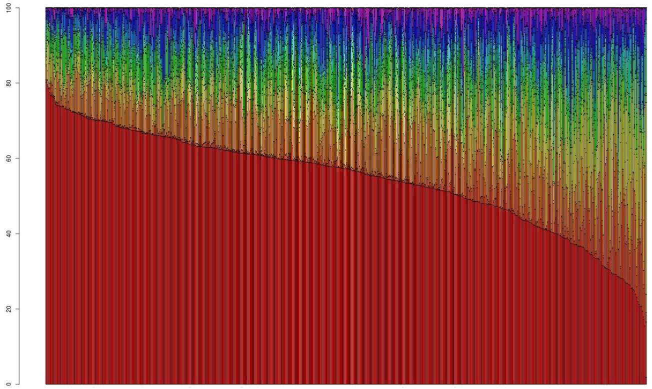
- **How can we define genetic resources at the holobiont level?**
  - How do we define and assess holobiont genetic diversity?
  - Both levels of diversity jointly or their combination independently?

➢ Host and microbiome genomes are non-randomly paired, highlighting the need to study them as a single unit.

SNP genotyping



OTU classification

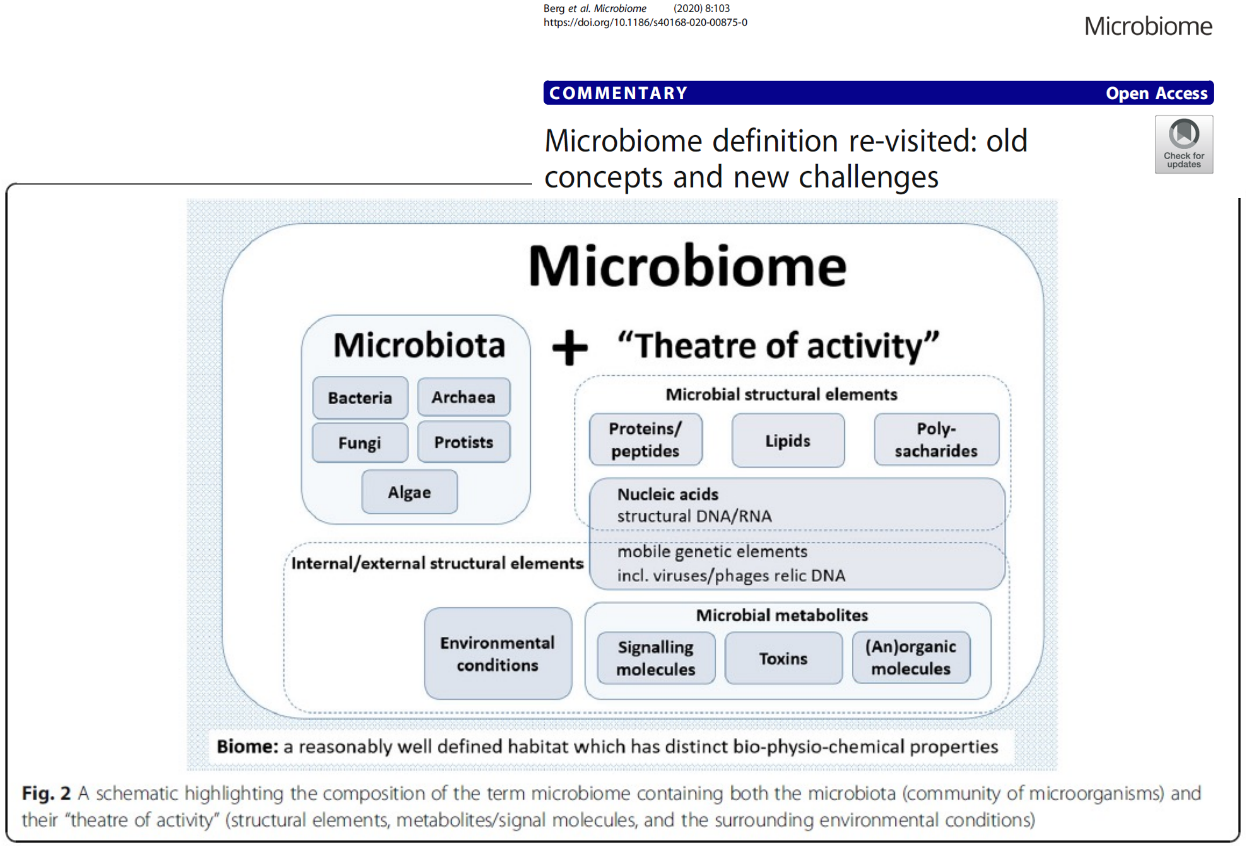


TOWARDS AN AGRICULTURE OF HOLOBIONTS - KEY QUESTIONS

- **How can we assess, secure and store holobiont diversity?**
  - In specialized biological resources centers (microbiota and hosts) or in the same?
  - What kind of metadata is needed and how to manage them (single or connected databases) ?

www.agrobrc-rare.org

www.crb-anim.fr/eng



Berg *et al. Microbiome* (2020) 8:103
https://doi.org/10.1186/s40168-020-00875-0

Microbiome

COMMENTARY **Open Access**

Microbiome definition re-visited: old concepts and new challenges

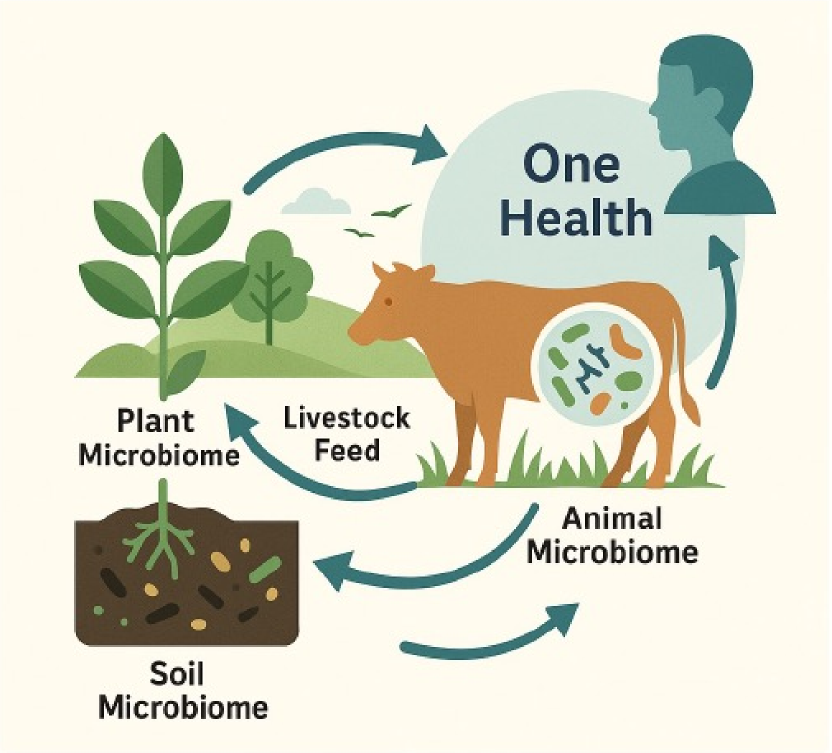
Fig. 2 A schematic highlighting the composition of the term microbiome containing both the microbiota (community of microorganisms) and their "theatre of activity" (structural elements, metabolites/signal molecules, and the surrounding environmental conditions)

TOWARDS AN AGRICULTURE OF HOLOBIONTS - KEY QUESTIONS

- **How can the knowledge on holobiont diversity transform agriculture and farming?**
  - How to evaluate the potential of holobiont genetic resources?
  - Can we predict the output of non-observed combinations on adaptation and resilience?

➢ Phenotyping
➢ Breeding and co-breeding strategies
➢ Modulation of microbiomes based on knowledge of « adoption » capacity of the host partly influenced by its genetics (all consortia may not work similarly depending on the host genome)

Plants, **animals**, **humans**, and their **environment** are interconnected. **Microbes**, from pathogenic to beneficial, are key connectors of health across systems.



THANK YOU

Animal Microbiomes Working Group of the Phytobiomes Alliance

https://phytobiomesalliance.org/people-categories/animal-microbiomes-working-group/