Unearthing the Ecological Roots of Microbiome Studies

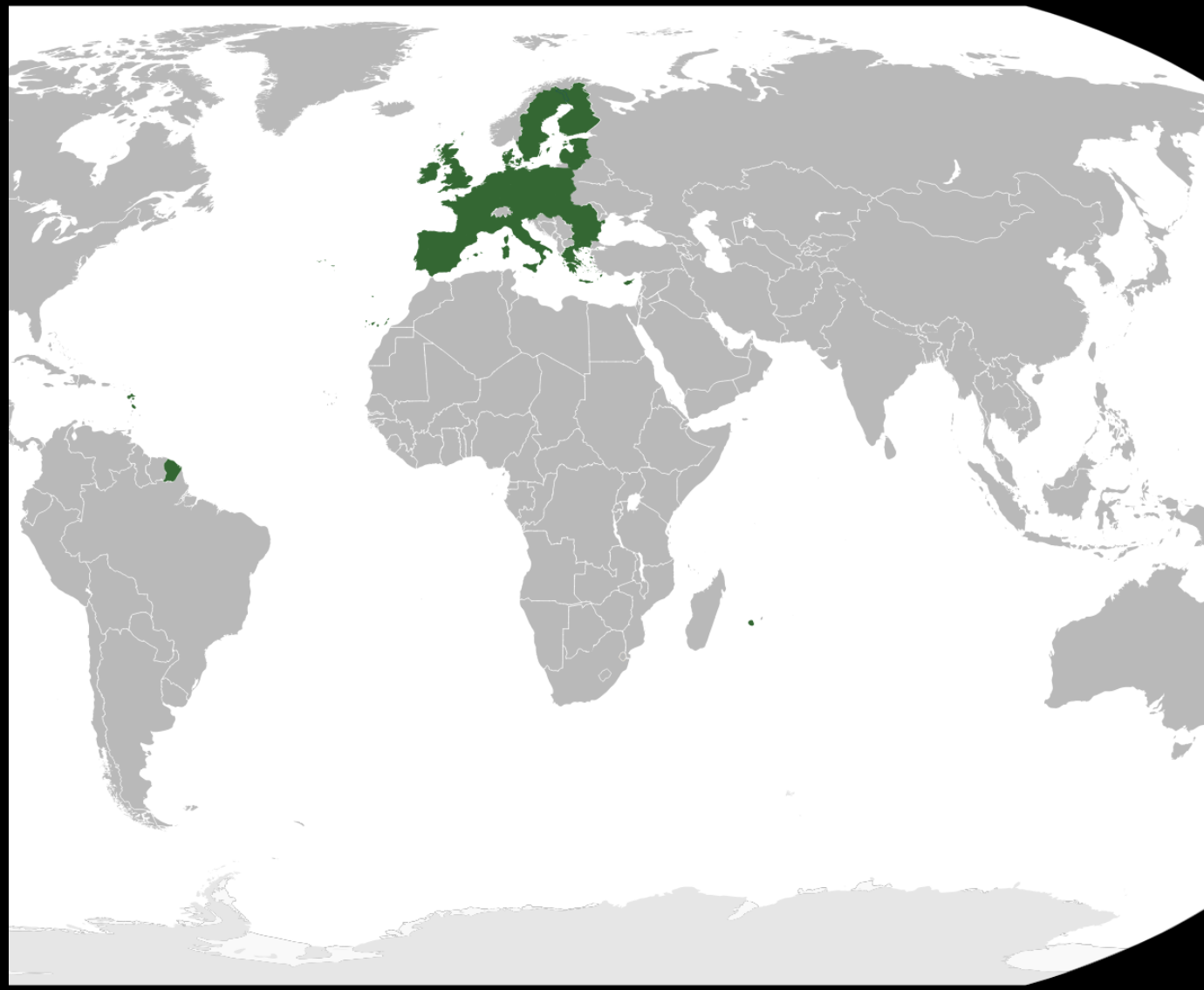
EPSA25

ALINE POTIRON

Utrecht University

Positionality Statement

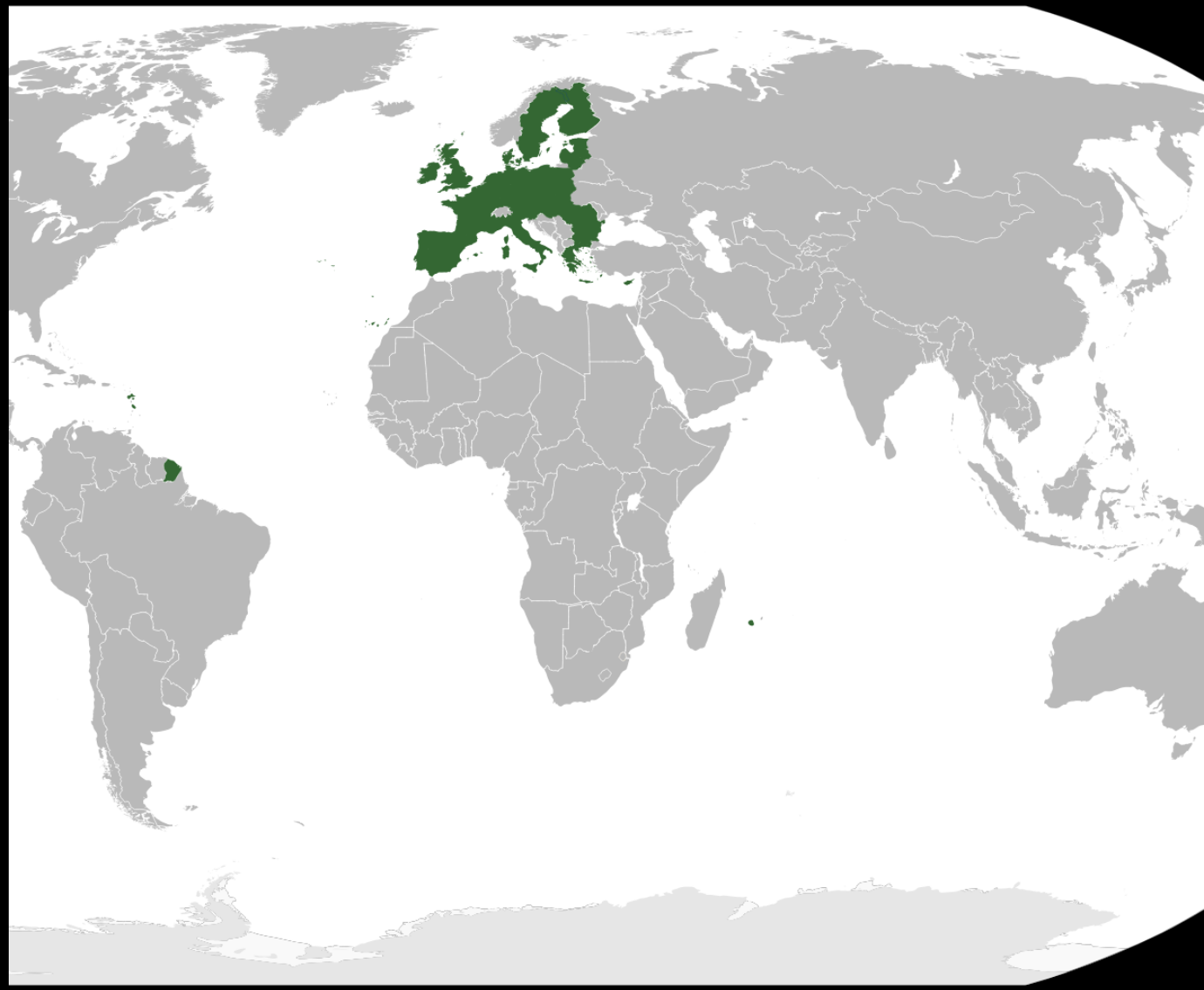
- White European woman who spent most of her professional life in Europe.



Positionality Statement

- White European woman who spent most of her professional life in Europe.

- **Biases:** The "history" of microbiology I will present is European/Western-centered.



Context – Microbiome

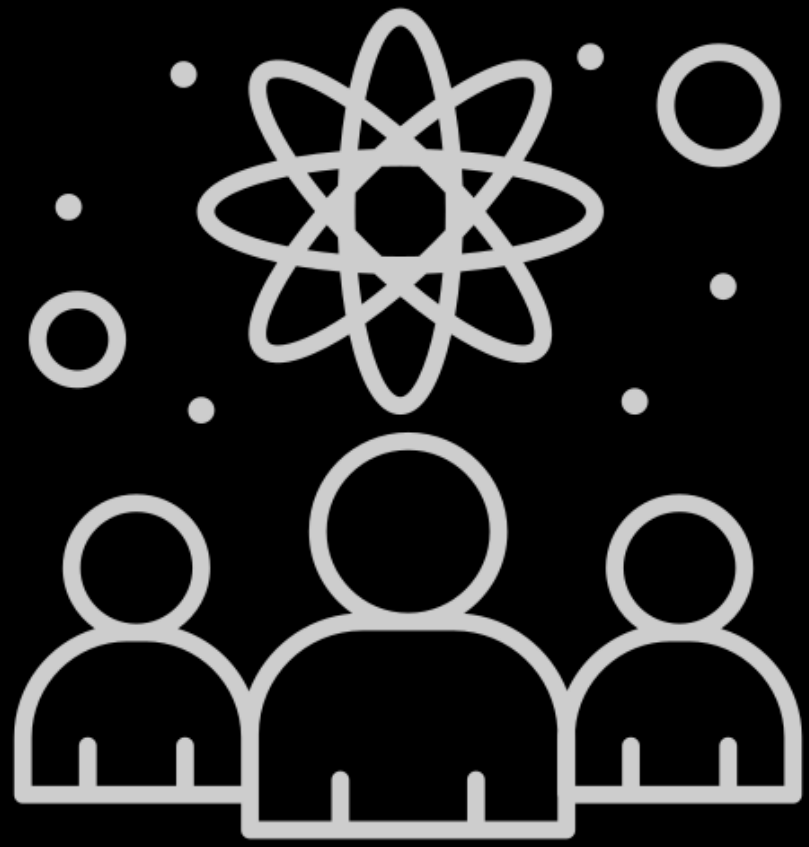
- Complexity of the microbiome

Context – Microbiome

- Complexity of the microbiome
- Call for more “ecology”
  - In establishing and evaluating causal claims (Vonaesch et al., 2018; Klassen, 2020; Schneider, 2020, 2023)
  - In ontological and methodological assumptions (Suárez, 2024; Schneider, 2025)

Context – Integration

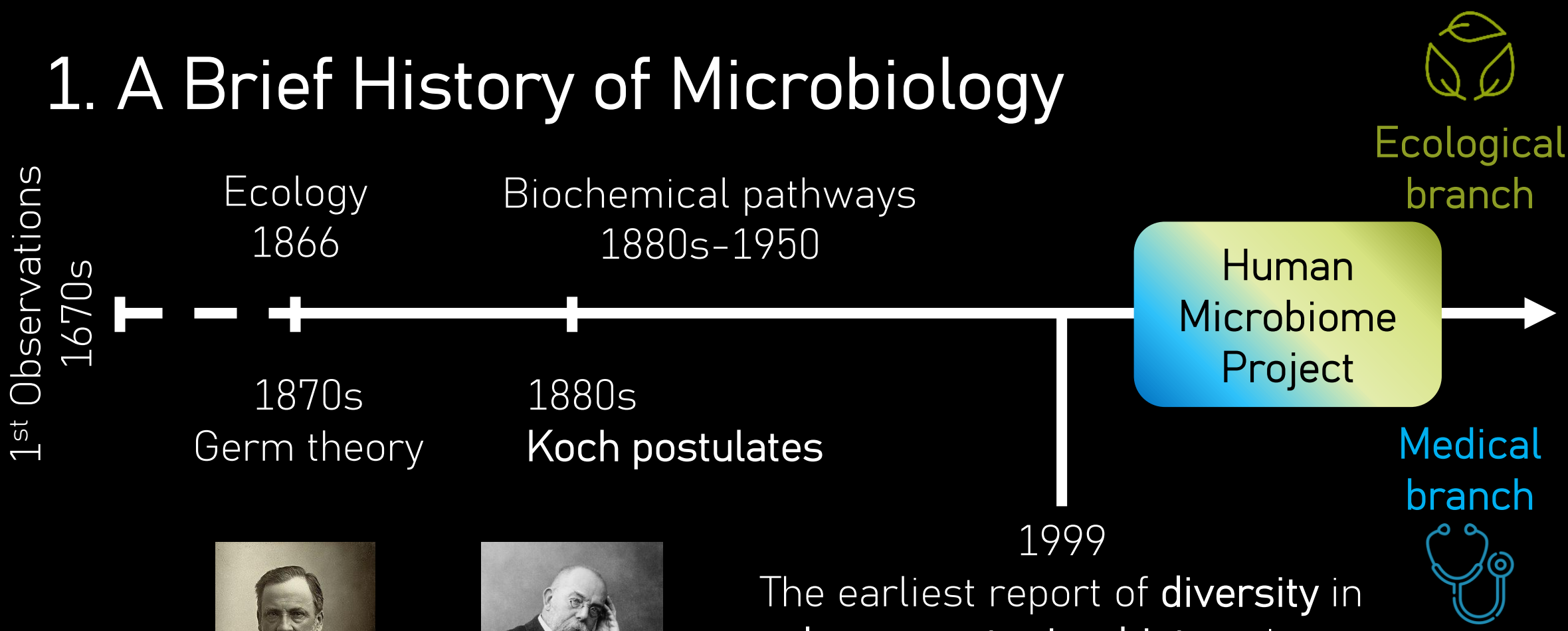
- What is it? Link with unification
- Focus on **explanation** (e.g., Kitcher, 1981; Mitchell, 2004; Brigandt, 2010)
- And also, to some extent, on **methodologies and data** (e.g., O'Malley and Soyer, 2012; Leonelli and Tempini, 2020)

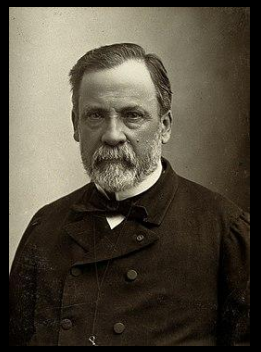


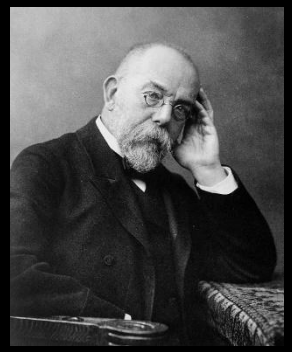
My argument

1. The history of microbiology is made up of **different paths**
2. These paths are characterized by different and quite distinct **ontological, methodological, and epistemic commitments**
3. These different **commitments** are still present in today's human microbiome studies
4. **Conclusion:** Thus, we may need more than the already discussed type of integration, and turn toward something akin to "weaving"

1. A Brief History of Microbiology

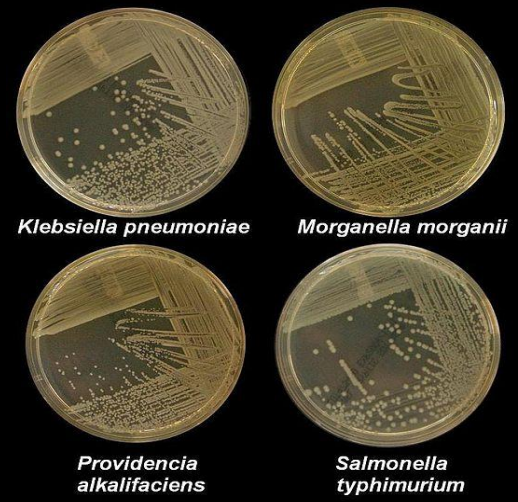


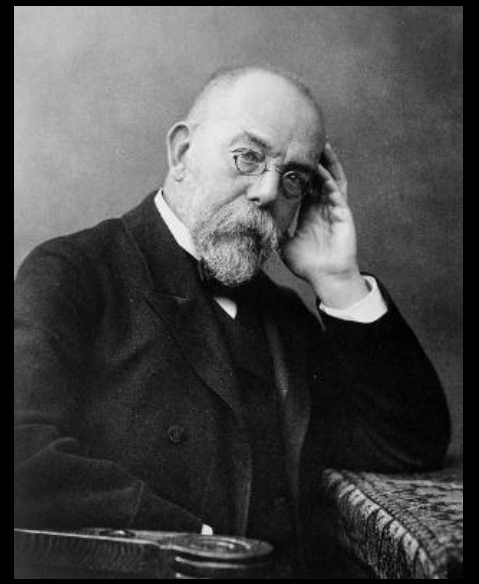




1. Medical Microbiology

- A methodological **reductionism** (e.g., pure culture)
- The assumption of **a simple and homogeneous causal architecture** (e.g., the germ theory of diseases)
- A clear separation between different causal elements (e.g., the host and the microorganisms)
- **Aim**: Prove the germ theory of disease by isolating a single agent (microorganism)





1. Microbial Ecology

- An “**environmental**” **methodology (e.g.,** elective method)
- More **complex causal architecture**: **actual functions** (and not only predicted functions), **flow** of material or energy, microorganismal **interactions**, **dynamic and context-dependent** processes
- **Aim**: Understand the dynamic of the natural environments (esp. soil and water)

2. Different Commitments

	Koch – Medical Microbiology	Winogradsky – Microbial Ecology	References
Methodology	Pure culture	Elective method Winogradsky column	Winogradsky, 1953; Ackert, 2013; Schneider, 2025
Ontological aspects	Microbial individuality in terms of **autonomy and innate traits** Two systems (host vs. microbiome)	Microbial individuality in terms of **interdependency and physiological processes** One cycle (of life)	Penn and Dworkin, 1976; Schneider, 2025
Explanations	Causal	Causal? General patterns	Carter, 2003; Ross and Woodward, 2016
Aim	Prove the germ theory of diseases	Understand the dynamic of the natural environments	Winogradsky, 1953; Carter, 2003

3. Contemporary Microbiome Studies

MEDICAL MICROBIOLOGY

- **Methodology:** mice experiments, gene expressions, -omics, immunology experiments.

3. Contemporary Microbiome Studies

MEDICAL MICROBIOLOGY

- **Methodology:** mice experiments, gene expressions, -omics, immunology experiments.
- Conceptually tries to **modify the Koch postulates**

PERSPECTIVES

INFECTIOUS DISEASE

Adapting Koch's postulates

Criteria for disease causation must take microbial interactions into account

By **Allyson L. Byrd**[1,2] *and* **Julia A. Segre**[1]

REVIEW ARTICLE

Pathogens, microbiome and the host: emergence of the ecological Koch's postulates

Pascale Vonaesch, Mark Anderson and Philippe J. Sansonetti*

Unité de Pathogénie Microbienne Moléculaire, Institut Pasteur, 28 Rue du Dr. Roux, Paris 75015, France

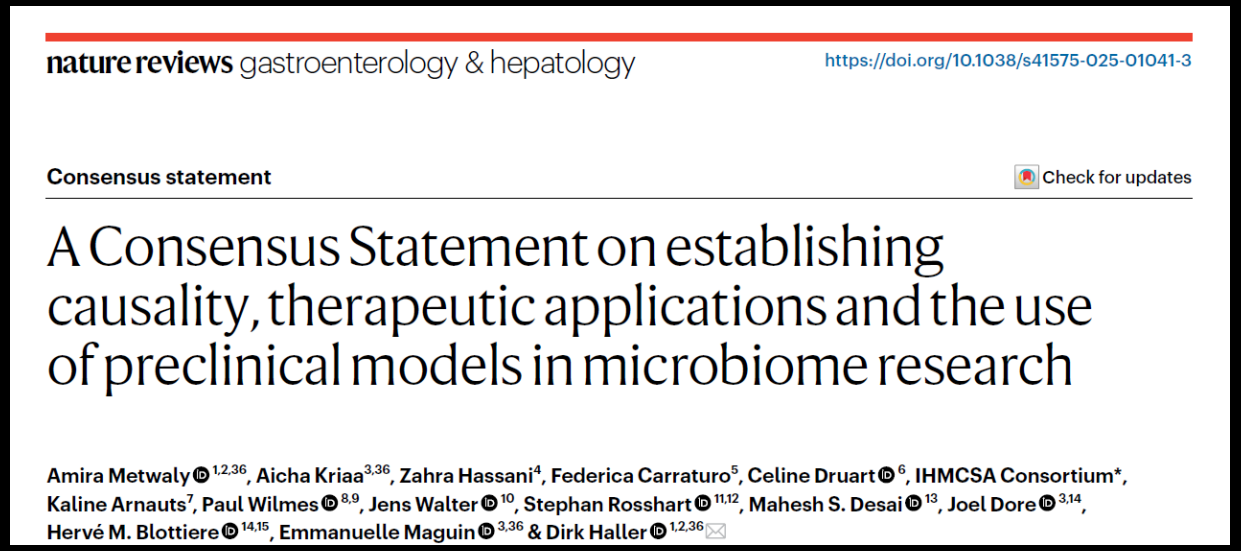
Commensal Koch's postulates: establishing causation in human microbiota research

B Anne Neville[1], Samuel C Forster[1,2,3] and Trevor D Lawley[1]

3. Contemporary Microbiome Studies

MEDICAL MICROBIOLOGY

- **Methodology:** mice experiments, gene expressions, -omics, immunology experiments.
- Conceptually tries to **modify the Koch postulates**
- **Explanations:** Causal and often (not always) **mono-causal** and **homogeneous**



nature reviews gastroenterology & hepatology
https://doi.org/10.1038/s41575-025-01041-3

Consensus statement

Check for updates

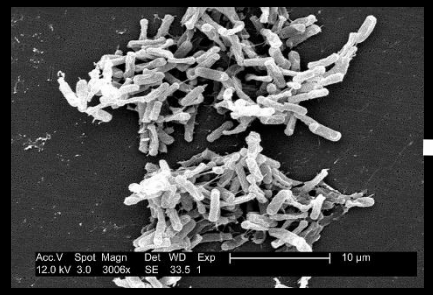
A Consensus Statement on establishing causality, therapeutic applications and the use of preclinical models in microbiome research

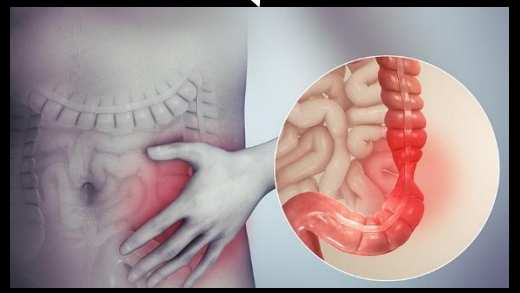
Amira Metwaly[1,2,36], Aicha Kriaa[3,36], Zahra Hassani[4], Federica Carraturo[5], Celine Druart[6], IHMCSA Consortium*, Kaline Arnauts[7], Paul Wilmes[8,9], Jens Walter[10], Stephan Rosshart[11,12], Mahesh S. Desai[13], Joel Dore[3,14], Hervé M. Blottiere[14,15], Emmanuelle Maguin[3,36] & Dirk Haller[1,2,36]

3. Contemporary Microbiome Studies

MEDICAL MICROBIOLOGY

- **Methodology:** mice experiments, gene expressions, -omics, immunology experiments.
- Conceptually tries to **modify the Koch postulates**
- **Explanations:** Causal and often (not always) **mono-causal** and **homogeneous**





3. Contemporary Microbiome Studies

MICROBIAL ECOLOGY

- Methodology: Network constructions and **analysis**, often, with few experimental data – simulations
- Conceptually, look at **the patterns of interactions,** the network, to explain the outcome of **a community**
- Explanation: Causal?

MICROBIOME

The ecology of the microbiome: Networks, competition, and stability

Katharine Z. Coyte,[1,2*] Jonas Schluter,[1,2,3*†] Kevin R. Foster[1,2†]

ARTICLE

Check for updates

https://doi.org/10.1038/s41467-020-17180-x OPEN

An ecological framework to understand the efficacy of fecal microbiota transplantation

Yandong Xiao[1,2], Marco Tulio Angulo[3,4], Songyang Lao[1], Scott T. Weiss[2] & Yang-Yu Liu[2,5]✉

nature ecology & evolution

REVIEW ARTICLE

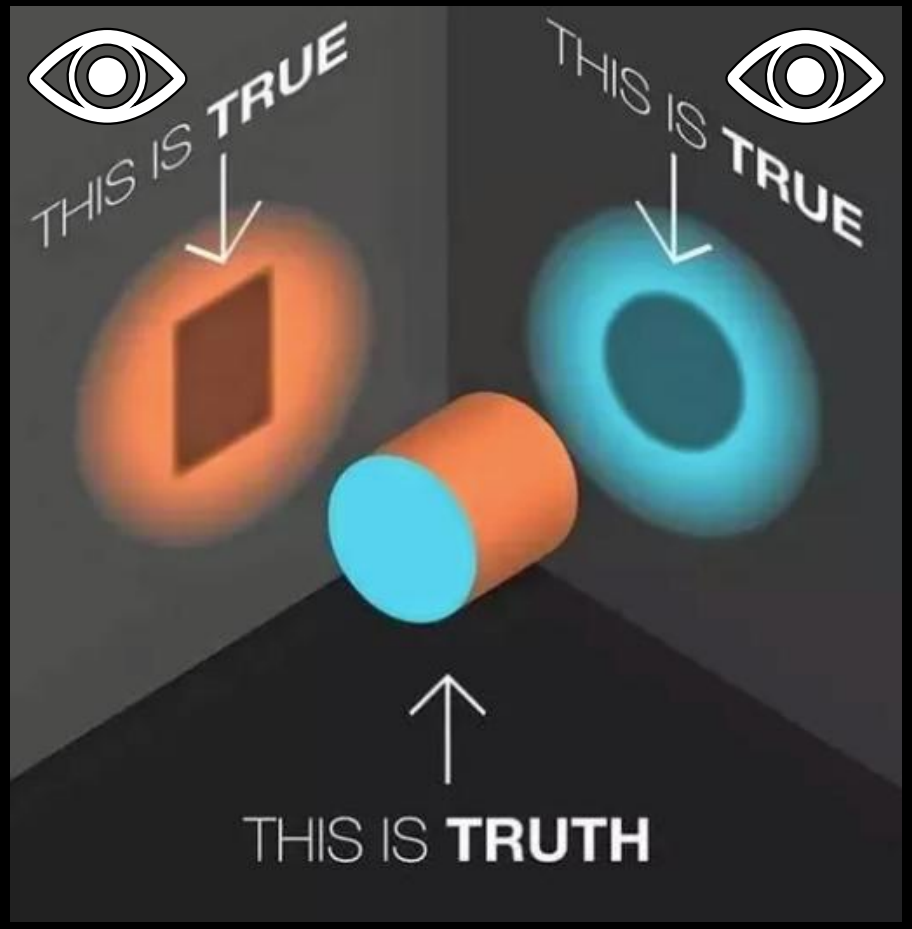
https://doi.org/10.1038/s41559-022-01746-7

Check for updates

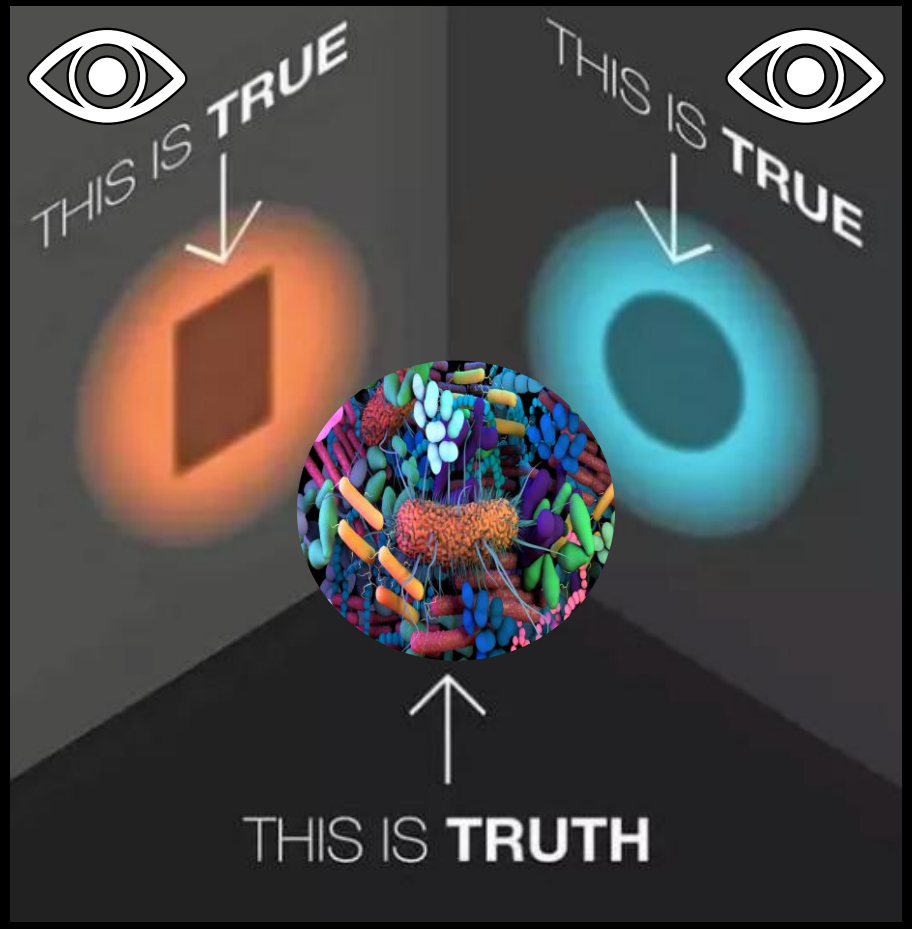
Ecological modelling approaches for predicting emergent properties in microbial communities

Naomi Iris van den Berg[1], Daniel Machado[2], Sophia Santos[3], Isabel Rocha[4], Jeremy Chacón[5], William Harcombe[5], Sara Mitri[6] and Kiran R. Patil[1]✉

3. Contemporary Microbiome Studies



3. Contemporary Microbiome Studies



3. Perspective?

3. Perspective?

01

Worldview (DeWitt, 2004); Paradigm (Kuhn, 1962); Program (Lakatos, 1970); etc.

02

More recently: Systems of practice (Chang, 2012); Repertoire (Ankeny and Leonelli, 2016); etc.

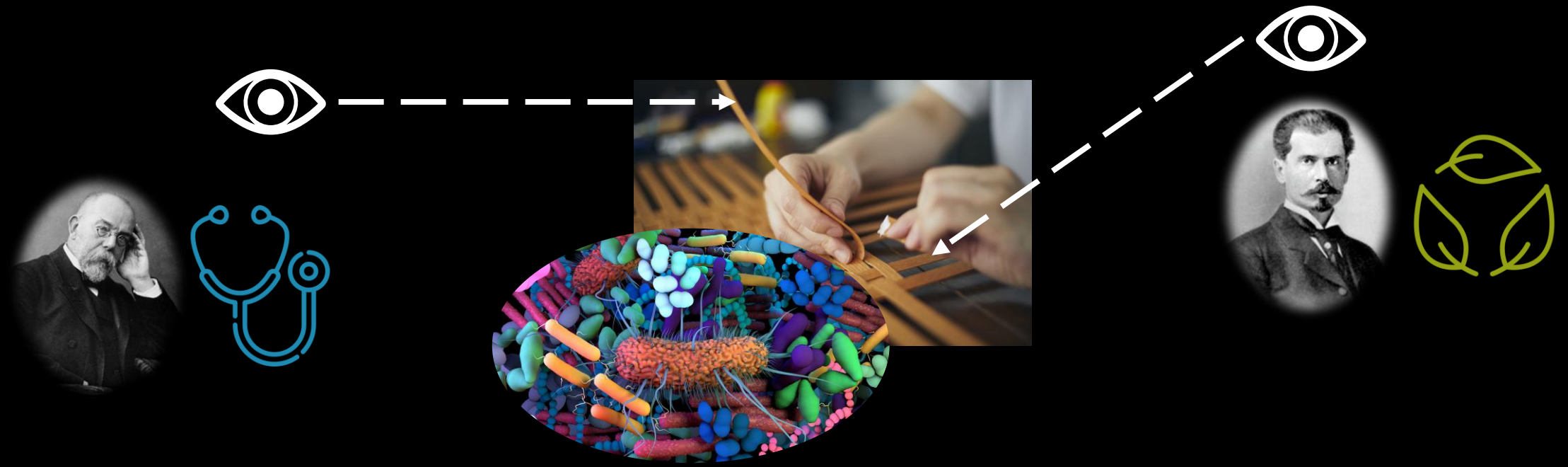
03

Perspective (Giere, 2006) – *color vision*

04

The basic idea is that the differences are strong and may impair integration.

4. “Weaving” both perspectives



4. “Weaving” both perspectives

- Factors contributing **to integration**:
  - Depend on the case and the problem pursued (Brigandt, 2010)
  - Exploratory questioning, technological innovation, and transfer of knowledge (O’Malley and Soyer, 2012)

  ⇒ **Multilevel**
- **Methodologically**: Integrate multiomics approaches with microbial cultures, computational approaches, and simulations – **which technological innovations do microbiome studies need?**
- **Conceptually**: Go beyond targeting specific pathogens or “silver bullet” microorganisms to managing the entire microorganismal community/holobiont and studying dynamic interactions.

Image by Anna from Pixabay

4. “Weaving” both perspectives

- “If approaches and researchers are too far apart in terms of perspective, integration is difficult to achieve in any meaningful way” (O’Malley and Soyer, 2012, p. 65).

⇒ **Weaving**: A metaphor for “how to bring multiple ways of knowing together in a respectful way that does not interfere with the qualities and processes of each knowledge system” (also worldview, research paradigms) (https://weavingknowledges.ca/).

- How to weave meaningfully different perspectives?
- Actionability?

Image by Alicja from Pixabay

Conclusion

- The history of microbiology is made up of different paths leading to different **perspectives** on microbiology – characterized by different **ontological, methodological, and epistemic commitments**
- These different **perspectives** are still present in today's human microbiome studies
- They pose a challenge for integration, while integration seems needed to understand the complex phenomena of microbiomes
- How to move forward?

Thank you!

https://apotiron.github.io