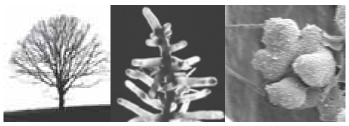


Microbial Biofertilizers and their Potential in sustainable Agriculture

Dr. Heike Bücking

RUTGERS
CAMDEN

Outline

Ectomycorrhiza Fagus

1. Overview – Plant Microbe Interactions

2. Mycorrhizal interactions

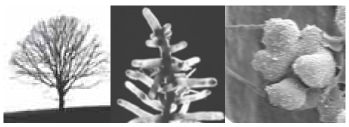
3. Effect of mycorrhizal interactions on nutrient uptake and pathogen resistance

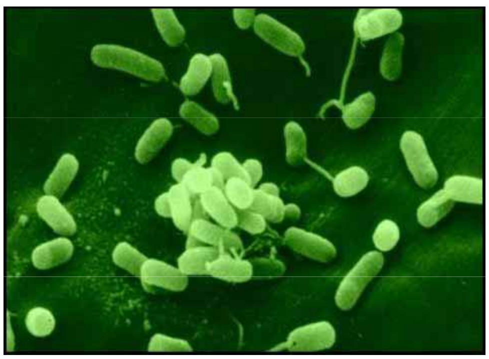
4. Interactions between exchange processes

5. Nitrogen flux in the symbiosis

6. Mycorrhizal fungi and their application

Overview – Plant-Microbe Interactions



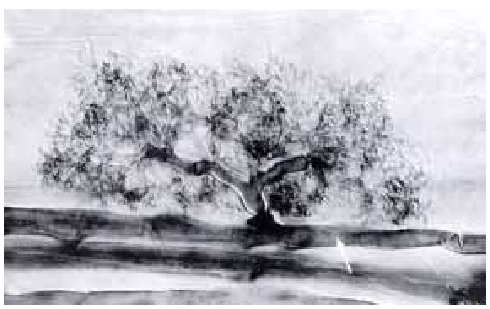

Abrosimov 2007

Bacteria

Nitrogen (N_2) Fixation

- Symbiotic bacteria (Rhizobia, *Frankia*)
- Associated bacteria (*Acetobacter* - sugarcane)
- Free-living bacteria (*Frankia* – rhizosphere)

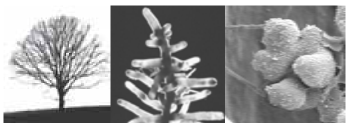
Plant Growth promoting Bacteria


Smith and Read 1997

Fungi

Mycorrhizal associations

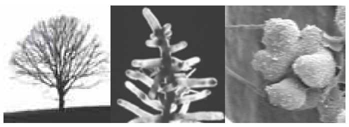
- Arbuscular mycorrhizal fungi
- Ectomycorrhizal fungi
- Other root colonizing fungi



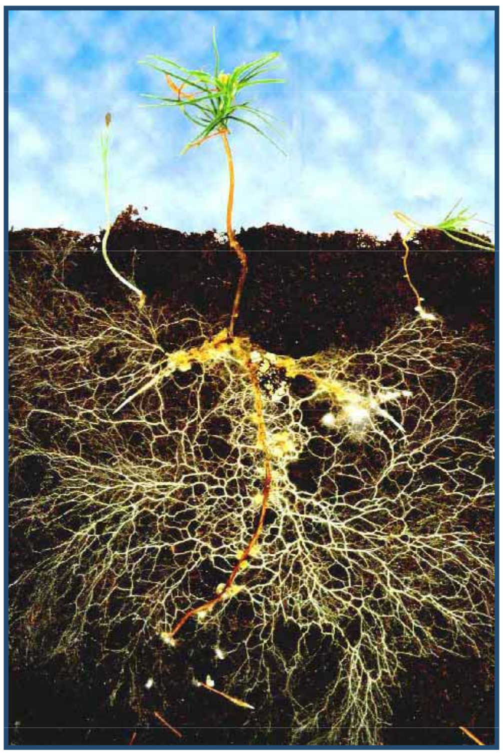
Plant-Growth Promoting Bacteria

Siberian soy beans, 1 – control, 2 - nodule bacteria; 3 - nodule bacteria and pseudomonads (Dashkevish 2007)

- Enhanced N supply to the host by N_2 fixation
- Enhanced supply of other plant nutrients (P mobilization, S oxidation, Fe chelation)
- Phytochrome production leading to increases in root surface area (IAA, cytokinin, gibberllin)
- Enhancement of other beneficical bacterial or fungal symbioses



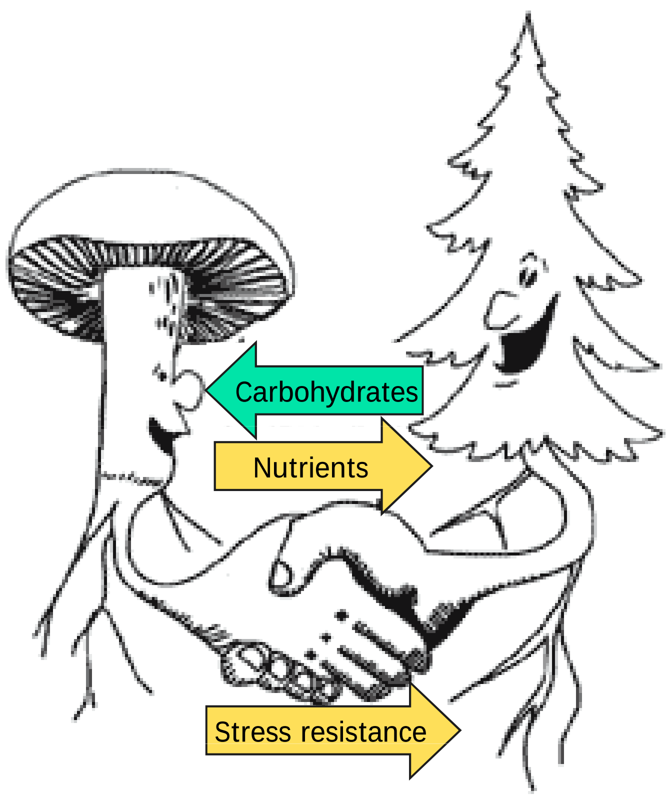
The significance of mycorrhizal interactions



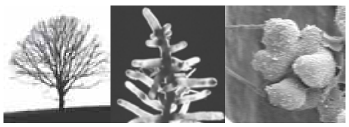
Smith and Read 1997

- 80-90% of all known plant species
- bryophytes, pteridophytes, gymnosperms and most of the angiosperms
- simultaneous colonization by various mycorrhizal types and fungal species, dependent on environmental conditions
- essential for achlorophyllous plants
- Increasing attention for their role as biofertilizers, bioprotectors and bioregulators

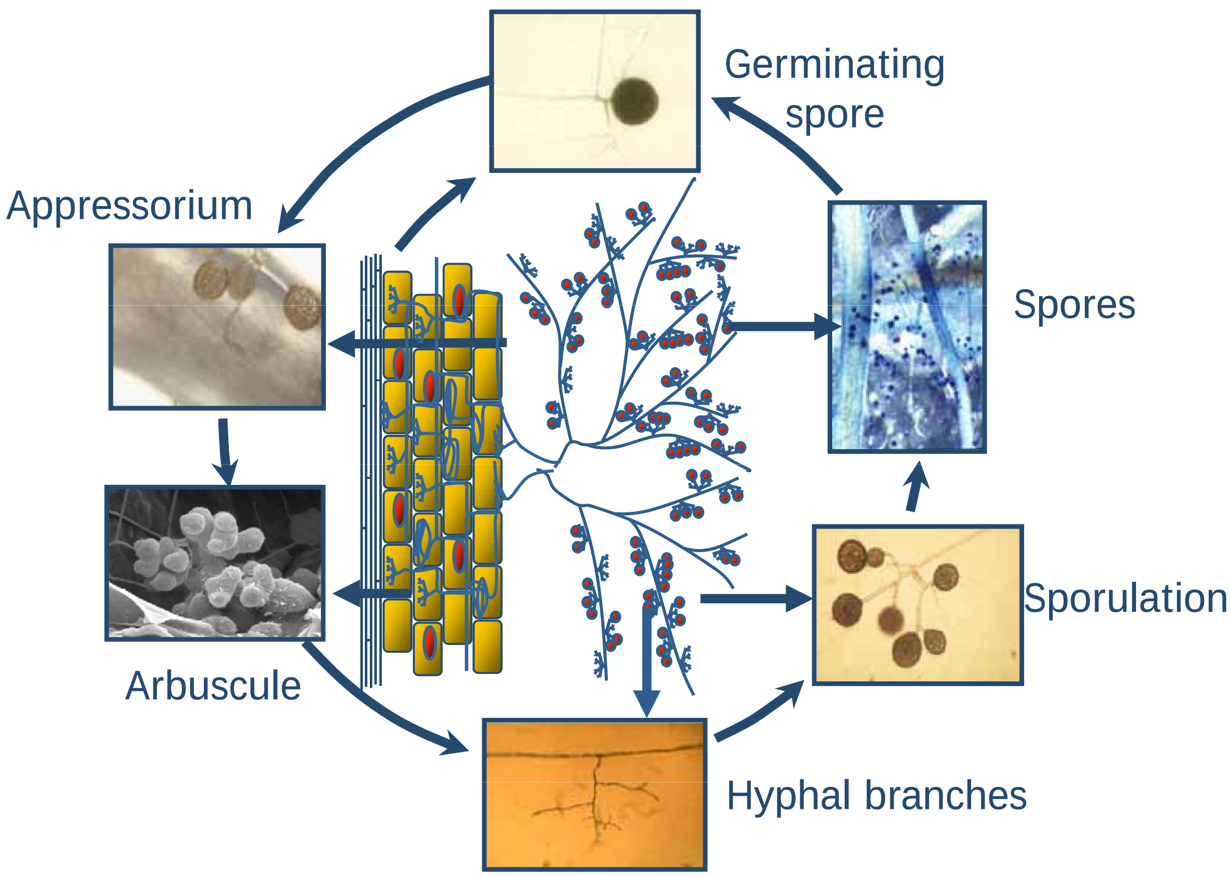
The benefits for both partners



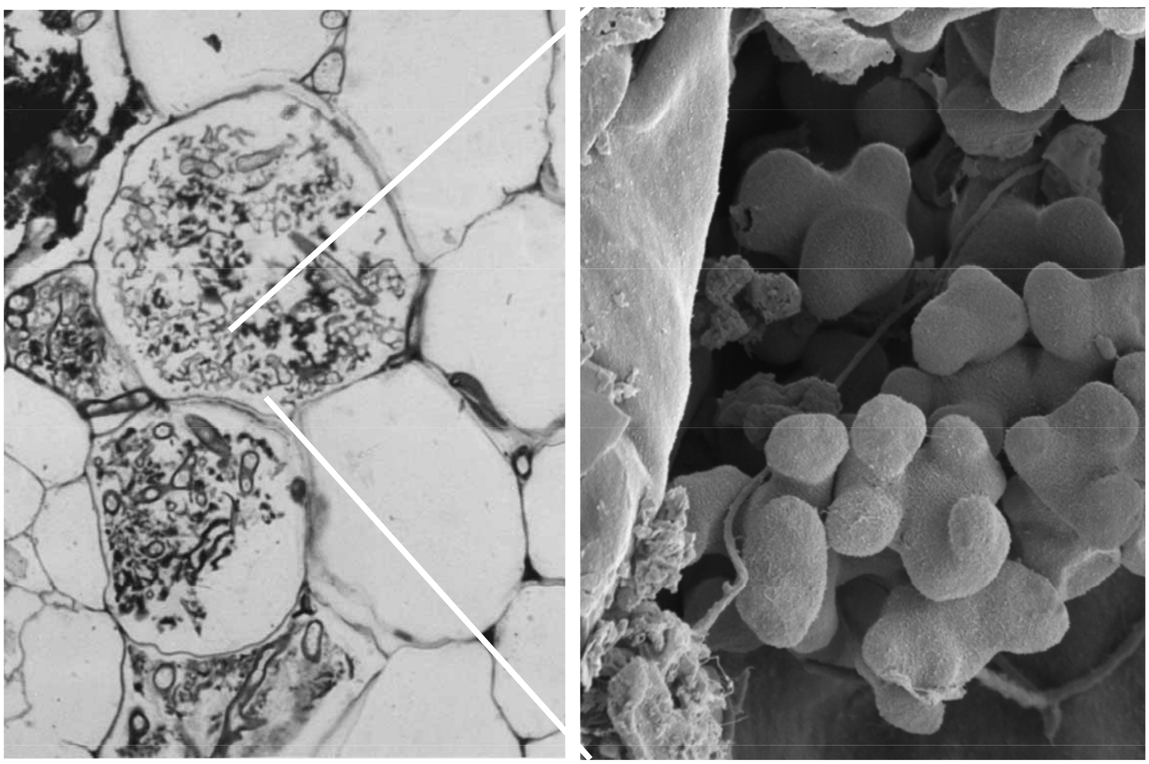
modified Egli, Brunner 2002



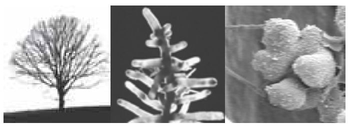
The life cycle and morphology of an asexual coenocytic obligate symbiont

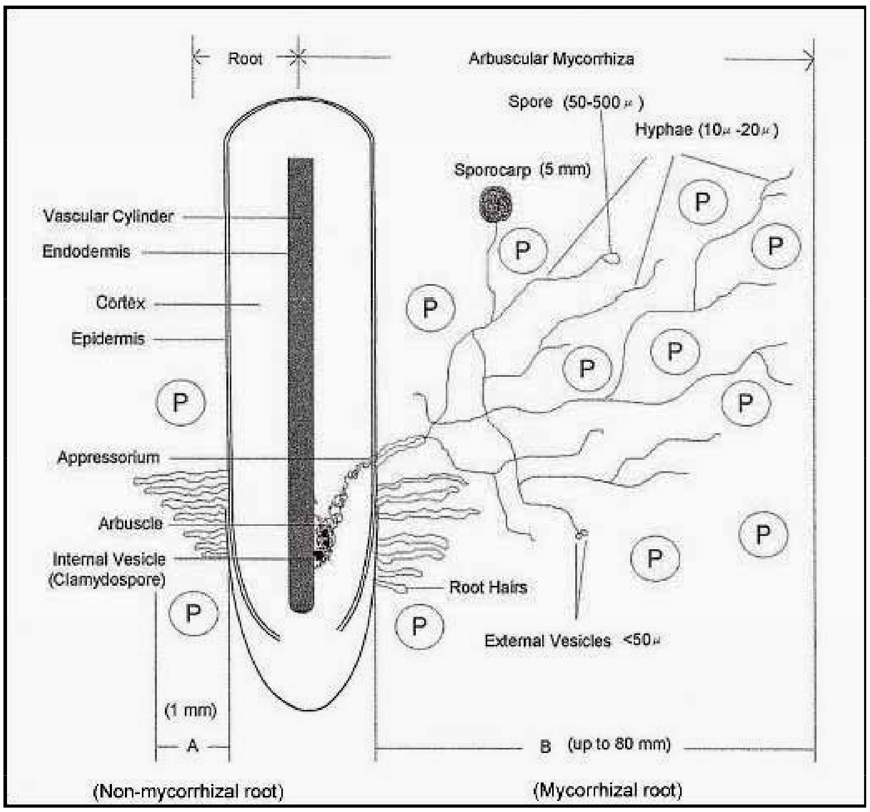


Structure of an arbuscular mycorrhizal root



How does the fungus-plant interaction work ?





- Increase in the nutrient absorbing surface area beyond the depletion zone of the root
- Highly efficient nutrient uptake systems
- Better P storage capabilities
- Utilization of organic nutrient resources

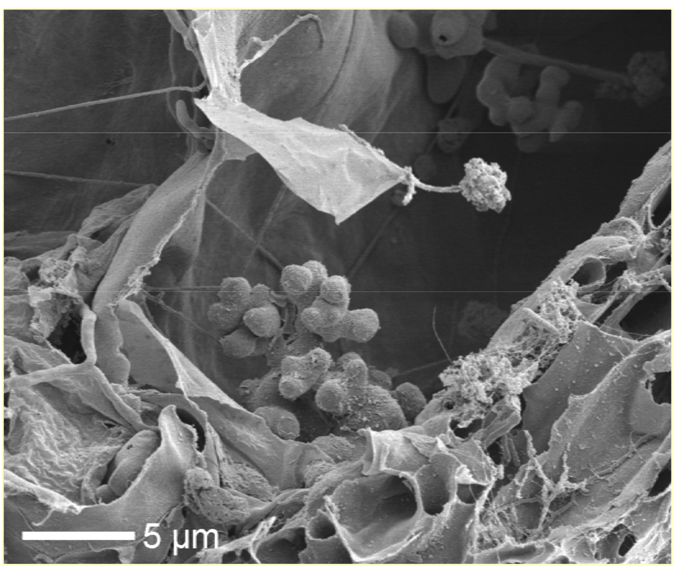
How does the fungus-plant interaction work ?

Mycorrhizal and nonmycorrhizal barley plants after colonisation with Cochliobolus sativus (Kogel, Giessen)

- Increased nutrient supply
- Competition among the microorganisms for limited nutrient resources
- Effect on the quantity and quality of root exudates
- Selective pressure on the microbial populations in the rhizosphere leading to an increase in the number of microorganisms with antagonistic properties
- Activation of defense mechanisms by the mutualistic fungus

Nutrient exchange always includes an apoplastic step

Intercellular interface
Arbuscular interface



arbuscular mycorrhiza

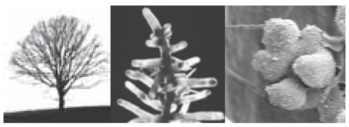
Plant plasma membrane

Plant cell wall

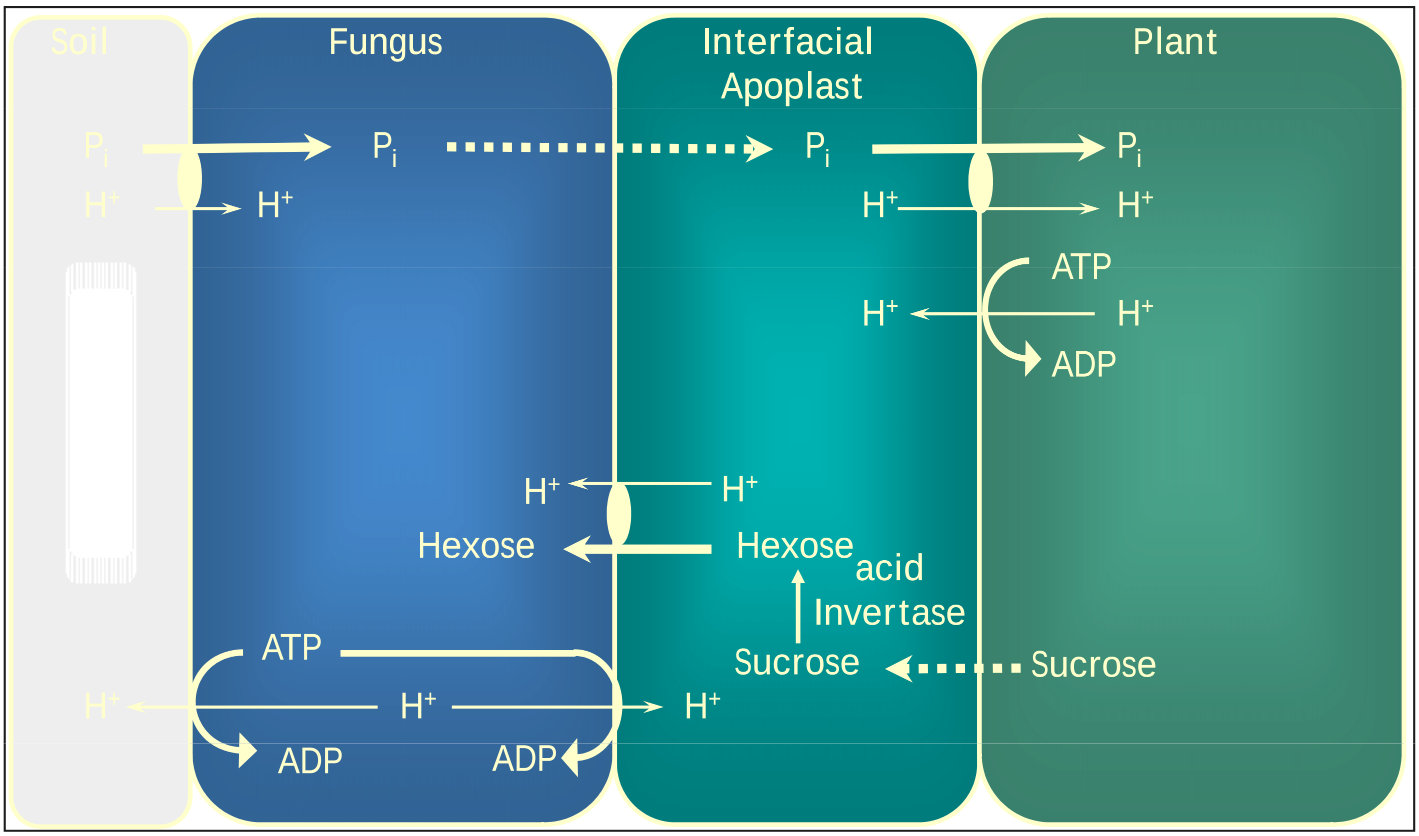
Interfacial matrix

Fungal cell wall

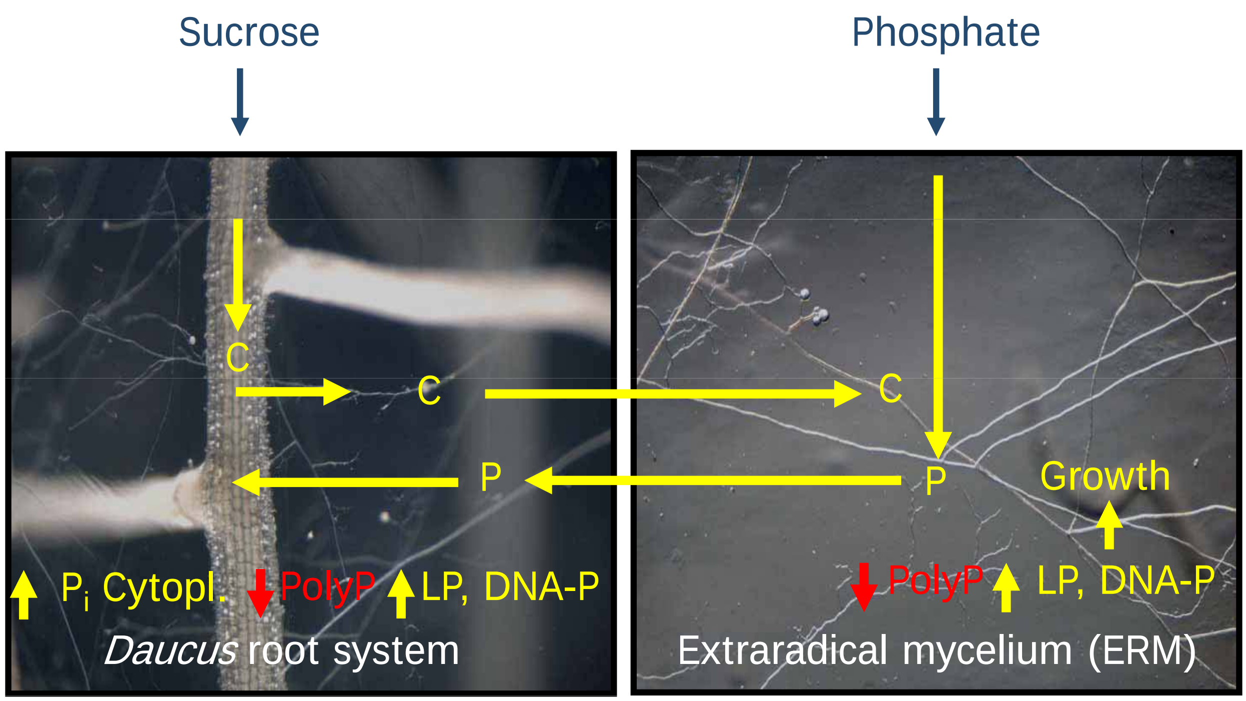
Fungal plasma membrane



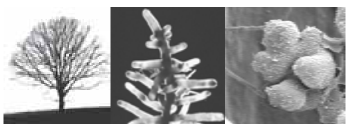
Nutrient exchange includes passive and active steps



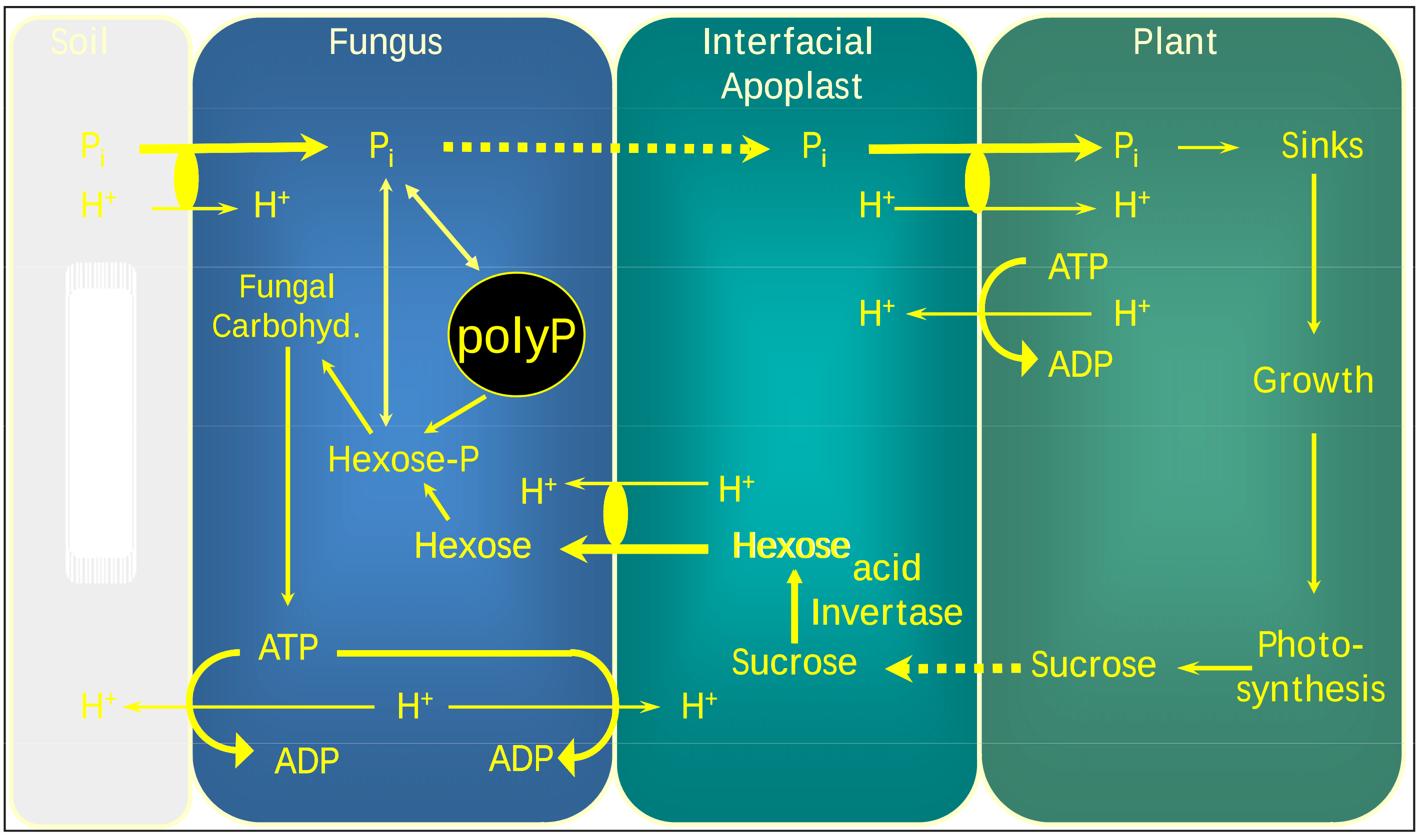
The C availability affects P uptake and P transfer by arbuscular mycorrhizas

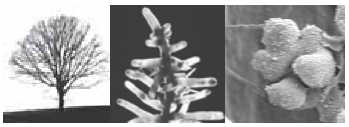


Bücking, Shachar-Hill, 2005

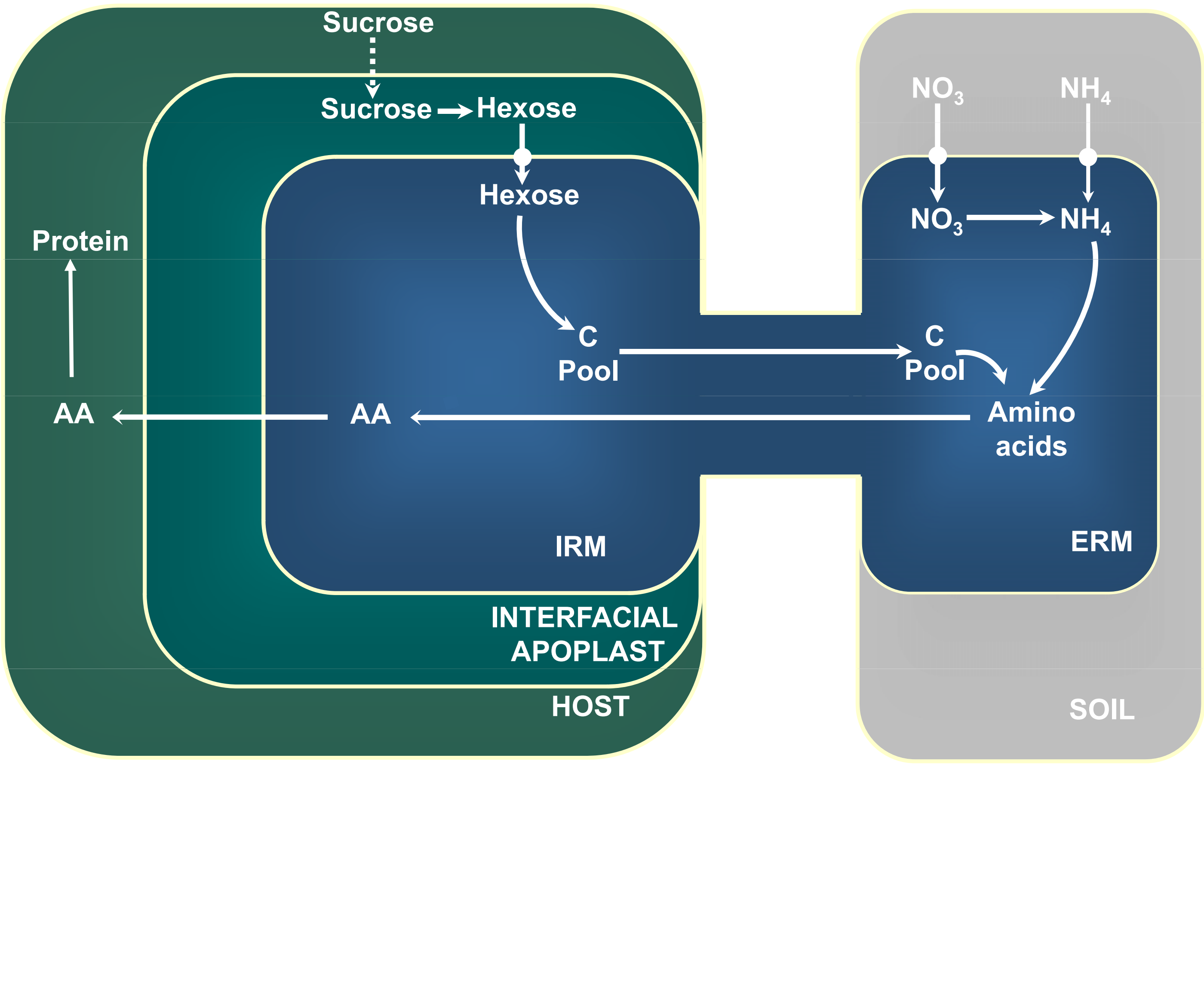


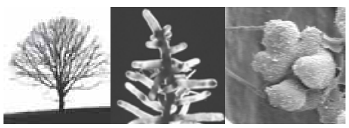
P uptake and P transfer is stimulated
by the carbohydrate availability



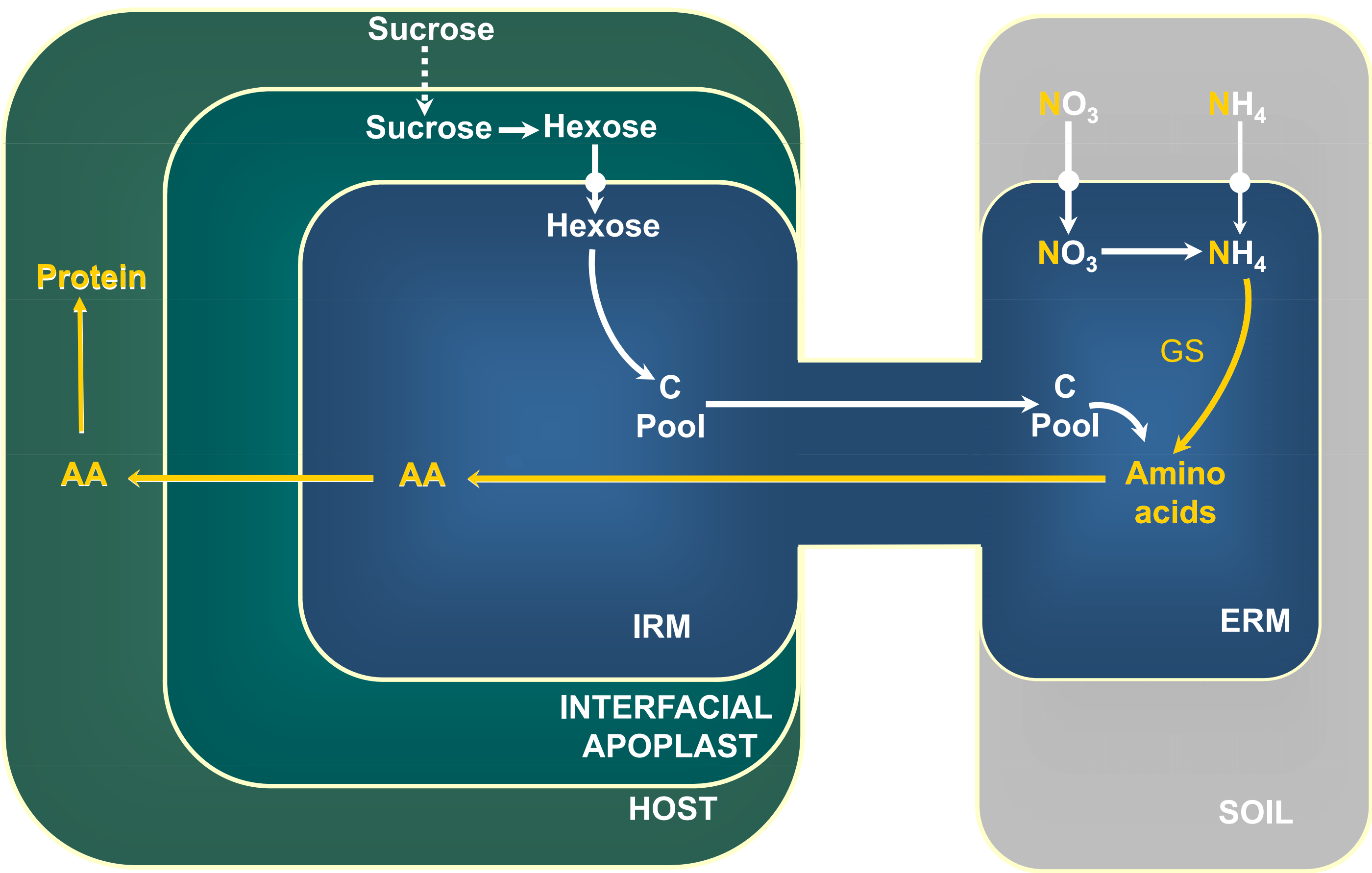


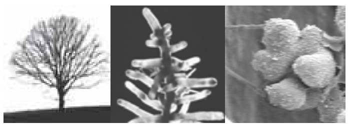
Nitrogen flux in the arbuscular mycorrhizal symbiosis



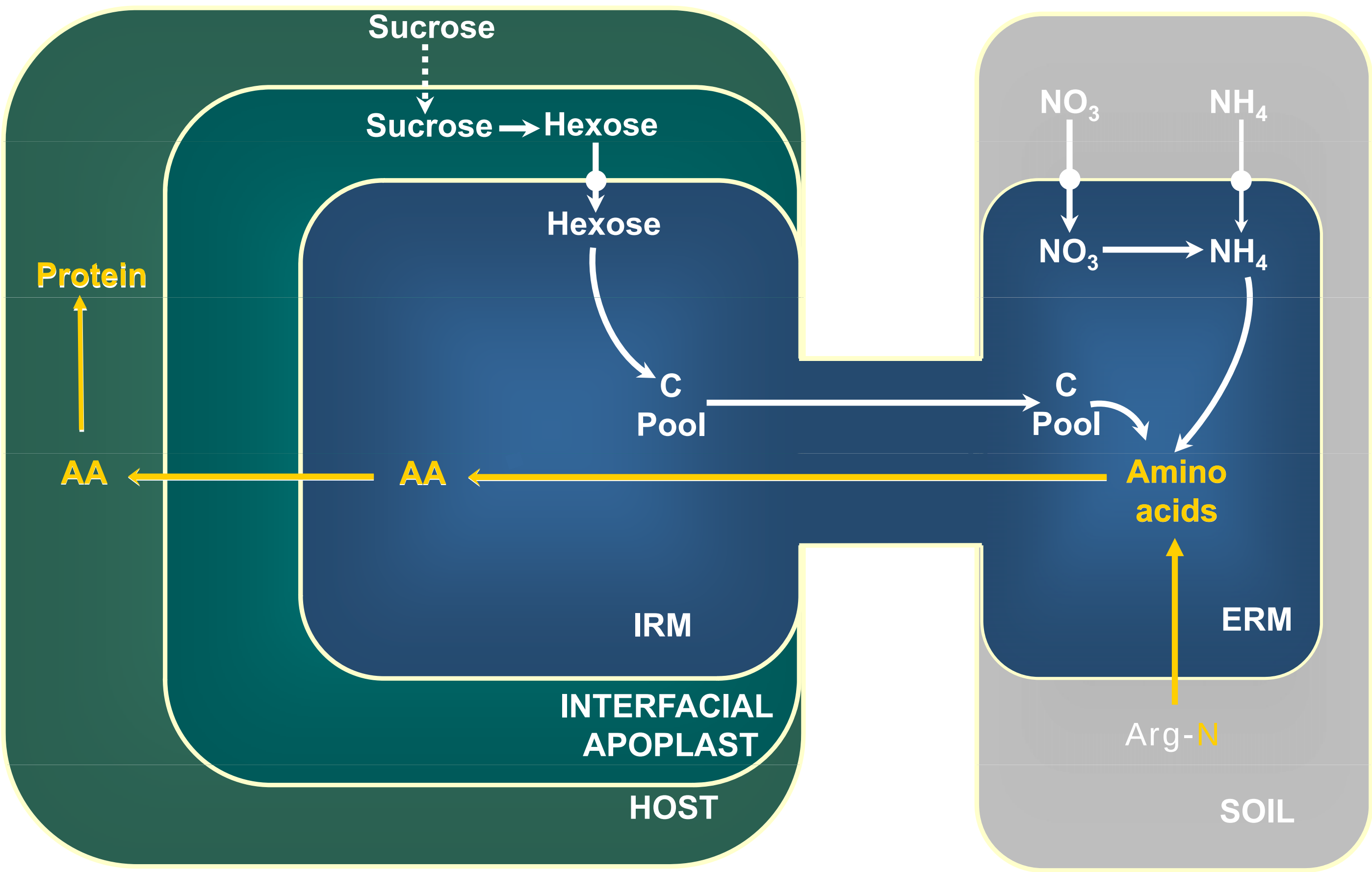


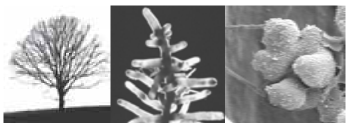
Nitrogen flux in the arbuscular mycorrhizal symbiosis



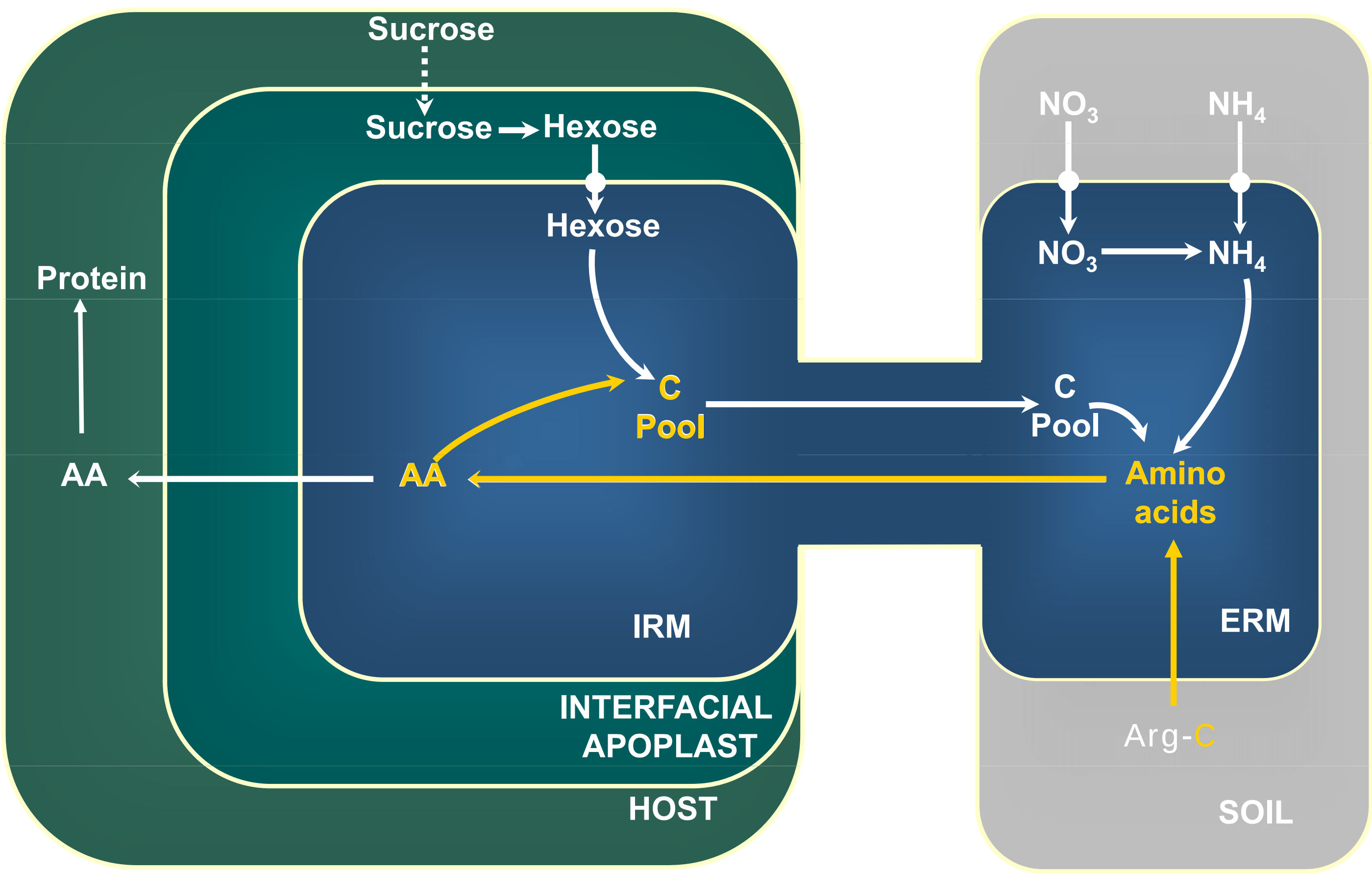


Nitrogen flux in the arbuscular mycorrhizal symbiosis

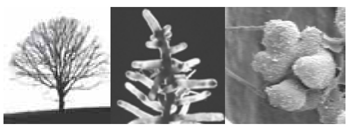


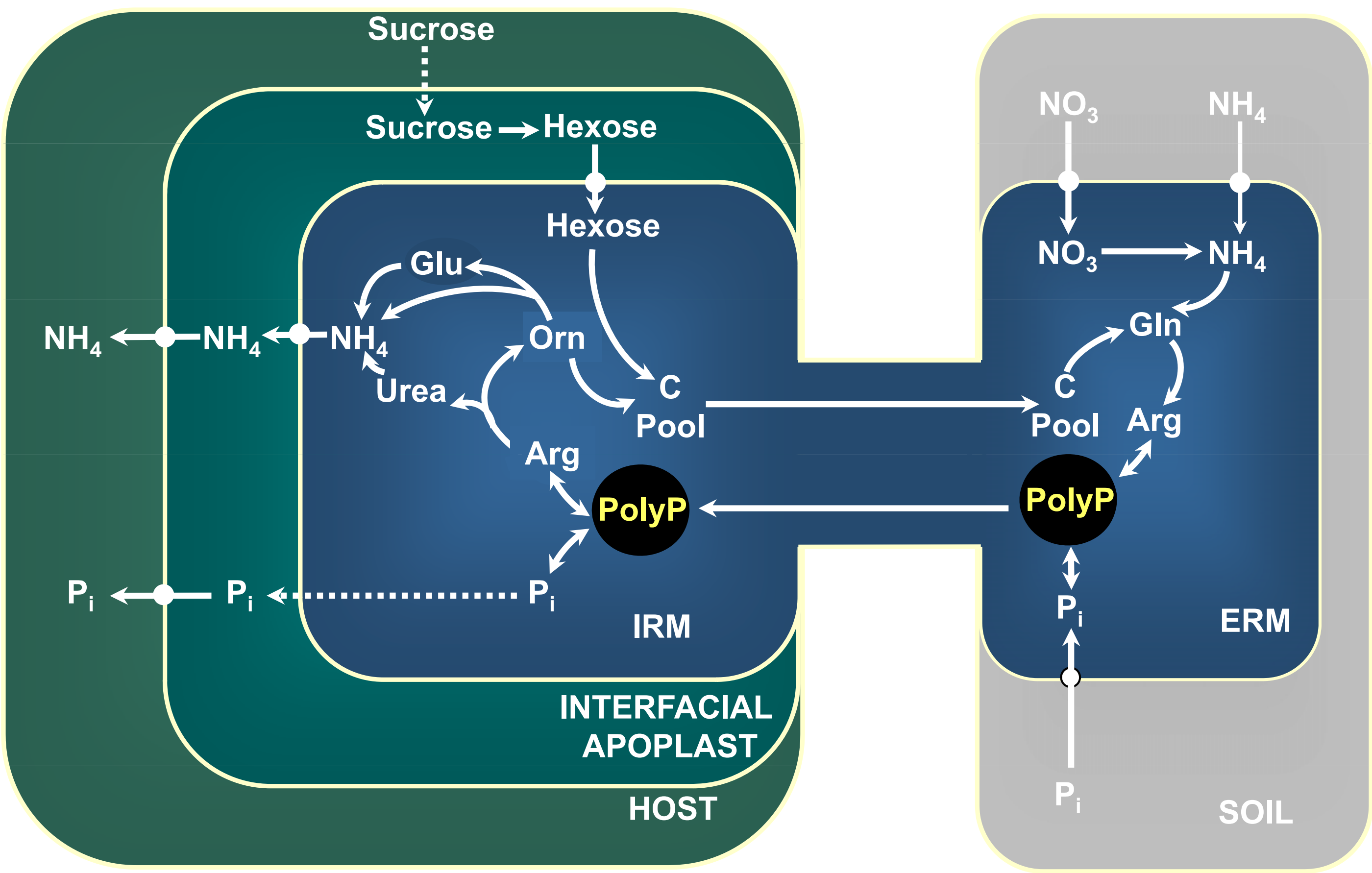


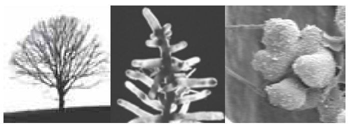
Nitrogen flux in the arbuscular mycorrhizal symbiosis



Nitrogen flux in the arbuscular mycorrhizal symbiosis



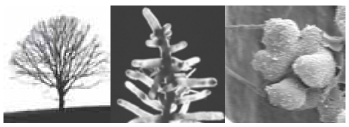




The dependency of various crop species on mycorrhiza

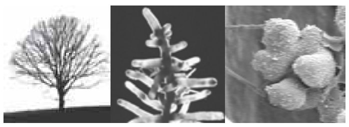
Mycorrhiza dependency	Potential yield loss without mycorrhiza	Crops
Very high	Greater than 90 %	Linseed
High	60 – 80 %	Sunflower, mungbean, pigeon pea, maize, chickpea
Medium	40 – 60 %	Sorghum, soybean
Low	10 – 30 %	Wheat, barley, triticale
Very low	0 – 10 %	Panicum, canary
Nil	0	Canola, lupins

The State of Queensland (Department of Primary Industries and Fisheries)



Application of mycorrhizal fungi

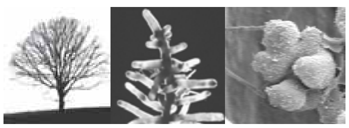
- Arbuscular mycorrhizal fungi can account for 5 – 50 % of the microbial biomass in the soil (Ryan and Graham, 2002)
- Efficient mycorrhizal symbiosis can substitute 222 kg P_2O_5 ha^{-1} (Kelly et al., 2001)
- In field studies, the growth yield of linseed could be correlated to the mycorrhizal colonization rate (Thompson et al., 1991)
- High P levels in the soil reduce significantly the colonization rate.



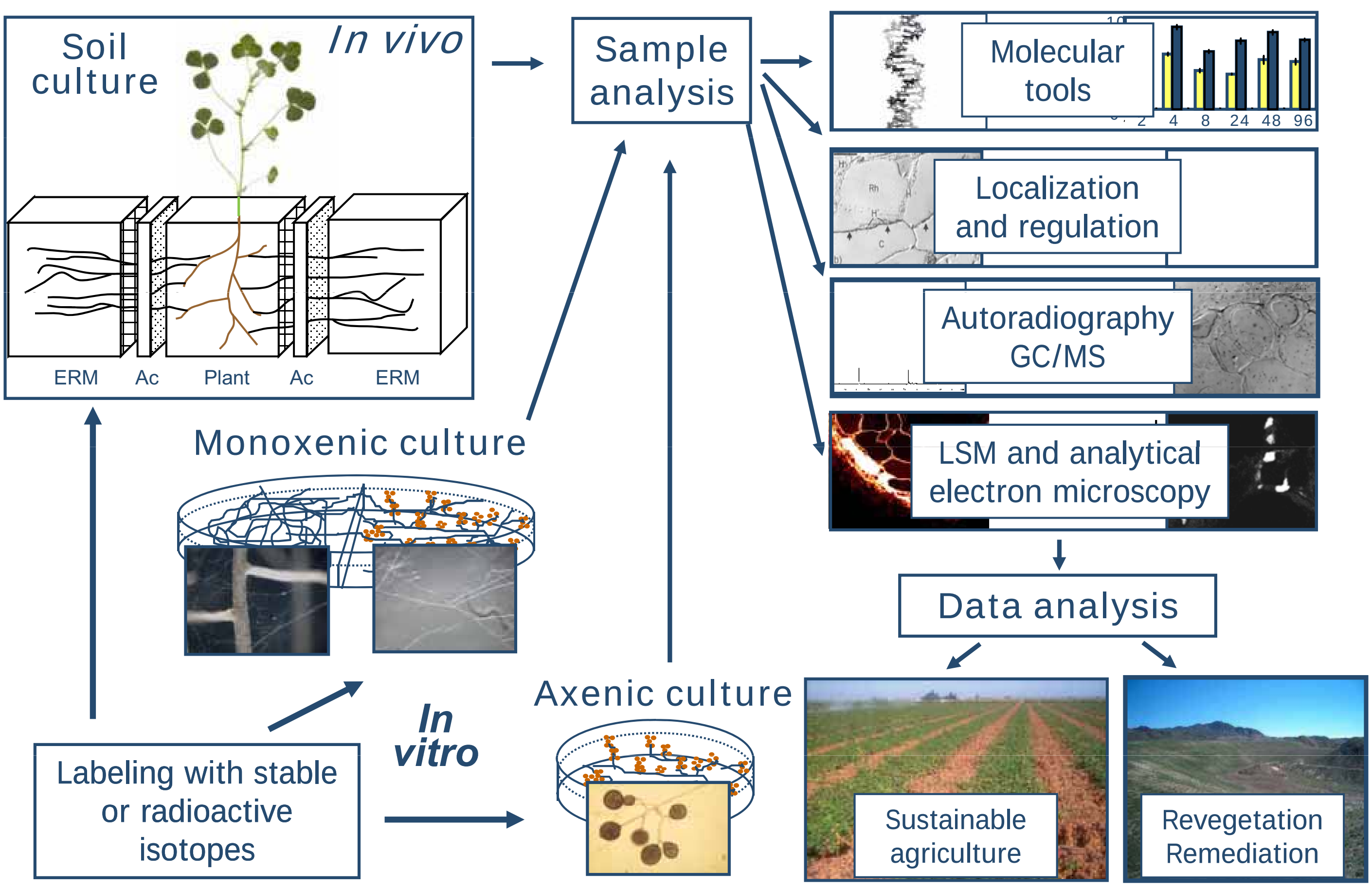
Why do we need mycorrhizal research?

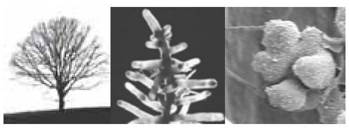
We need to better understand:

- Regulation of transport processes (beneficial nutrient transport in relation to the carbon costs for the plant)
- Complex role of arbuscular mycorrhizal fungi in resource allocation
- Partner choice in mycorrhizal systems
- Effects of mycorrhizal colonization on the nutritional value
- Interactions between arbuscular mycorrhizal fungi and root pathogen under field conditions
- P management

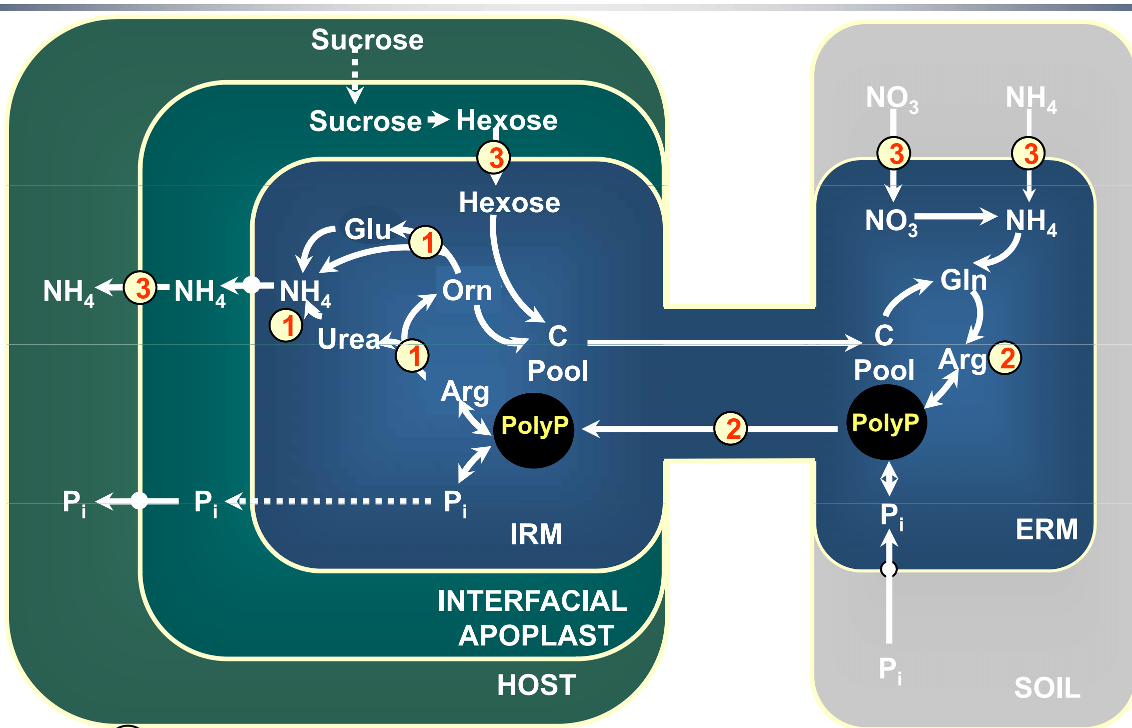


Studying metabolism and transport in arbuscular and ectomycorrhizal associations





Nitrogen metabolism and transport in the symbiosis

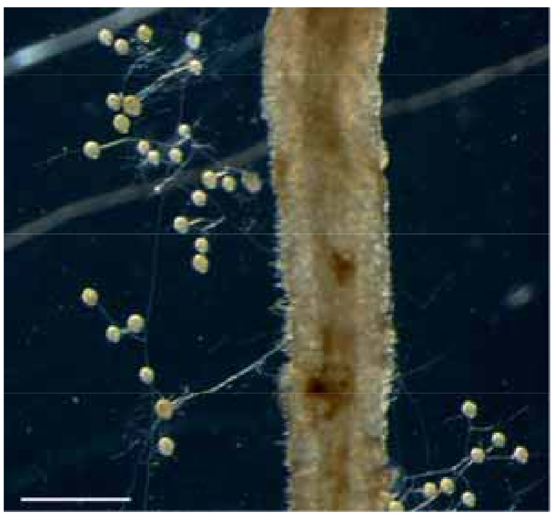


1 Activity and regulation of the urea cycle in the IRM

2 Interactions between the N and P flux in the symbiosis

3 Regulation of plant and fungal N transporters and interactions of C and N flux

Gene expression, in situ hybridization, labeling studies, GC/MS, microautoradiography, enzymatic assays, Western blots, EDXS

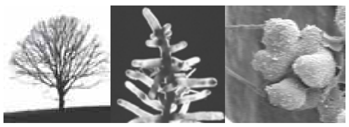


Maximal benefit of mycorrhizal fungi by:

- Inoculation with efficient mycorrhizal fungi
- Increase of activity by proper cultural practices

Cultural practices that increase the activity

- Reduced tillage
- Crop rotations
- Cover crops
- Phosphorus management



Collaborators

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- Philip E. Pfeffer, USDA – Wyndmoor
- Peter Lammers, New Mexico State University
- Toby Kiers, University Amsterdam

Thanks for your attention