



Philippe Vandenkoornhuyse

Concept d'Holobionte, analyses de séquences et perspective de recherche offertes



Université de Rennes I
Campus de Beaulieu
CNRS
UMR6553 EcoBio,
Rennes, France

Ilya Prigogine



The irreversibility of time is the mechanism that brings order out of chaos.

(Ilya Prigogine)

"This is indeed an essential part of the scientific revolution we are witnessing at the end of the 20th century. Science is a dialogue with nature. In the past this dialogue has taken many forms. We feel that we are at the end of the period which started with Galileo, Copernicus and Newton and culminated with the discovery of quantum mechanics and relativity. This was a glorious period but in spite of all its marvelous achievements it led to an oversimplified picture of nature, a picture which neglected essential aspects. Classical science emphasized stability, order and equilibrium. Today we discover instabilities and fluctuation everywhere. Our view of nature is changing dramatically"

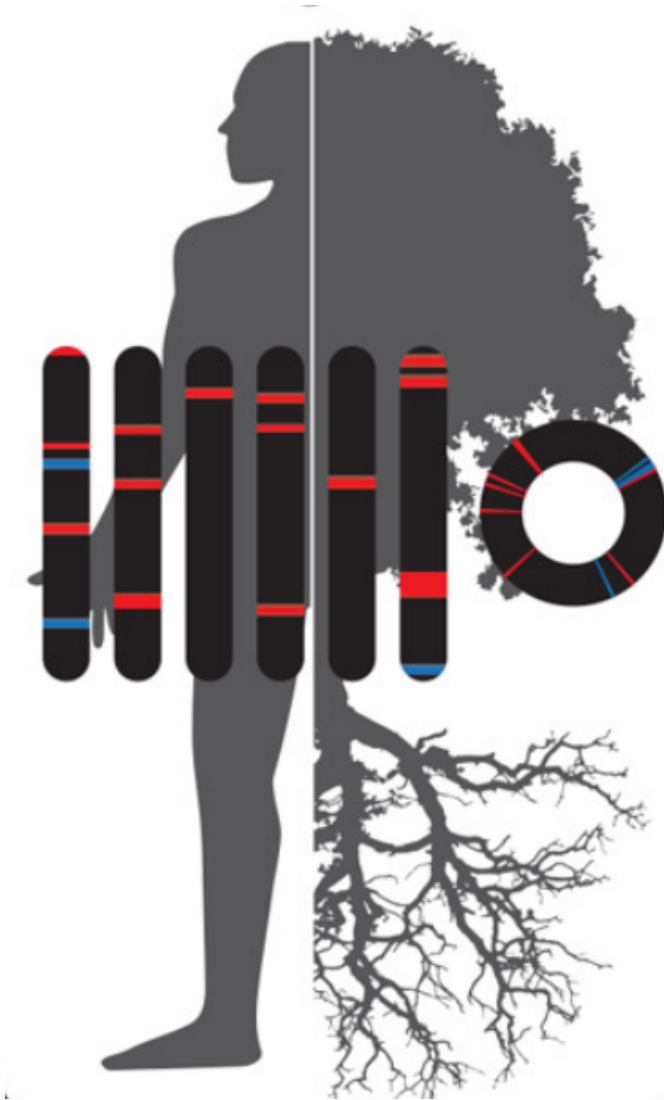
... trapped within a reductionist view of life ?

Microorganisms diversity ... comes close to the infinity

- $1,3 \cdot 10^{28}$ microorga dans l'eau (océan + eau douce) = 100 millions de fois le nombre d'étoiles connues dans l'univers

-1kg de sol: $1.0 \cdot 10^{13}$ microorganismes $\sim$ 100 fois le nombre d'étoiles dans notre galaxie

-Le nombre de gènes contenus dans la microflore intestinale $>$ 150 fois le nombre de gènes portés par notre génome



Past and current 'Paragon' :

Macro-organisms are regarded as standalone entities

Conceptual consequences

- theoretical corpus and knowledge basically developed on reductionist bases (p. ex. genetics, community ecology)
- individual/species reduced to a genome



Past and current 'Paragon' :

Macro-organisms are regarded as standalone entities

Applied Consequences

- Human health
- Agriculture

Natural ecosystems have never experienced this before

→ conventional agriculture practices, artificialization of agrosystems
But diversity ?



Organism/crop-centred view

Huge areas with a single
crop species or cultivar

Agriculture and crop productivity

- Plant centred vision (past & recent years)
 - Plant breeding
 - GMOs
 - CRISPR/Cas9
 - plant genome editing

Paroxysm in the plant centred vision reached !



Illustration by Erin Dunn, Ensia.com

GMOs, Silver Bullets and the Trap of Reductionist Thinking

The biggest problem with GMOs isn't technology. It's when technology is used as a silver bullet, without considering the broader context within which it operates.

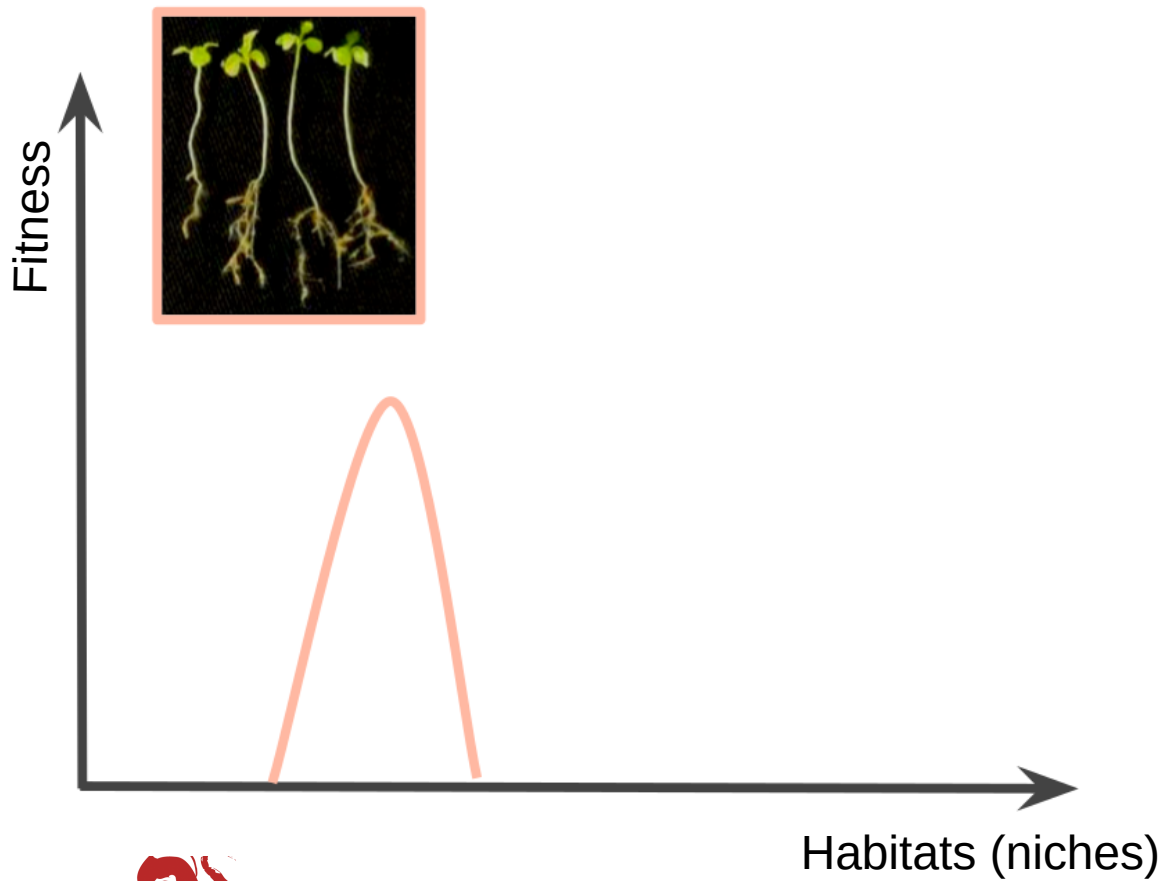
J Foley (2016)

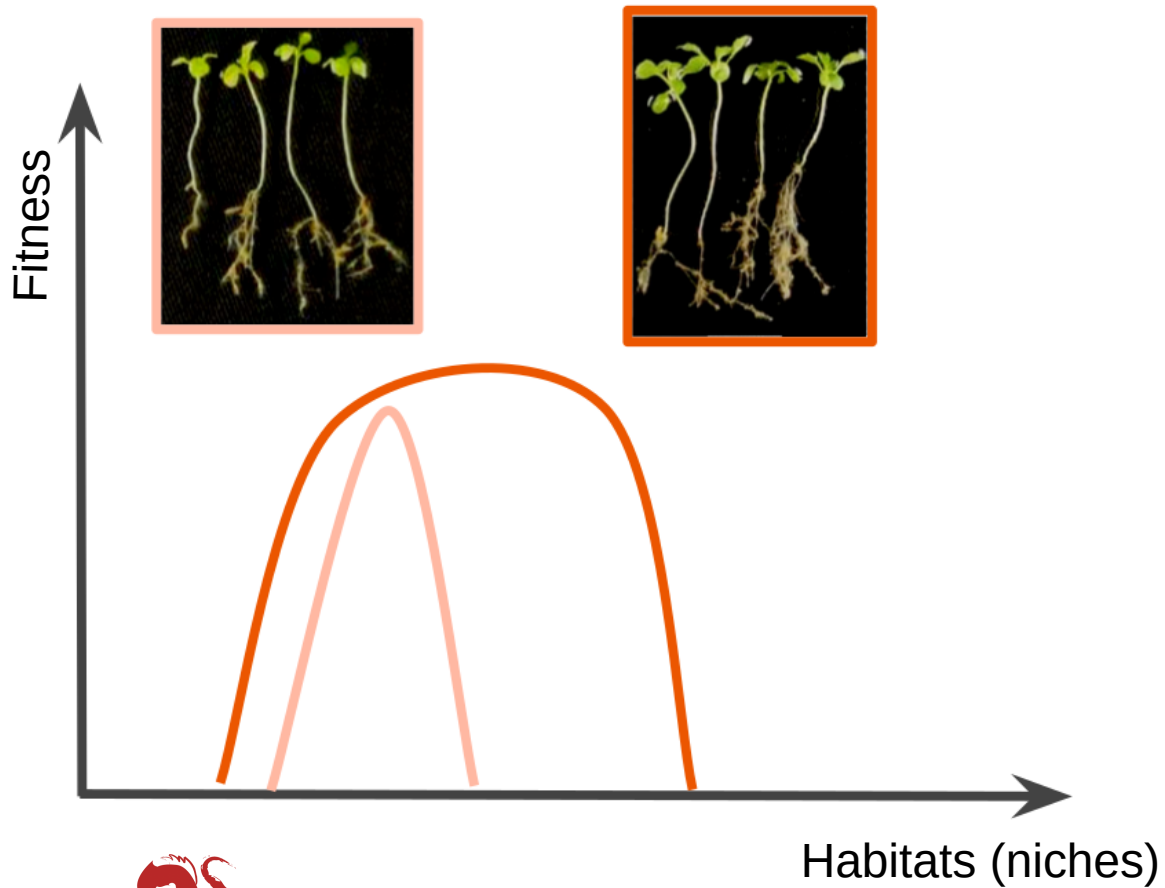
Agriculture and crop productivity

- Agriculture practices fingerprint
 - Evolution
 - Ecology
- } Particular effect on the plant symbiotic compartment



**... trapped within a reductionist view of life
toward or more holistic perception**

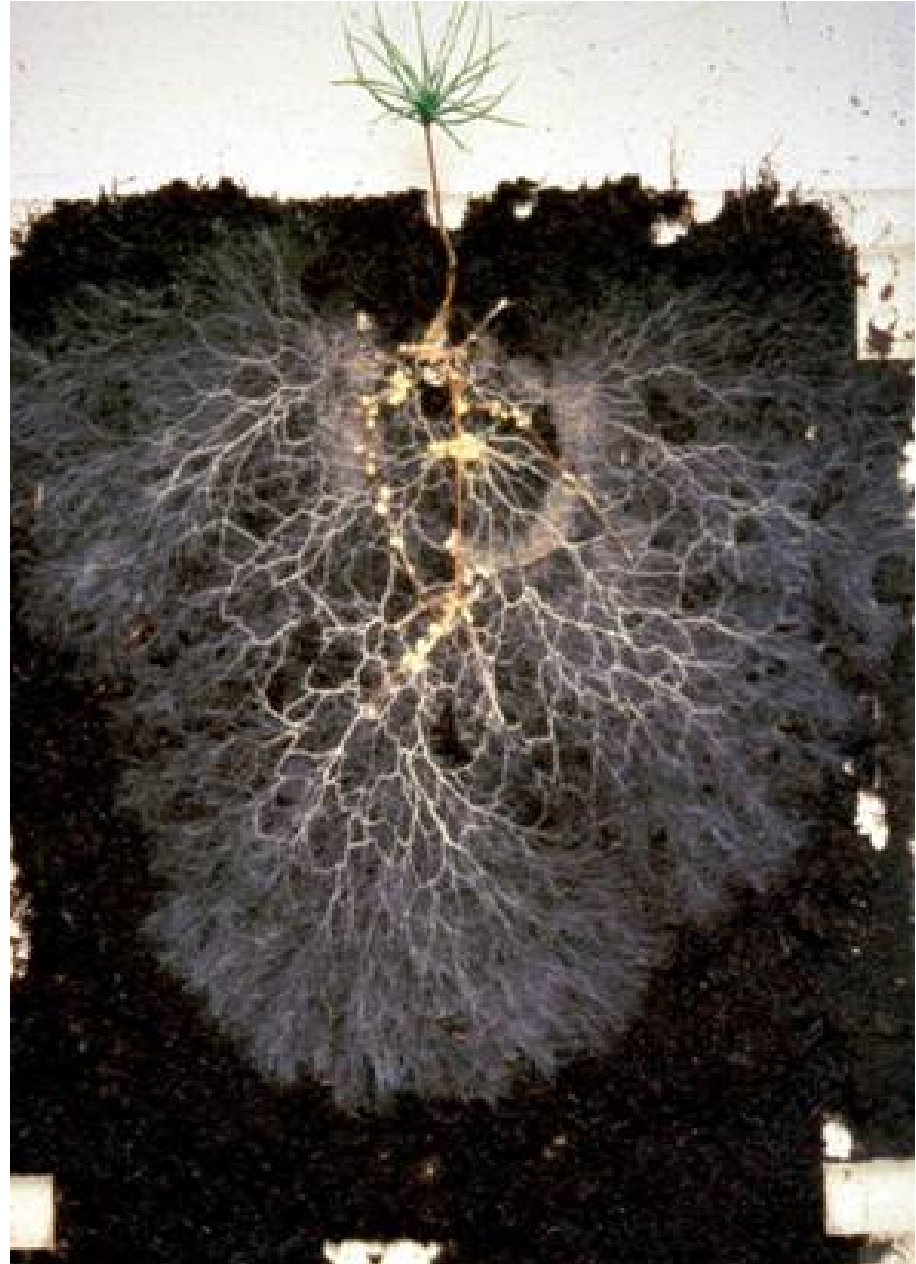


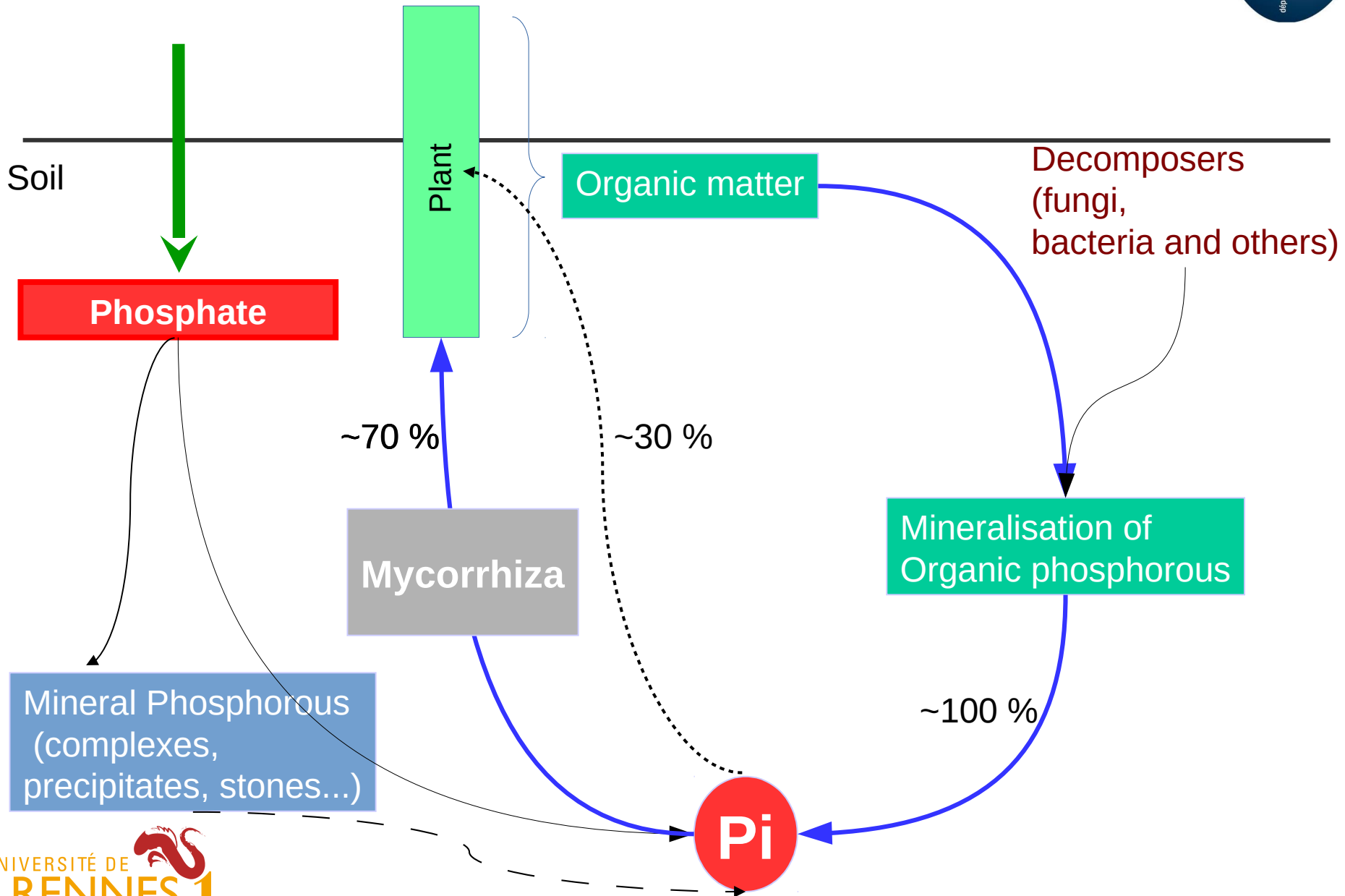


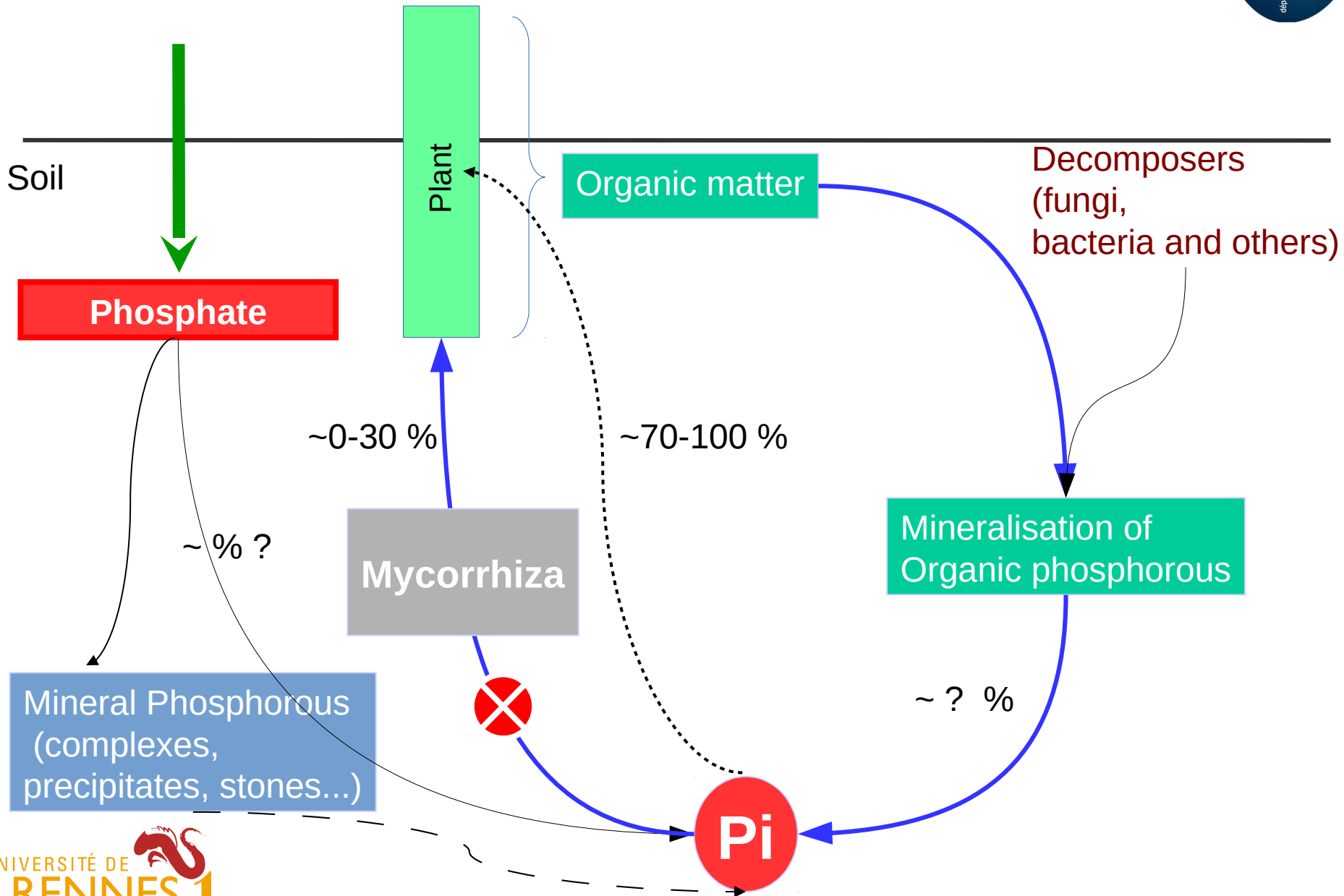
> 80 % of land plants with
Arbuscular mycorrhiza

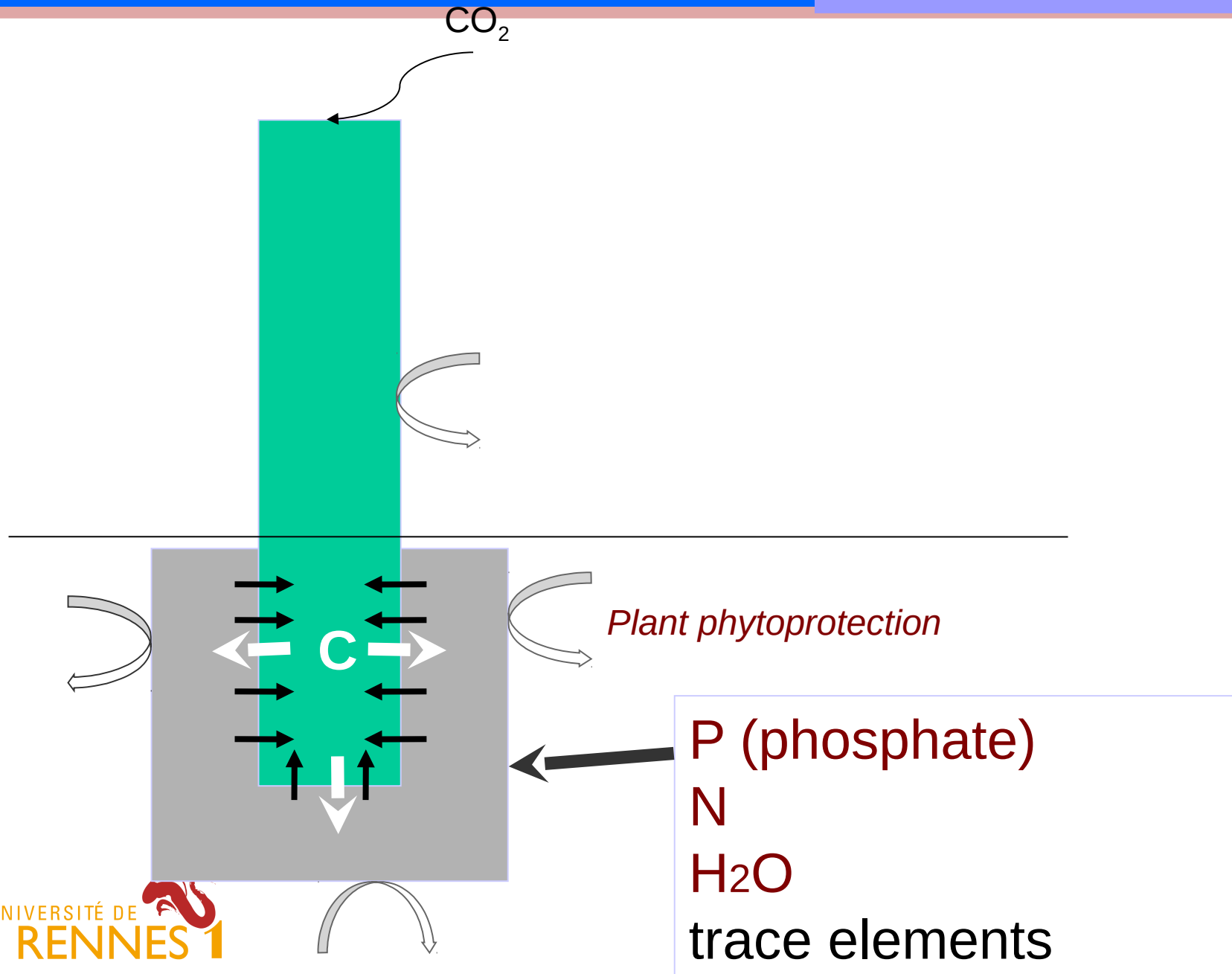
+5-10 % with other mycorrhizal types

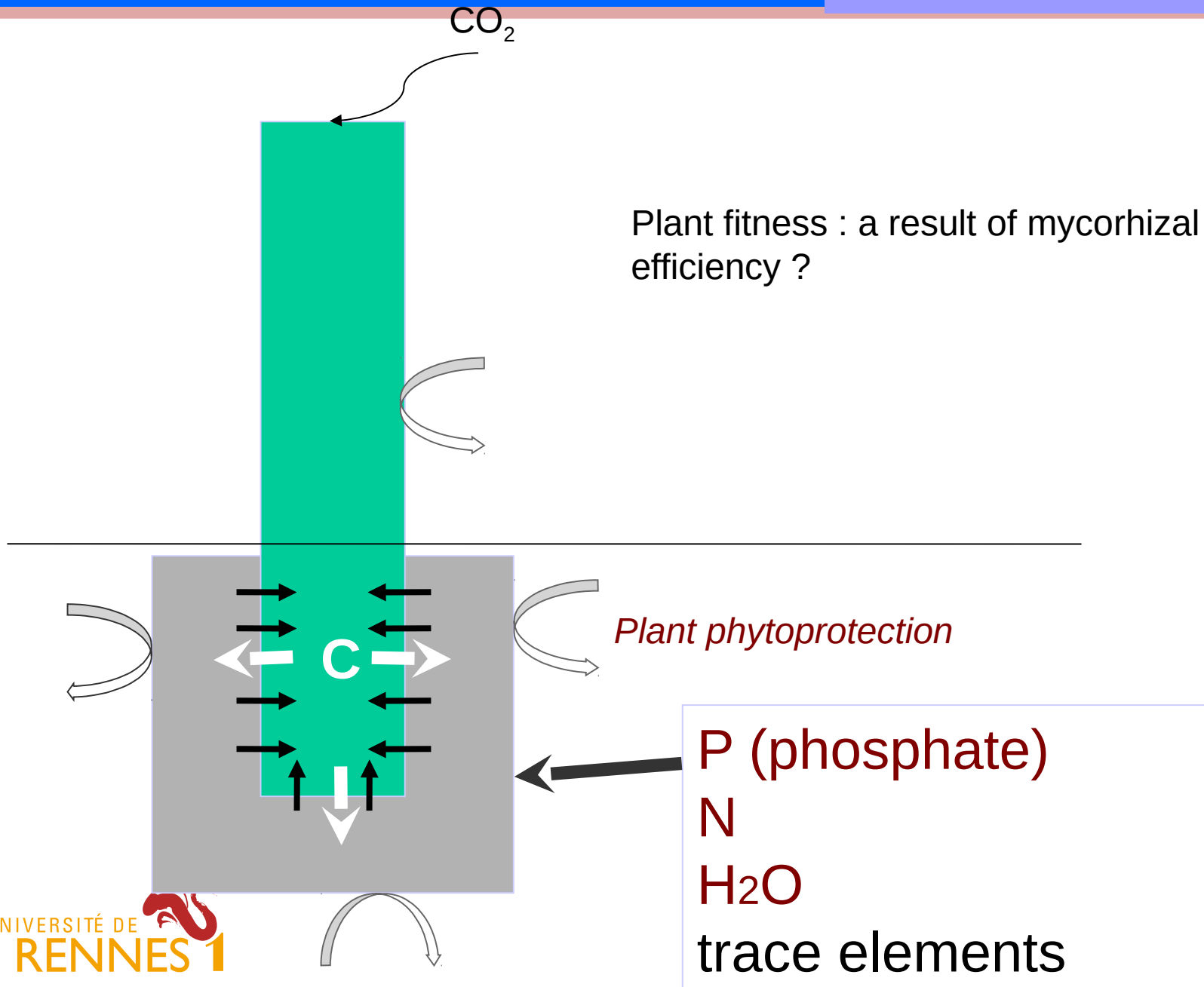
Very dense hyphal network exploring
A huge volume of soil (high
surface exchange)









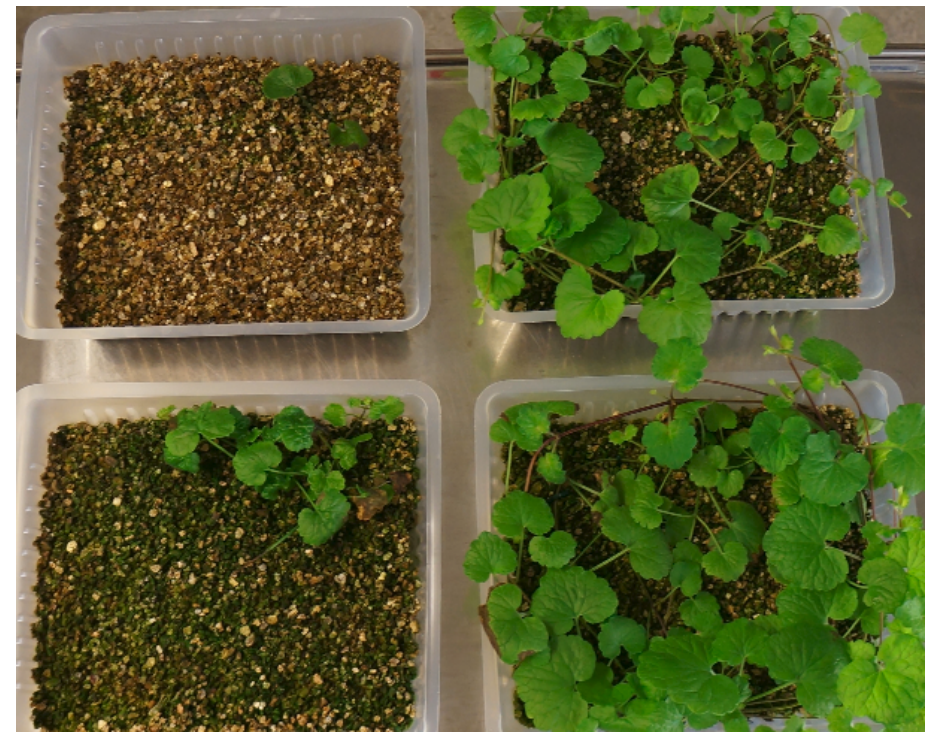


Plant fitness

Not necessarily a consequence of plant genome itself !

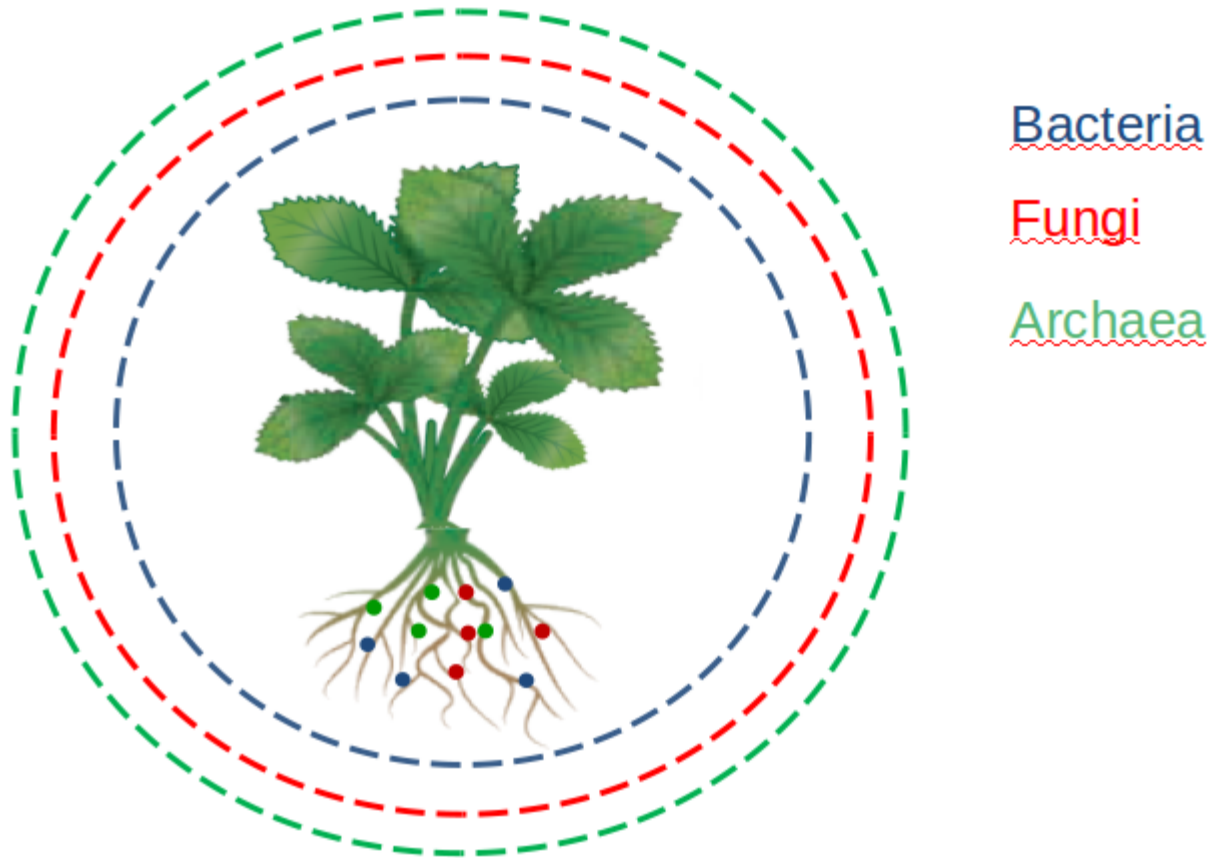
Microbiota do matter

*Plants of a single genotype
same growth conditions and duration
3 different mycorrhizal inocula
+ control, top left*
Ricono et al, unpublished

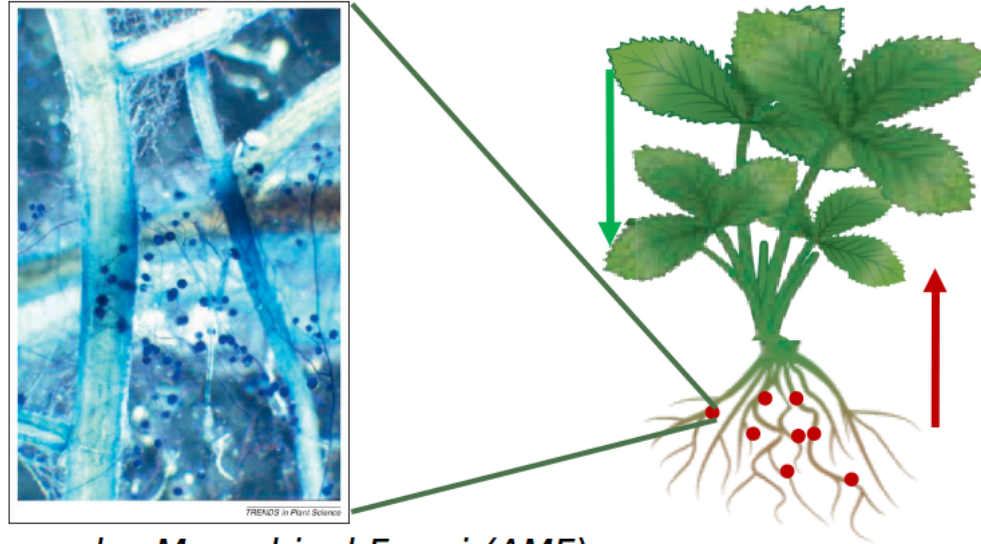


Plant microbiome is far more complex than previously believed (e.g. Bulgarelli et al., 2012; Lundberg et al., 2012; Lê Van et al., 2017...)
Their interactions, functions and consequences for plant fitness ?





The microorganisms functions (microbiota)
extend the plant adaptive abilities



Arbuscular Mycorrhizal Fungi (AMF)

Associations plants/microorganisms are regulated by :

- colonization filters
- rewarding processes
- host preference

Microorganisms transmission between generations

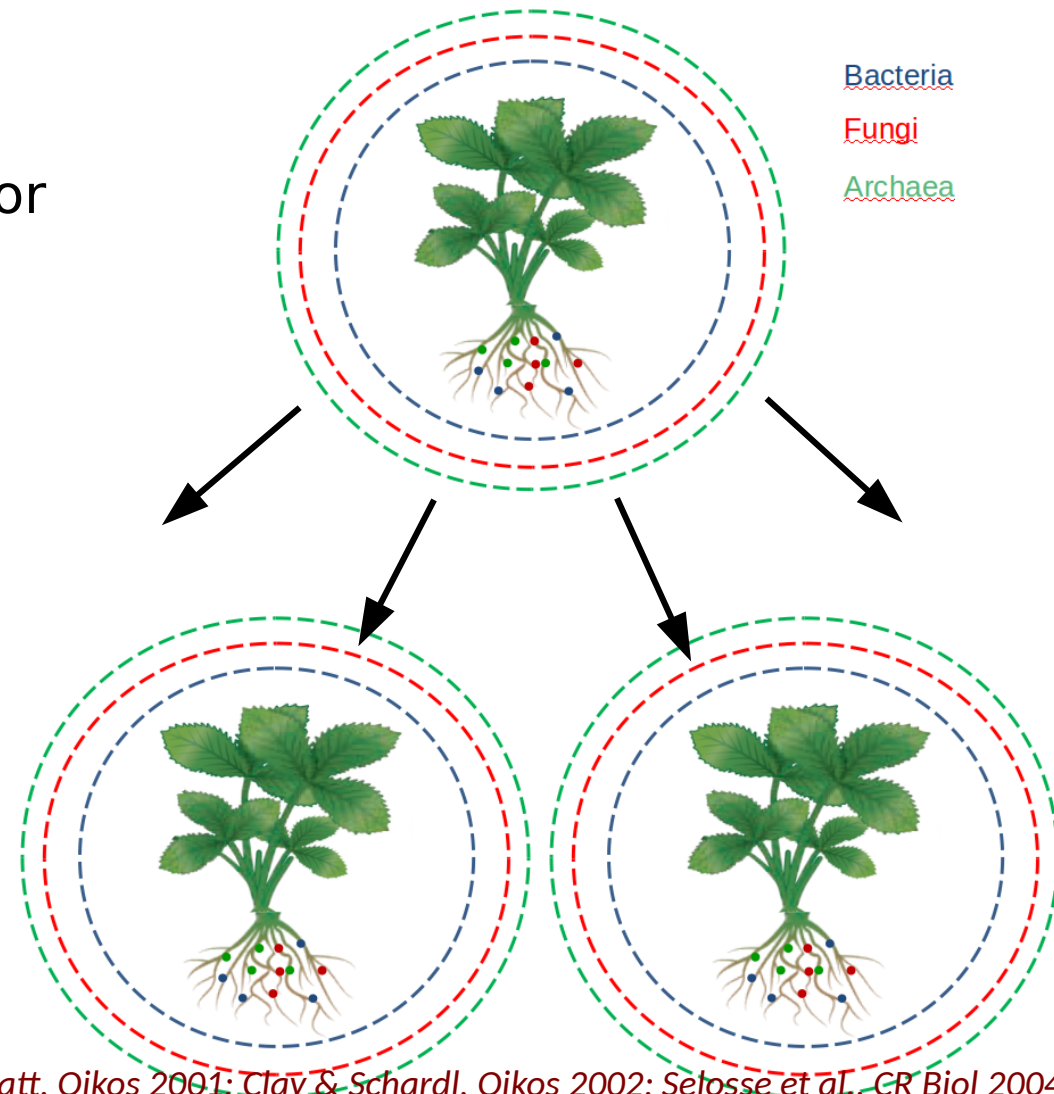
Avoids the cost of searching for symbionts

Ensures habitat quality

Constitutes a continuity of partnership

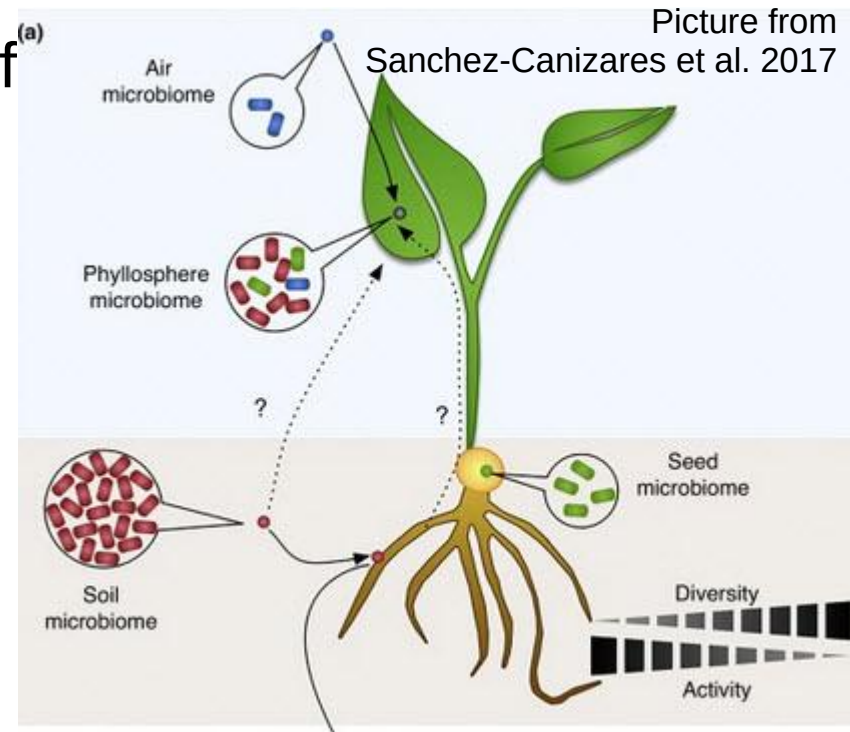
Examples of heritability :

- Pseudo-vertical
- Vertical through seeds
- Vertical transmission from mother to daughter ramet

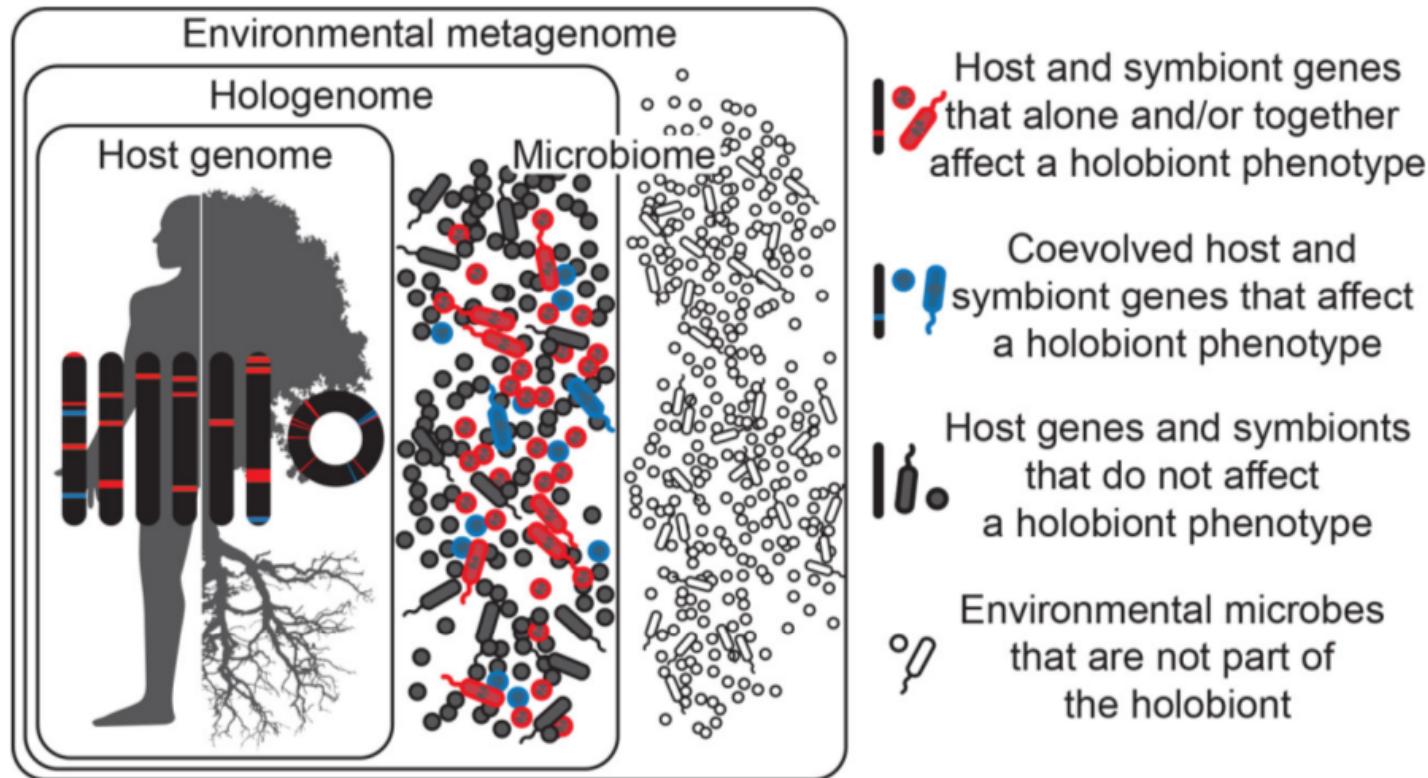


The holobiont & hologenome concept redefine what is a plant

- Individual phenotype is a product of interactions among the host's genome, its microbiome & the environment
- Holobiont is the emergent entity of a host plus its symbiotic microbes
- Hologenome is the host genome plus the microbiome



The holobiont & hologenome concept redefine what is a plant



The plant microbiota : keystone for survival

Plants are sessile. They have to face environmental constraints
=> the most important mechanism for plant survival = to buffer environmental constraints

→ Recruitment from the microbial reservoir of a single microorganism = mobilization of a number of new genes associated to this microorganism

→ Much more efficient and dynamic process than plant-genome changes

From plants to plant-holobionts, a possible revolution ?



Tillage



Fertilizers & Biocides



Monocultures



NEGATIVE
EFFECTS



Hyphal
network
disruption

Decrease in
symbiont
efficiency



<http://amicreative.org>



<http://sydney.edu.au/newsresearch/support2379.htmlnewsstoryid=9519>

Current Plant Breeding

→ Plant centred vision

→ Best adaptation to conventional agriculture & soil artificialization

(plants able to capture soil nutrients and water by their own)



<http://amicreative.org>



<http://sydney.edu.au/newsresearch/support2379.html#newsstoryid=9519>

Consequence of current Plant Breeding

- Loss of sanction trait by modern crops (hypothesis)
- Bad cooperators (higher fitness) invade populations in these soils



<http://amicreative.org>



Plant Breeding & Sustainable agriculture

Restoration of damaged ecological services mediated by plant symbionts and modify their current evolutionary trajectory

A move toward the plant holobiont perception is required

Forecasted human population growth & agriculture : How to feed the world ?

To understand, protect and make a better use of the microbiota, huge needs in terms of sequencing

Genomes

Transcriptomes

Meta-genomes and meta-transcriptomes

Single cell analyses (resolution of the microbiota)
both genome & transcriptome scale

Nova seq 6000 →
human genome at
1000 \$



GEH : 600 TO



Forecasted human population growth & agriculture : How to feed the world ?

Opinion

Trends in Plant Science November 2013, Vol. 18, No. 11

Sustainable agriculture: possible trajectories from mutualistic symbiosis and plant neodomestication

Marie Duhamel^{1,2} and Philippe Vandenkoornhuyse¹



**Evolution of Cooperation
behaviour of plants-Symbionts**



CNRS-EC2CO MICROLAND



Thanks to :

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Ludmilla Sarbu

Anthony Bretaudeau

Olivier Collin

Yvan Le Bras

Toby Kiers

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