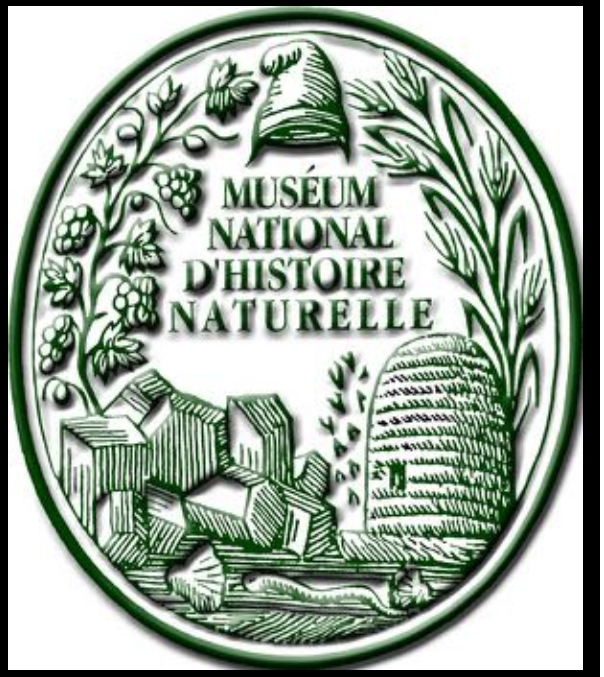
La plante, entre holobionte et réseaux d'interactions



M.-A. SELOSSE

Muséum nat. d'Histoire naturelle, Paris

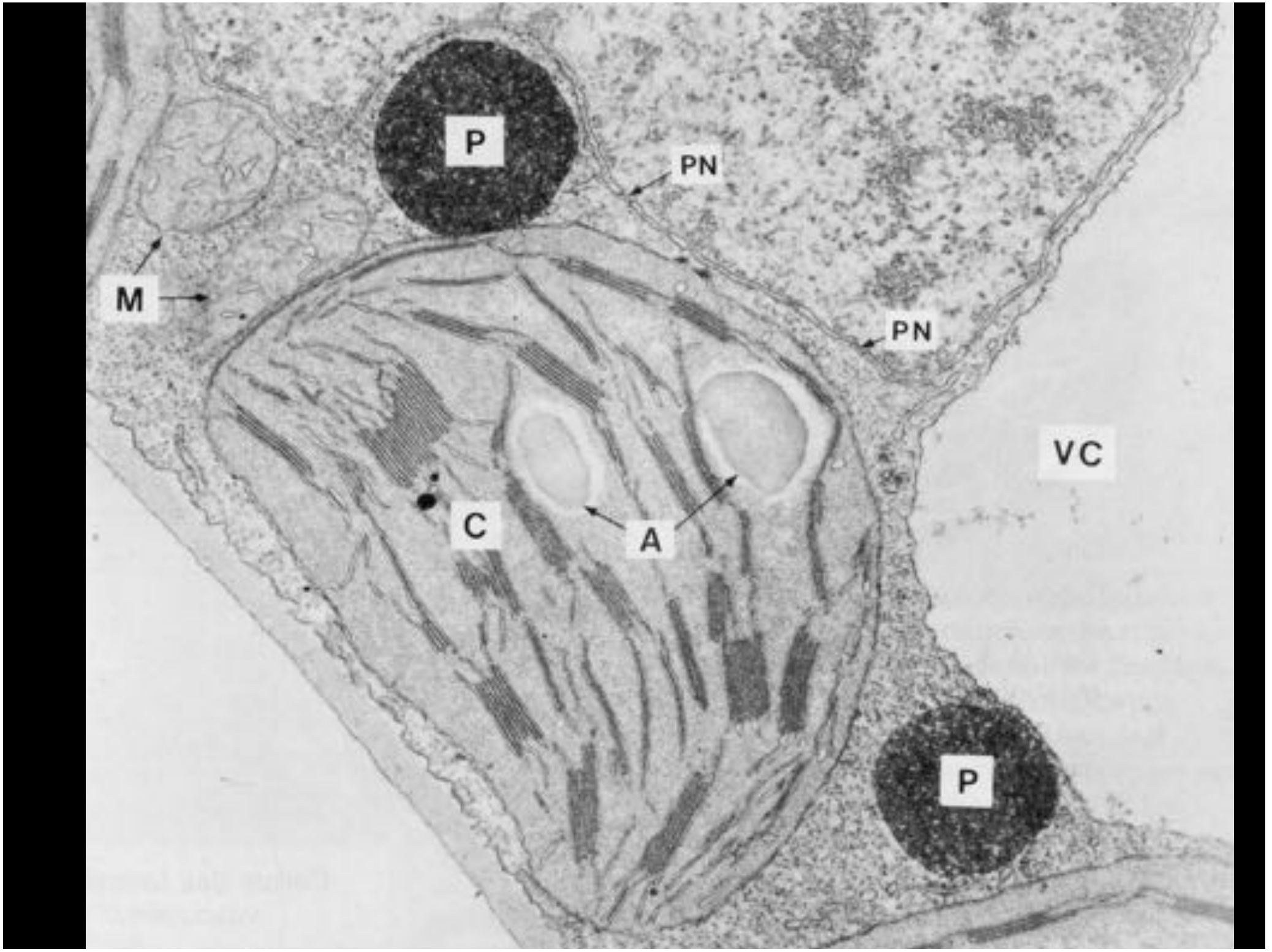
Universities of Gdansk (Poland) & Viçosa (Brazil)

Microbiotique par essence

Microbiote et nutrition

Microbiote et défense

De l’holobionte au réseau


P
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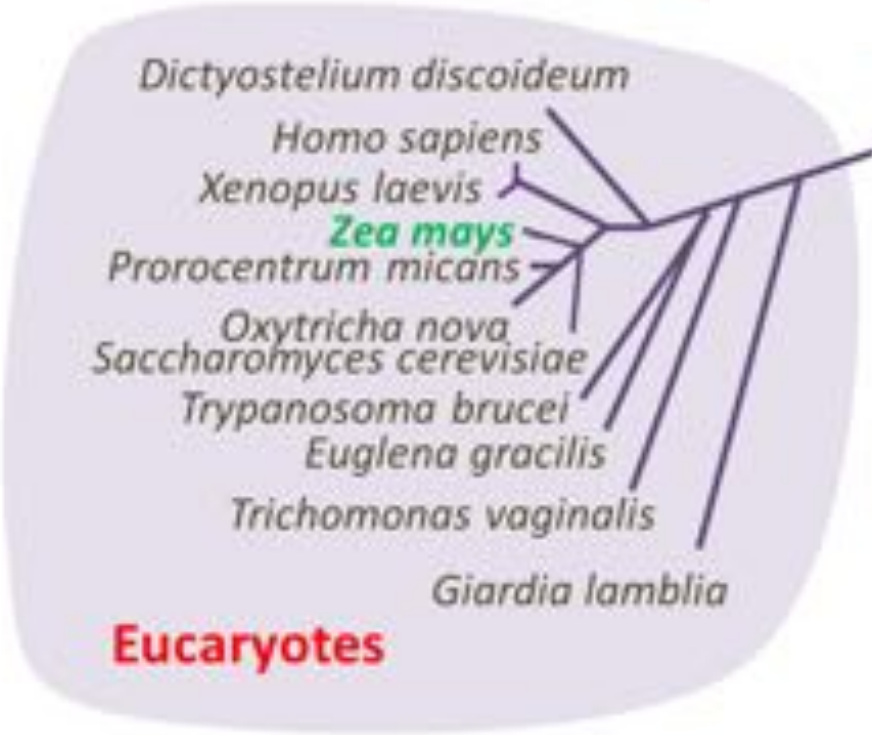
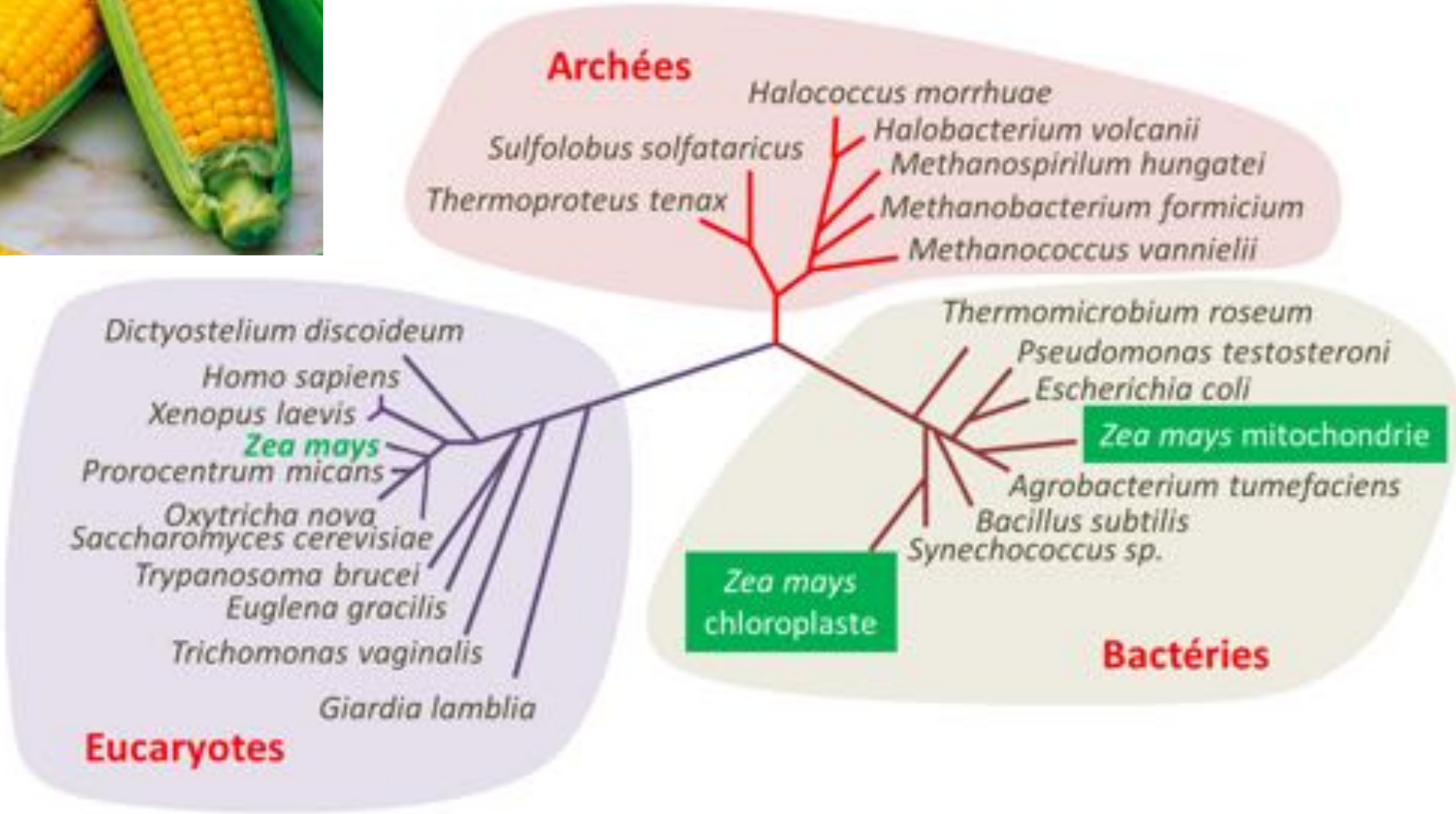
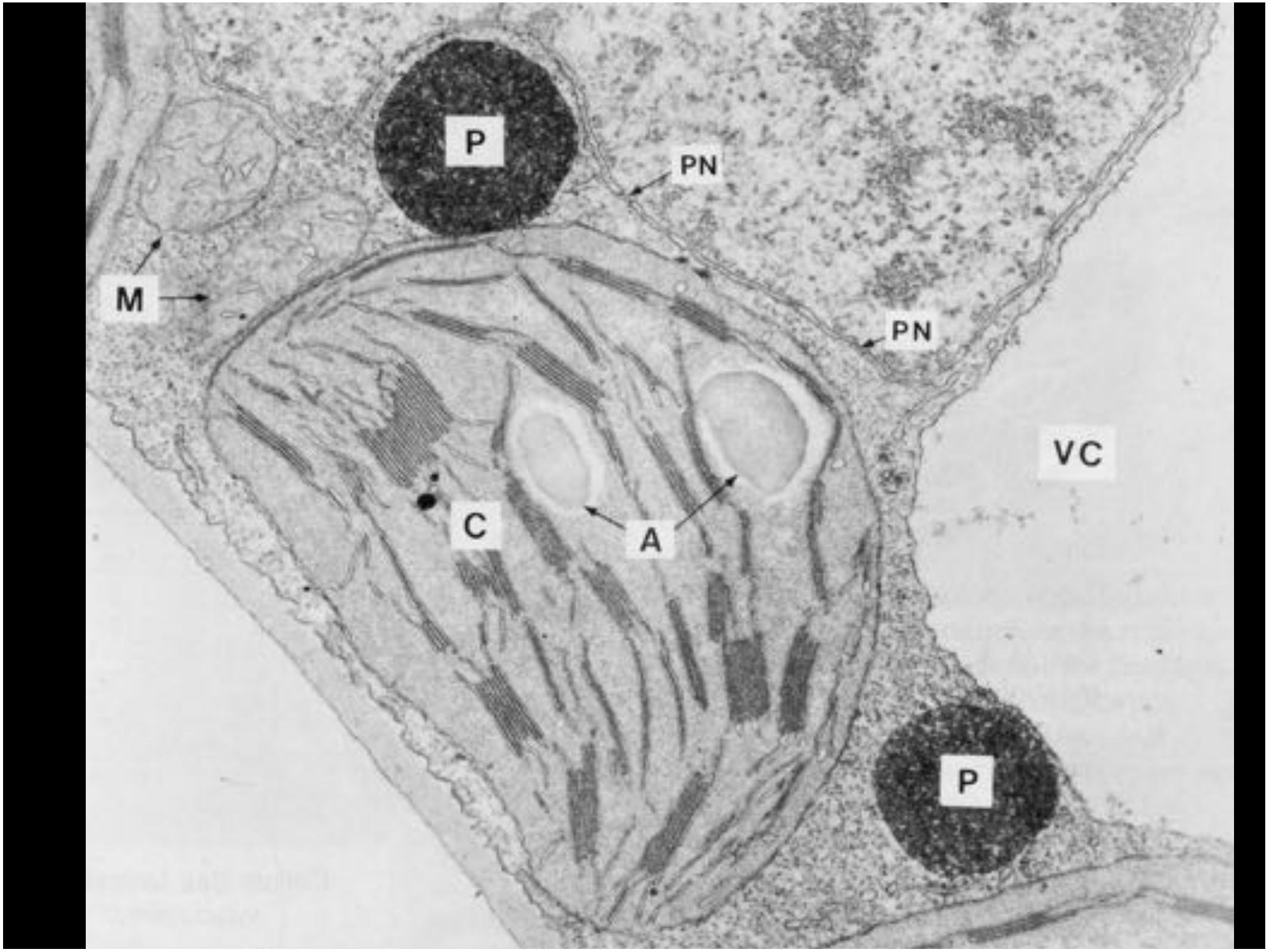

Dictyostelium discoideum
Homo sapiens
Xenopus laevis
Zea mays
Prorocentrum micans
Oxytricha nova
Saccharomyces cerevisiae
Trypanosoma brucei
Euglena gracilis
Trichomonas vaginalis
Giardia lamblia
Eucaryotes


Archées
Halococcus morrhuae
Halobacterium volcanii
Sulfolobus solfataricus
Methanospirilum hungatei
Thermoproteus tenax
Methanobacterium formicium
Methanococcus vannielii
Thermomicrobium roseum
Pseudomonas testosteroni
Escherichia coli
Zea mays mitochondrie
Agrobacterium tumefaciens
Bacillus subtilis
Synechococcus sp.
Zea mays chloroplaste
Bactéries
Dictyostelium discoideum
Homo sapiens
Xenopus laevis
Zea mays
Prorocentrum micans
Oxytricha nova
Saccharomyces cerevisiae
Trypanosoma brucei
Euglena gracilis
Trichomonas vaginalis
Giardia lamblia
Eucaryotes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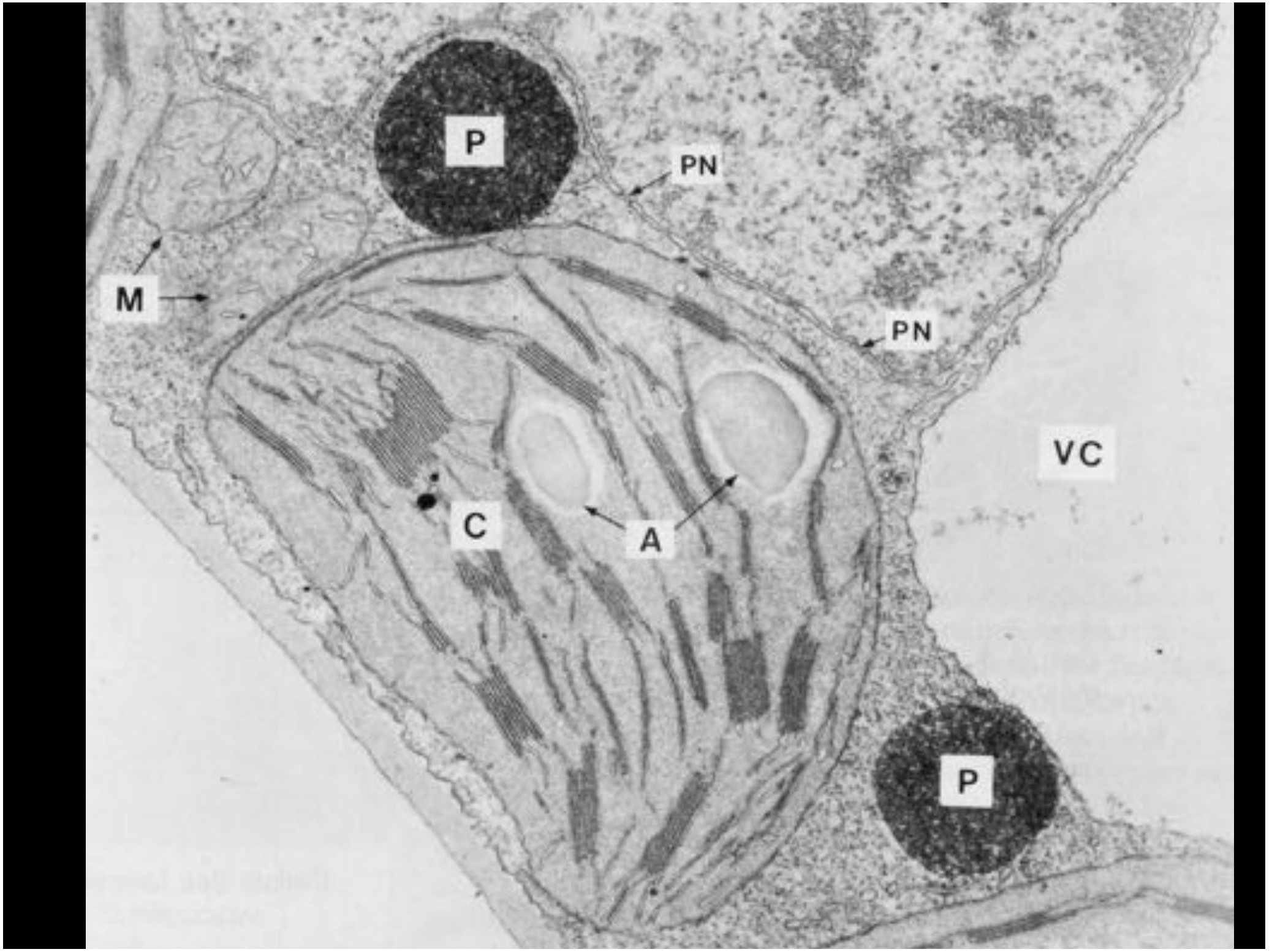
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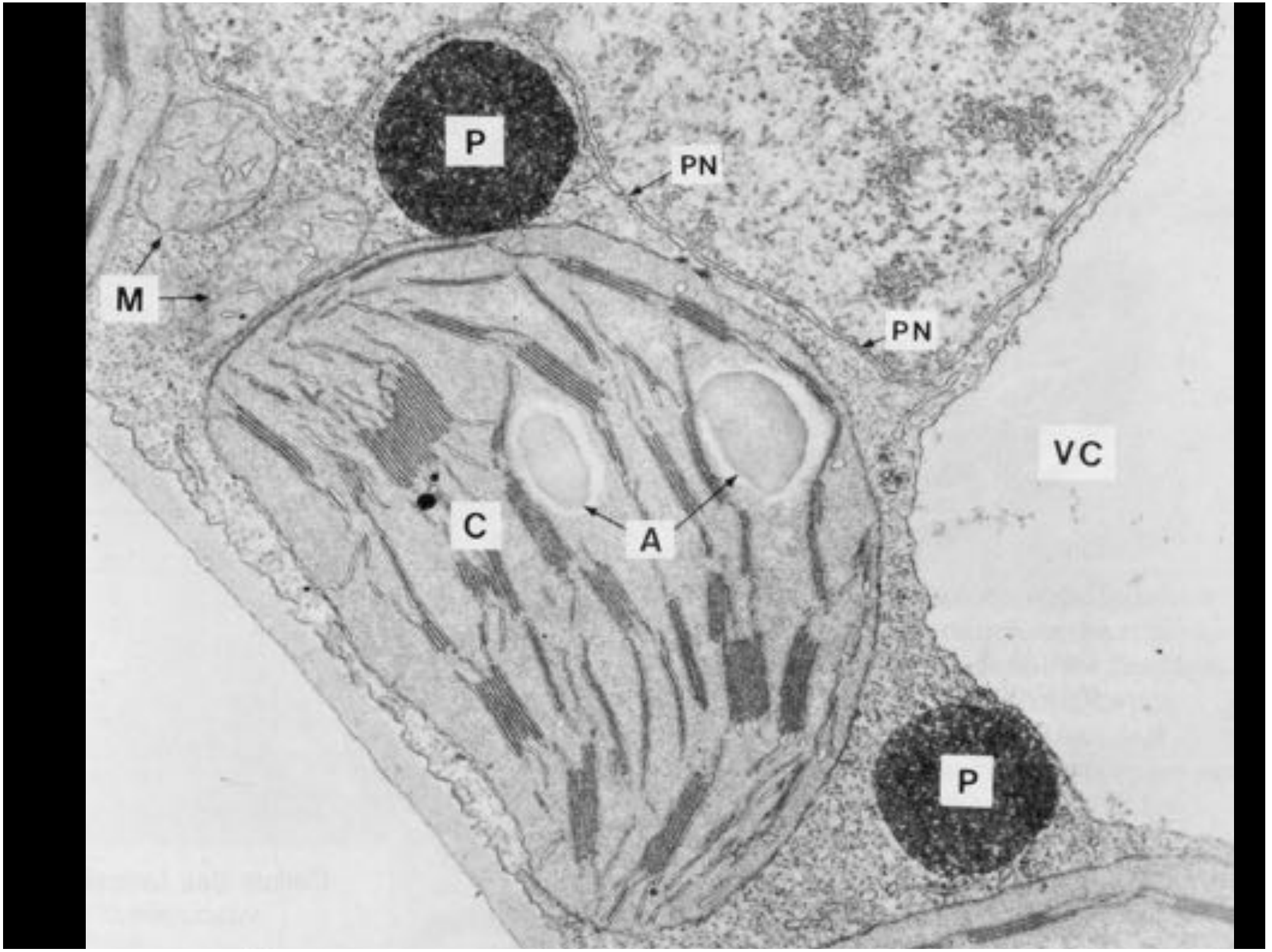
P

Espèce :	**Nombre de gènes nucléaires total**	**% d'origine cyanobactérienne**
Arabidopsis thaliana (Embryophytes)	30 897	8,9 %
Oryza sativa (Embryophytes)	26 712	8,7 %
Physcomitrella patens (Embryophytes)	35 468	10,2 %
Chlamydomonas reinhardtii (Lignée Verte)	14 262	10,6 %
Cyanidioschyzon merolae (Rhodophytes)	4 761	11,4 %
Ostreococcus tauri (Hétérocontes)	7 715	11,5 %

Dagan *et al*. *2015*. Genome Biol. Evol. 5: 31–44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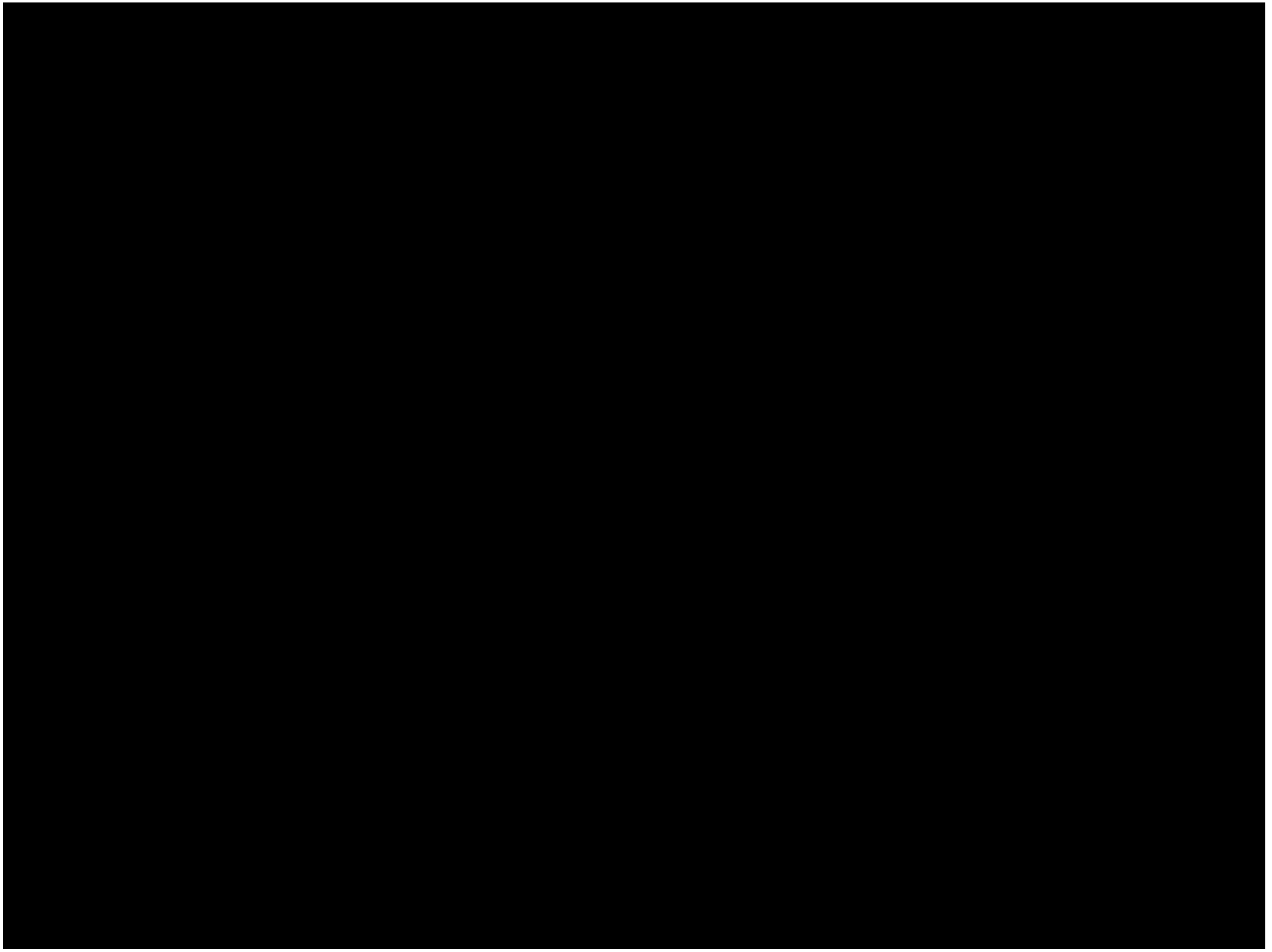
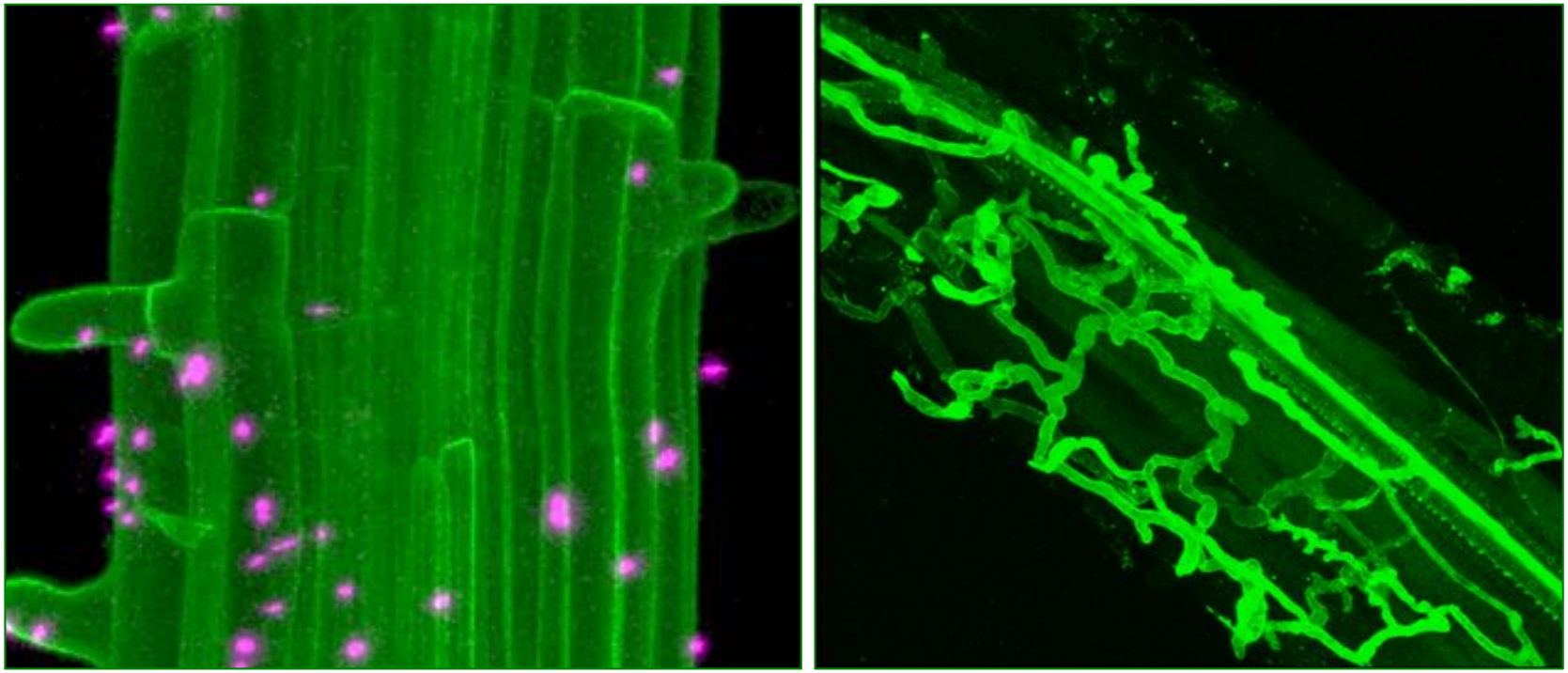
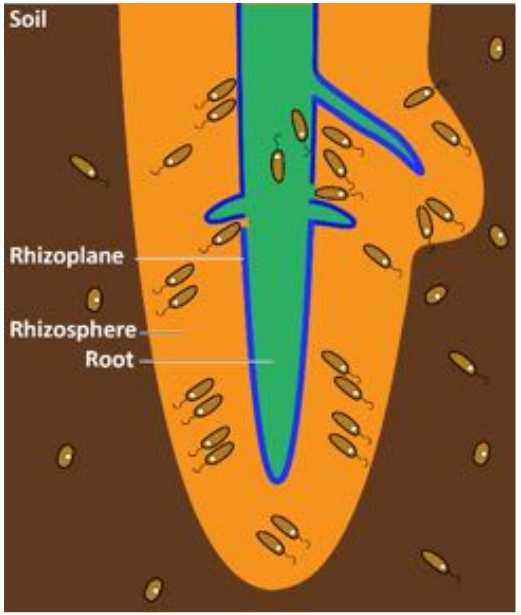


Bacteria (V5-V6) Fungi (ITS1) Oomycetes (ITS1-O)

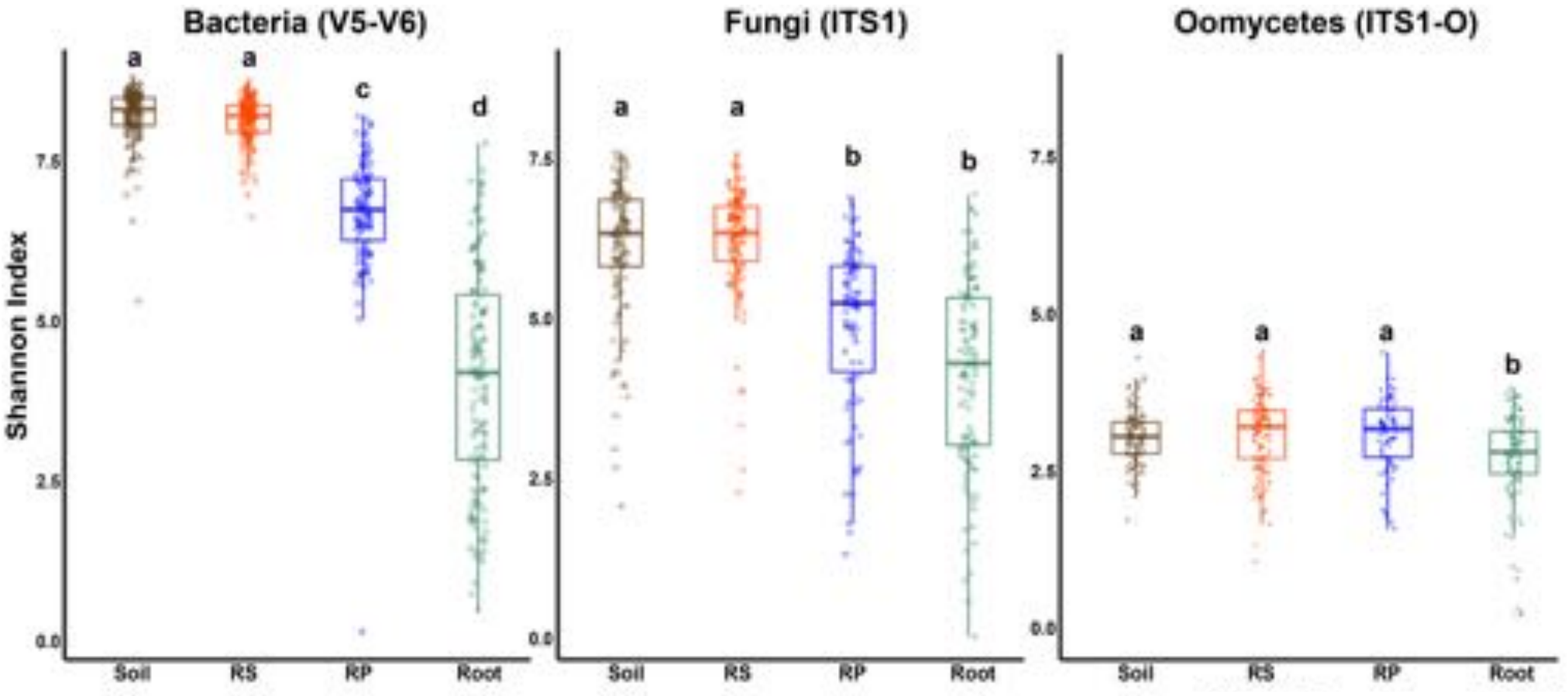


SOIL RHIZO-SPHERE RHIZO-PLANE ROOT

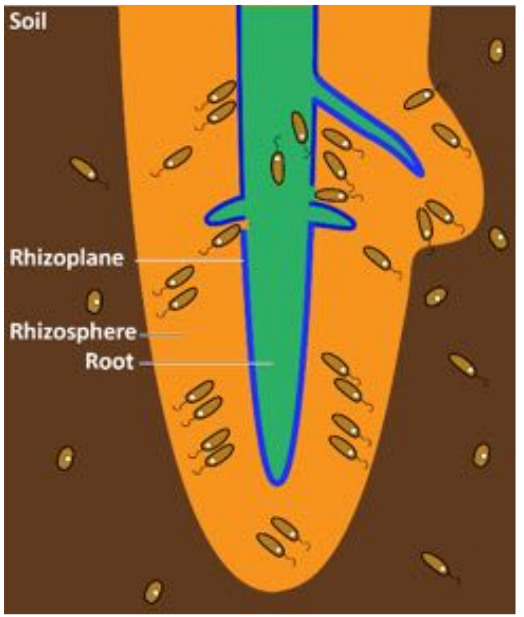


***A. thaliana* root microbiota in Europe**

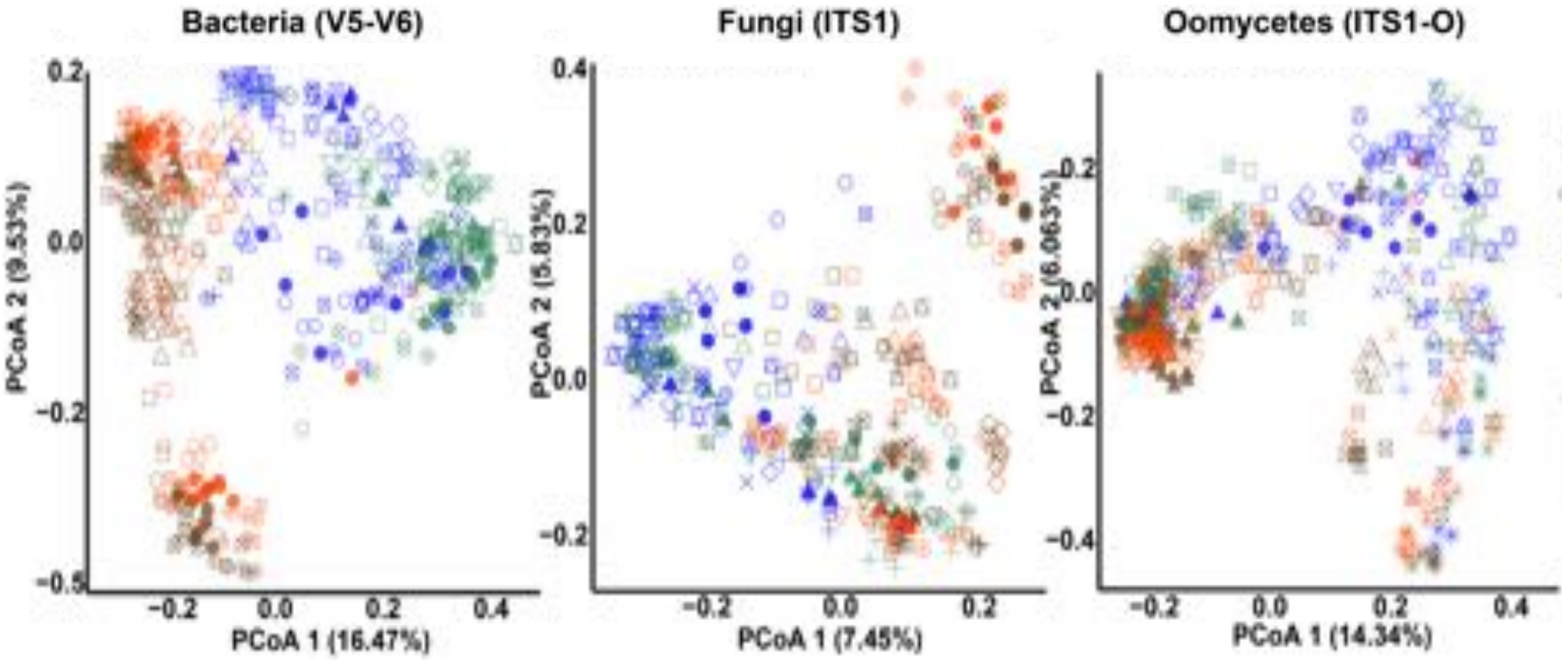
Stéphane Hacquart & Paloma Duran
(Max Planck Institute), in press



SOIL **RHIZO-SPHERE** **RHIZO-PLANE** **ROOT**

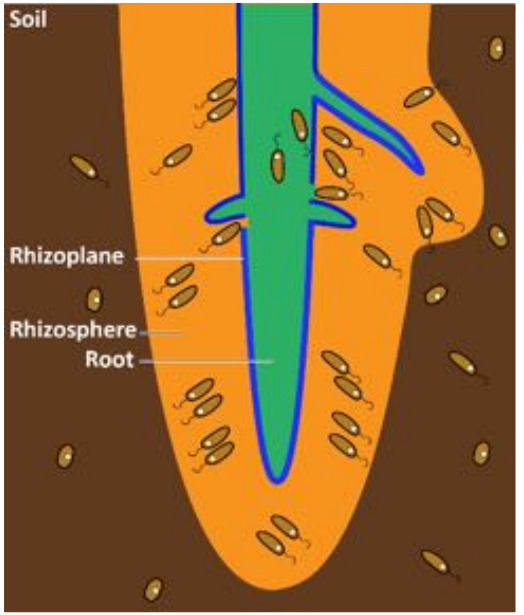


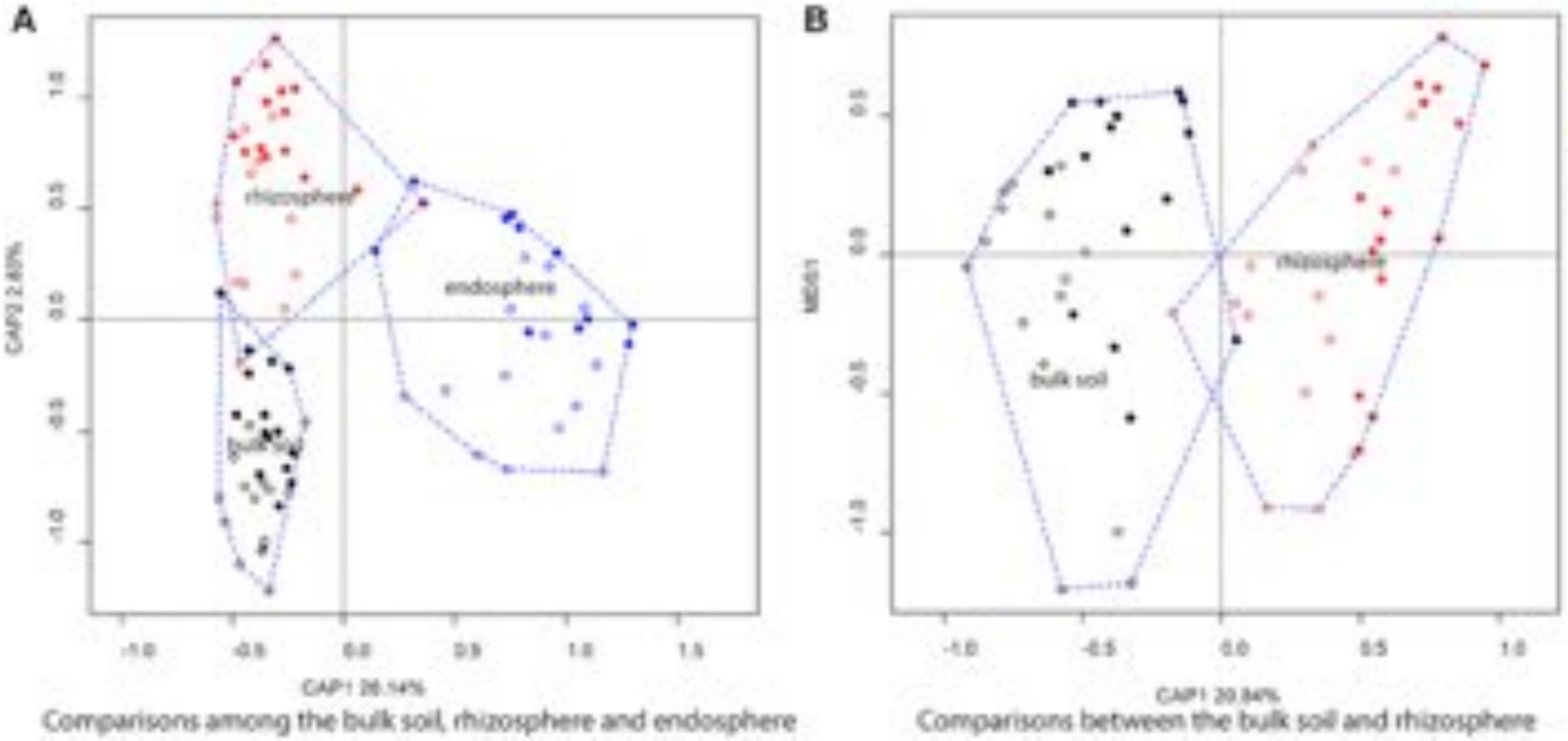
- Diversité des communautés bactériennes et “fongiques” décroissant du sol à la racine: effet de filtration de la communauté.



SOIL **RHIZO-SPHERE** **RHIZO-PLANE** **ROOT**

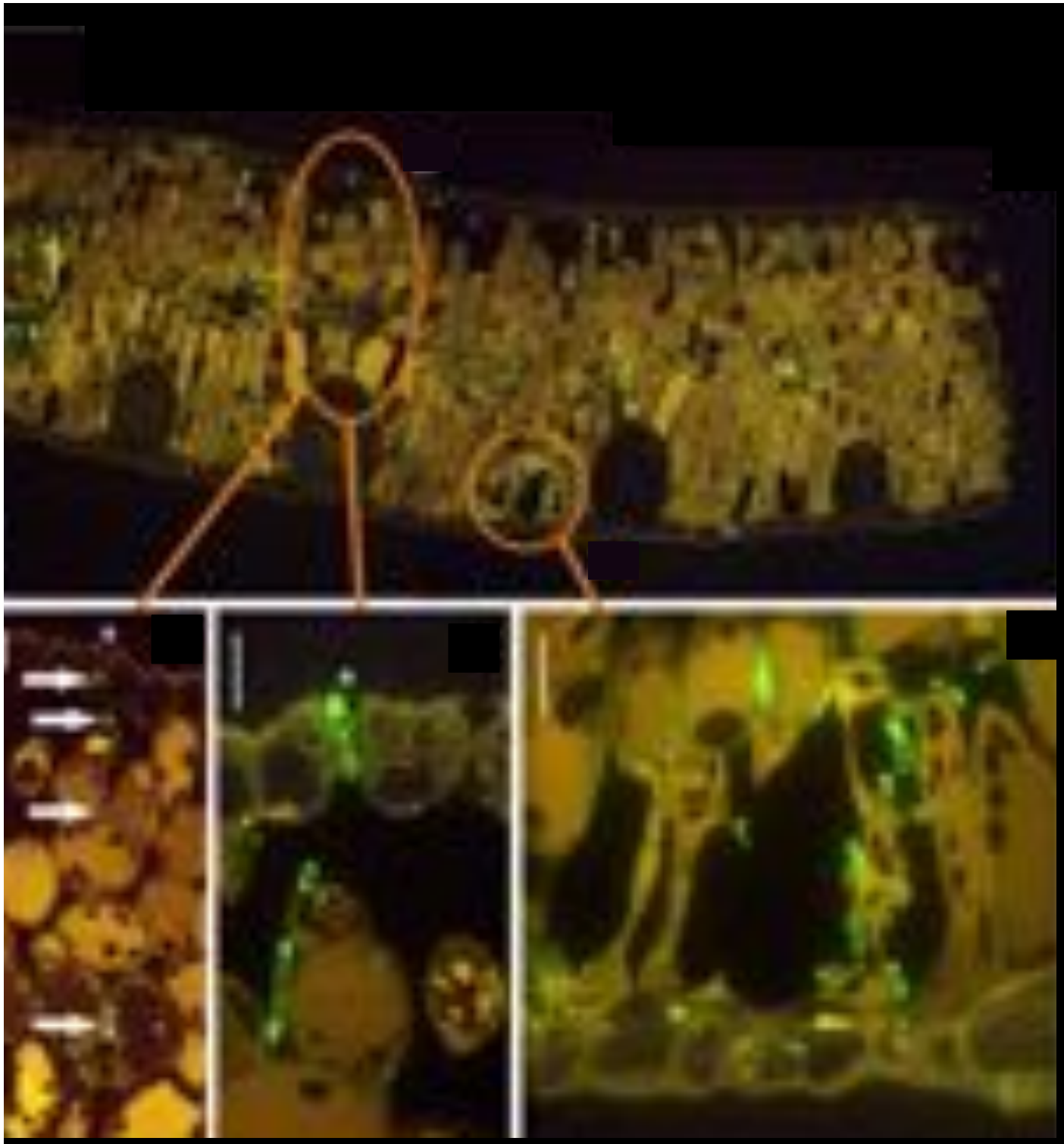
- Communautés bactériennes convergentes du sol à la racine, malgré la variabilité édaphique, mais effet moindre pour les organismes filamenteux





Limonium vulgare **sur schorre à Schiermonnikoog (Pays-Bas). Communautés bactérienne du sol brut (*bulk soil*), de la rhizosphere, avec (A) ou sans (B) le compartiment intra-racinaire (endosphere).**

Wand *et al.* 2015, Front. Pl. Sci. 6: 1188.



Une hyper-diversité foliaire ignorée…

Jusqu’à une centaine d’espèce de champignons endophytes dans une feuille en milieu tropical !

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L'ECTOMYCORHIZE

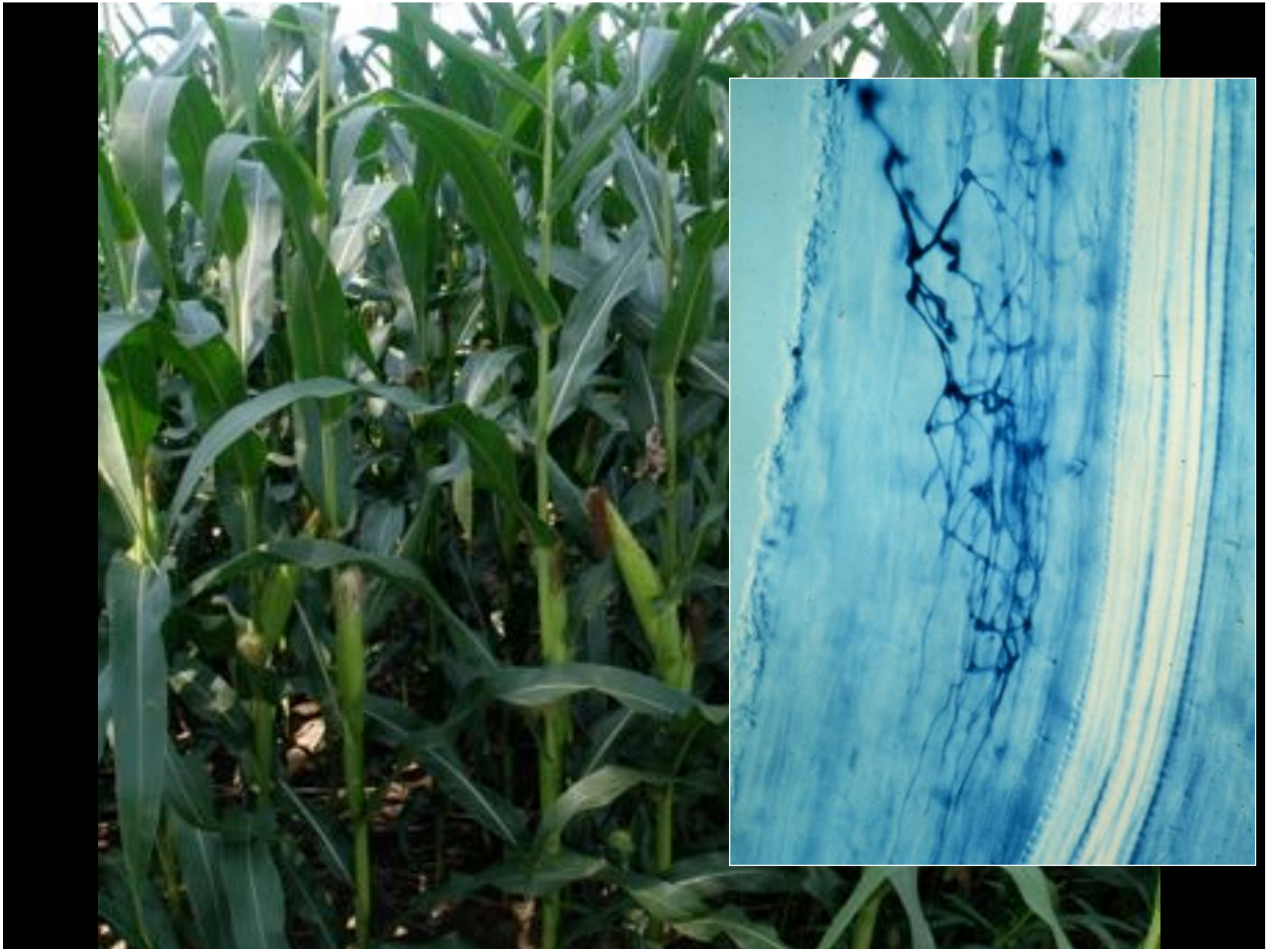
L’ECTOMYCORHIZE

L'ECTOMYCORHIZE

5% plantes
(surtout ligneuses tempérées)
sont ectomycorhizées

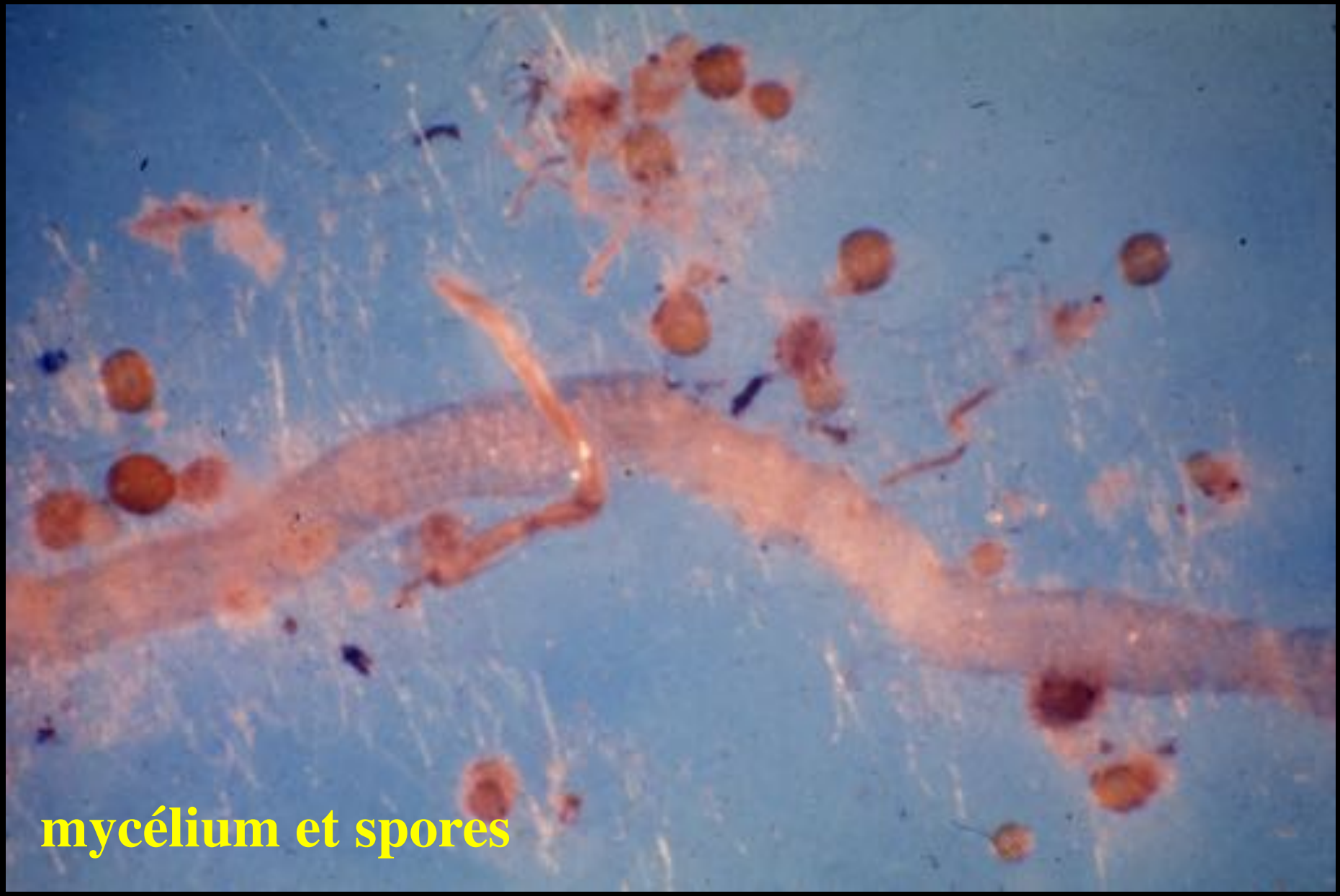
5% plantes
(surtout ligneuses tempérées)
sont ectomycorhizées

80% des plantes
(moy. sous toutes les latitudes)
sont endomycorhizées

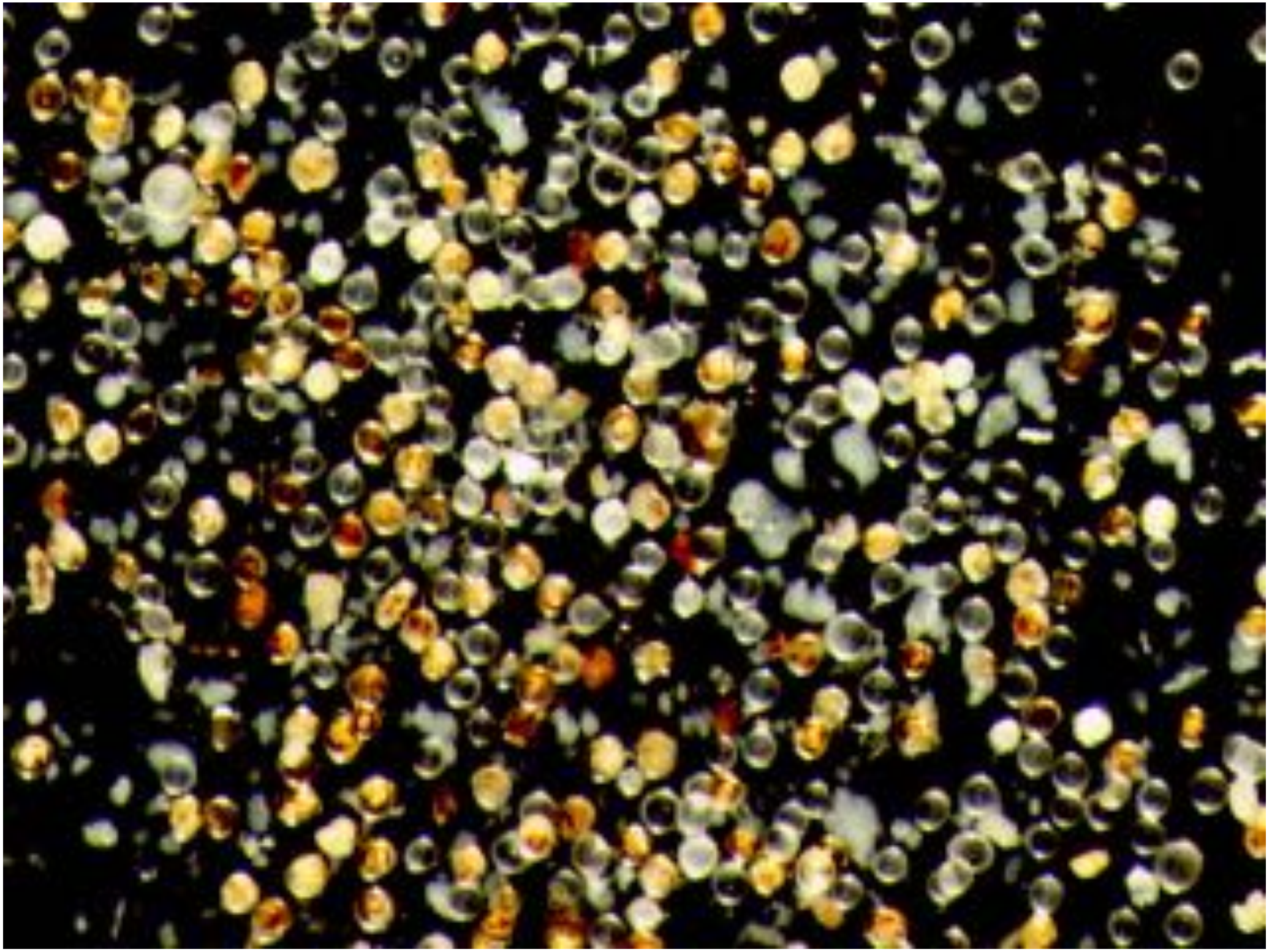


L'ENDOMYCORHIZE

L'ENDOMYCORHIZE



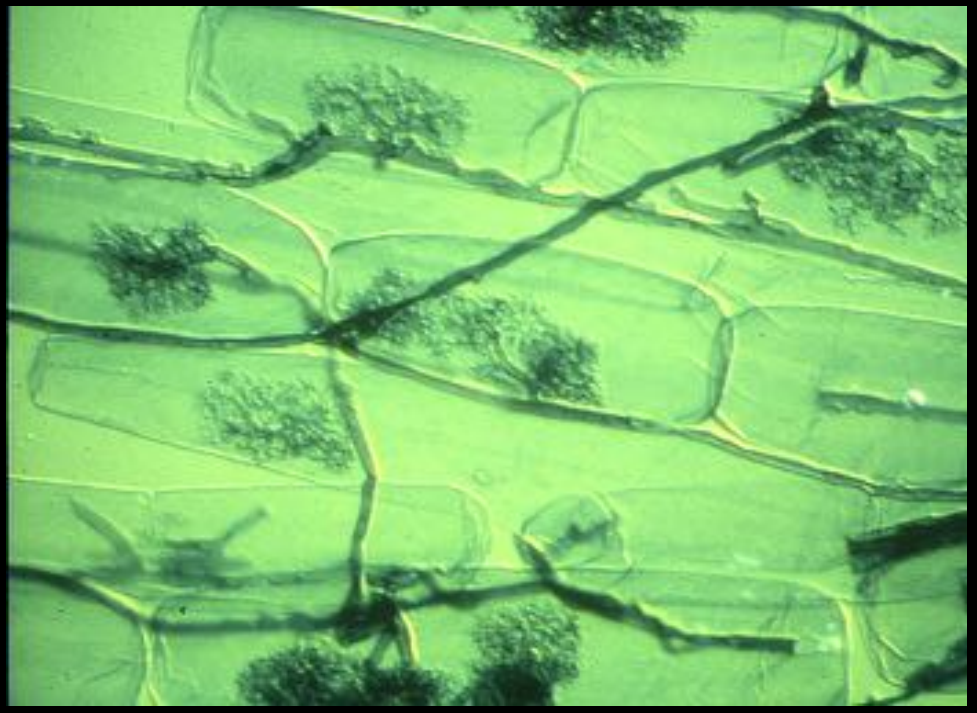
mycélium et spores



L'ENDOMYCORHIZE

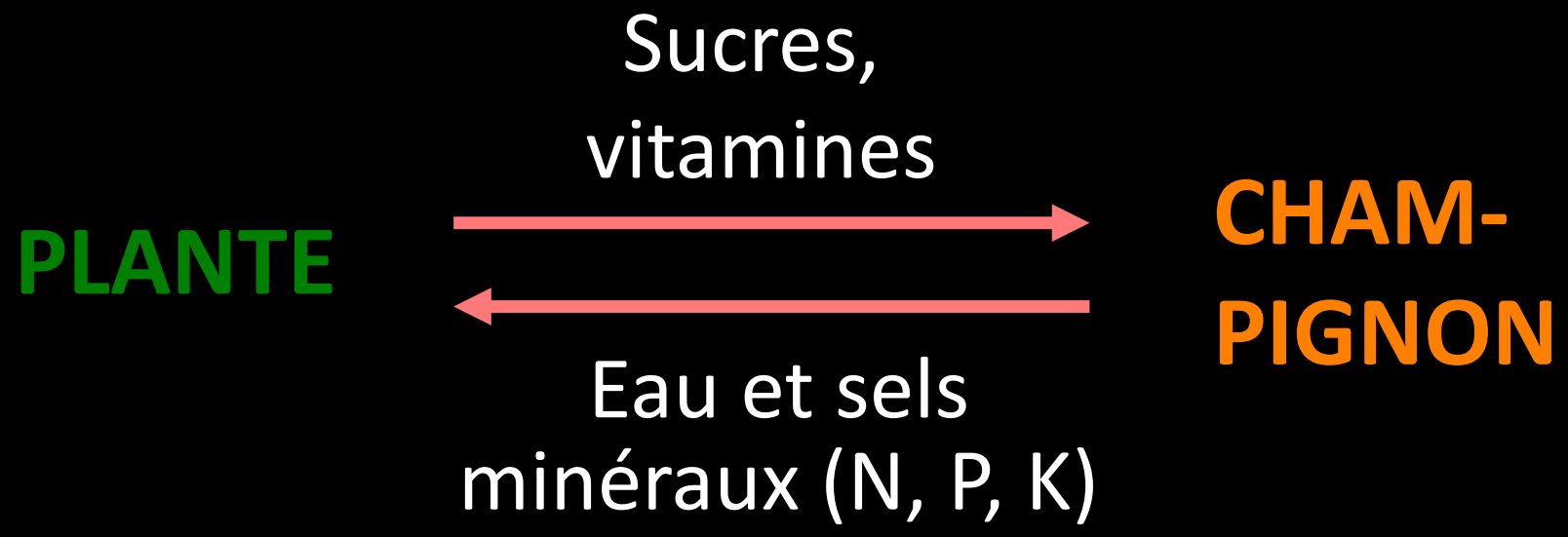
− +

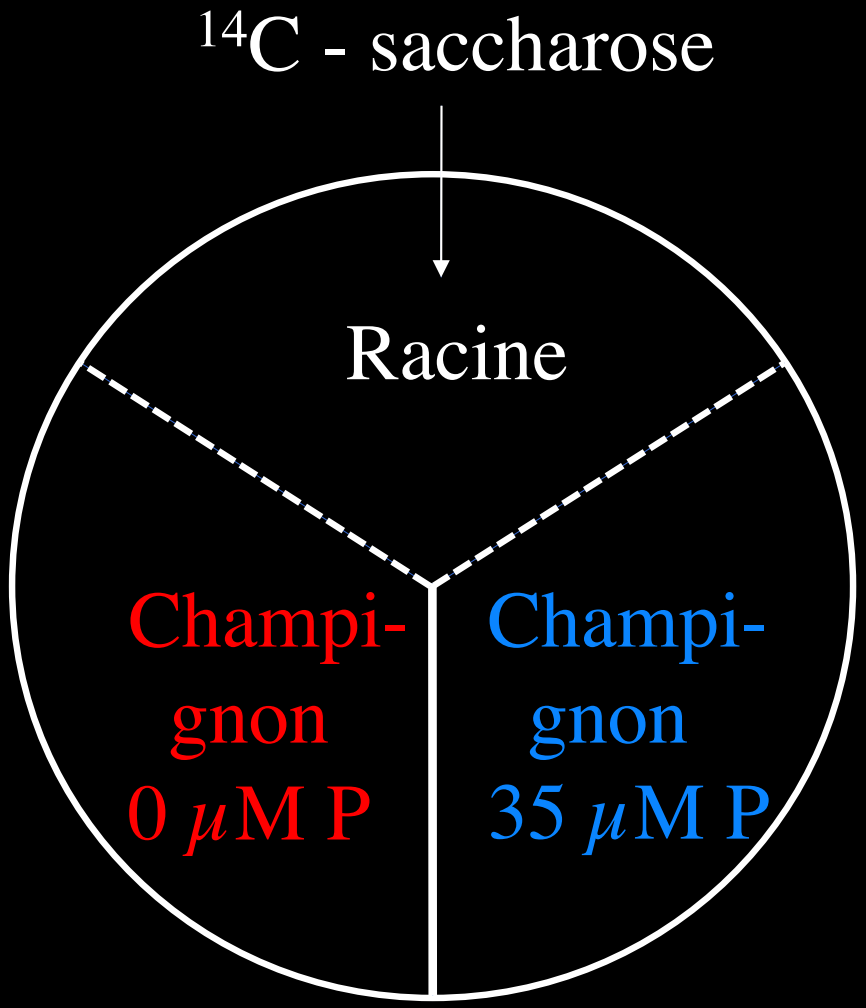
LA MYCORHIZE, UNE SYMBIOSE

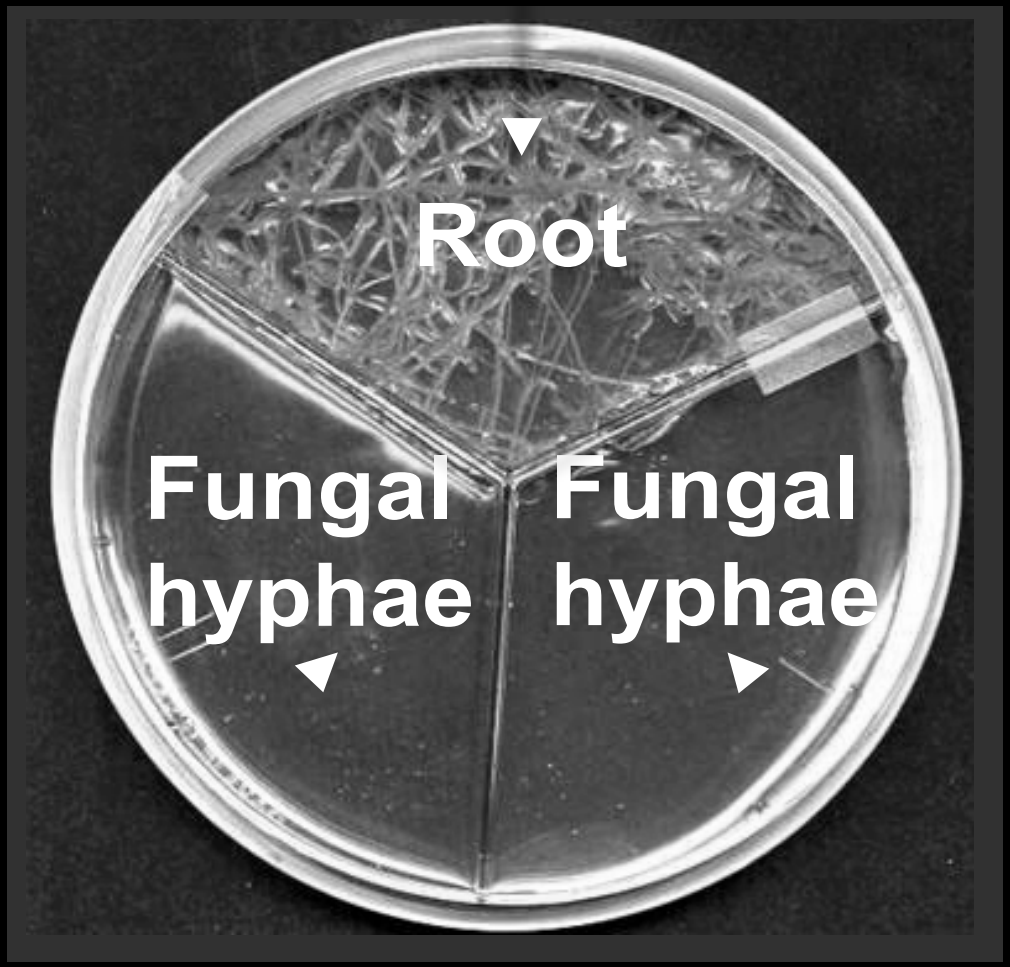


Un organe mixte racine+champignon, présent chez 90% des plantes

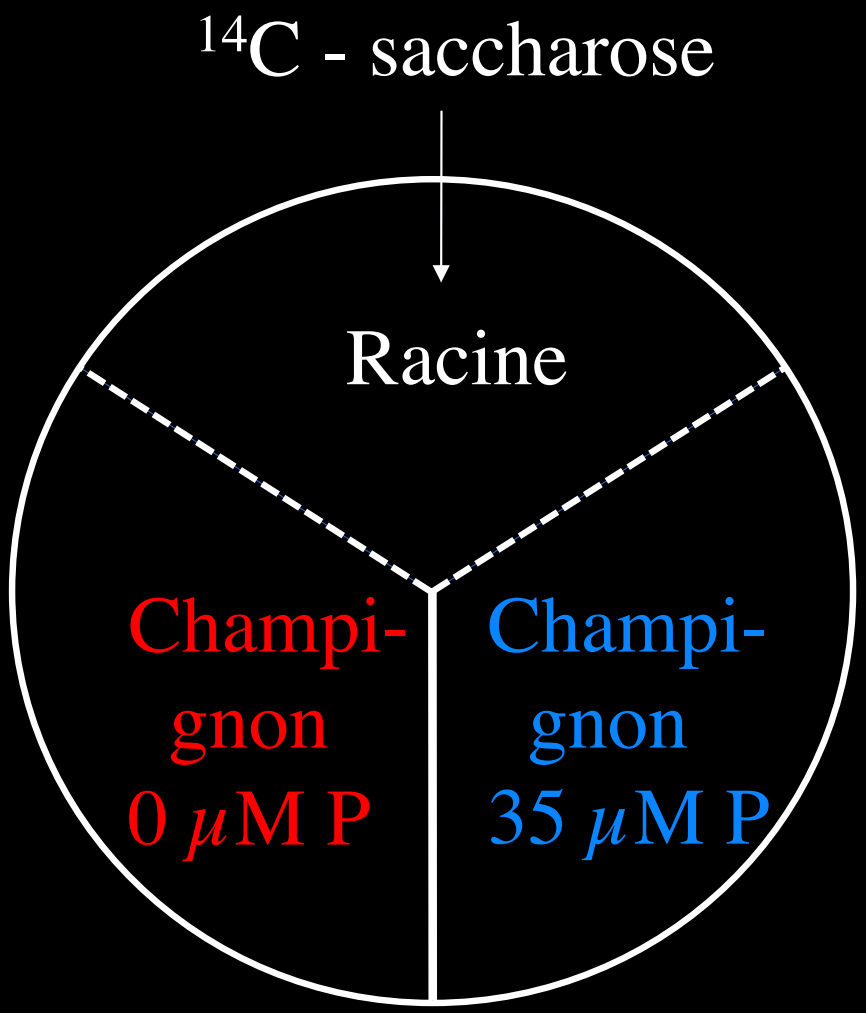
LA MYCORHIZE, UNE SYMBIOSE chez 90 % des plantes terrestres



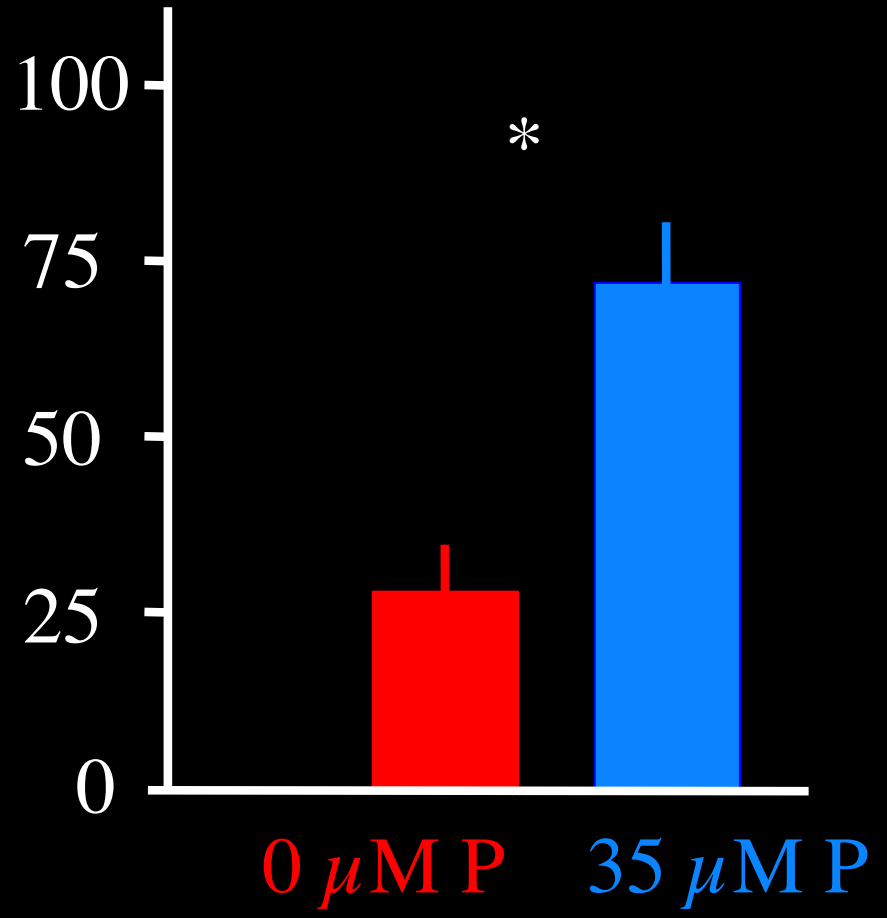




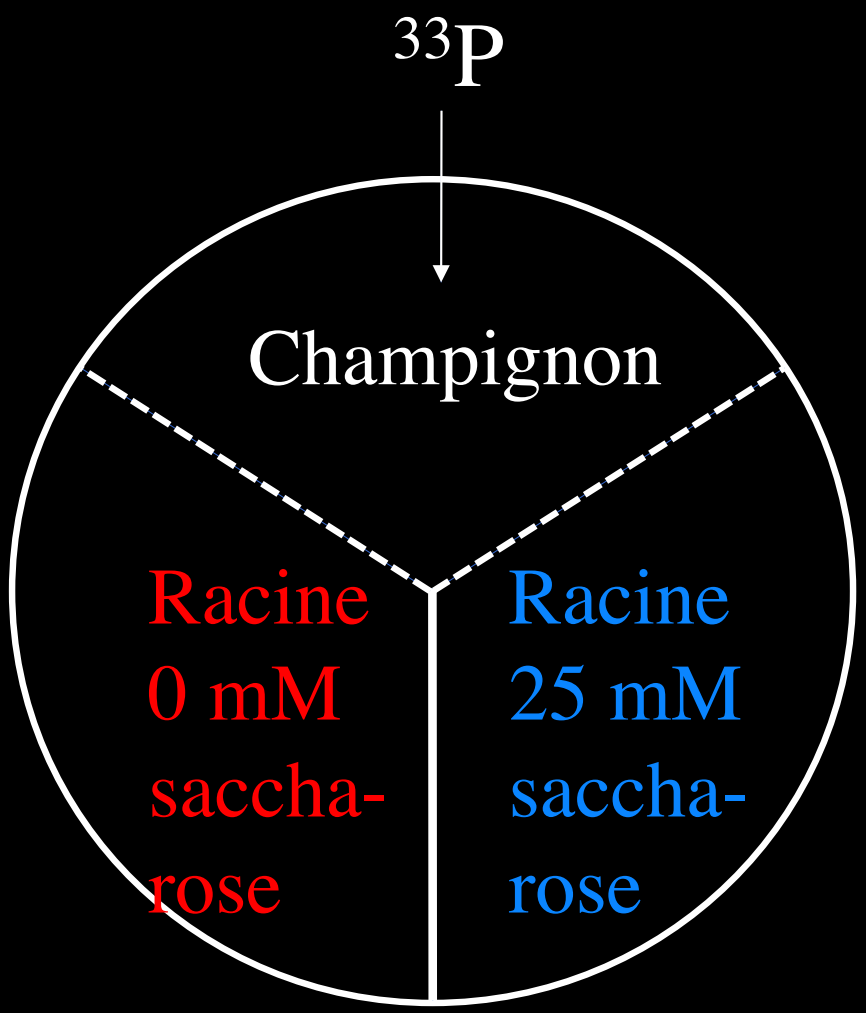
Kiers *et al*. 2011, *Science* 333, 880
Selosse & Rousset 2011, *Science* 333, 828

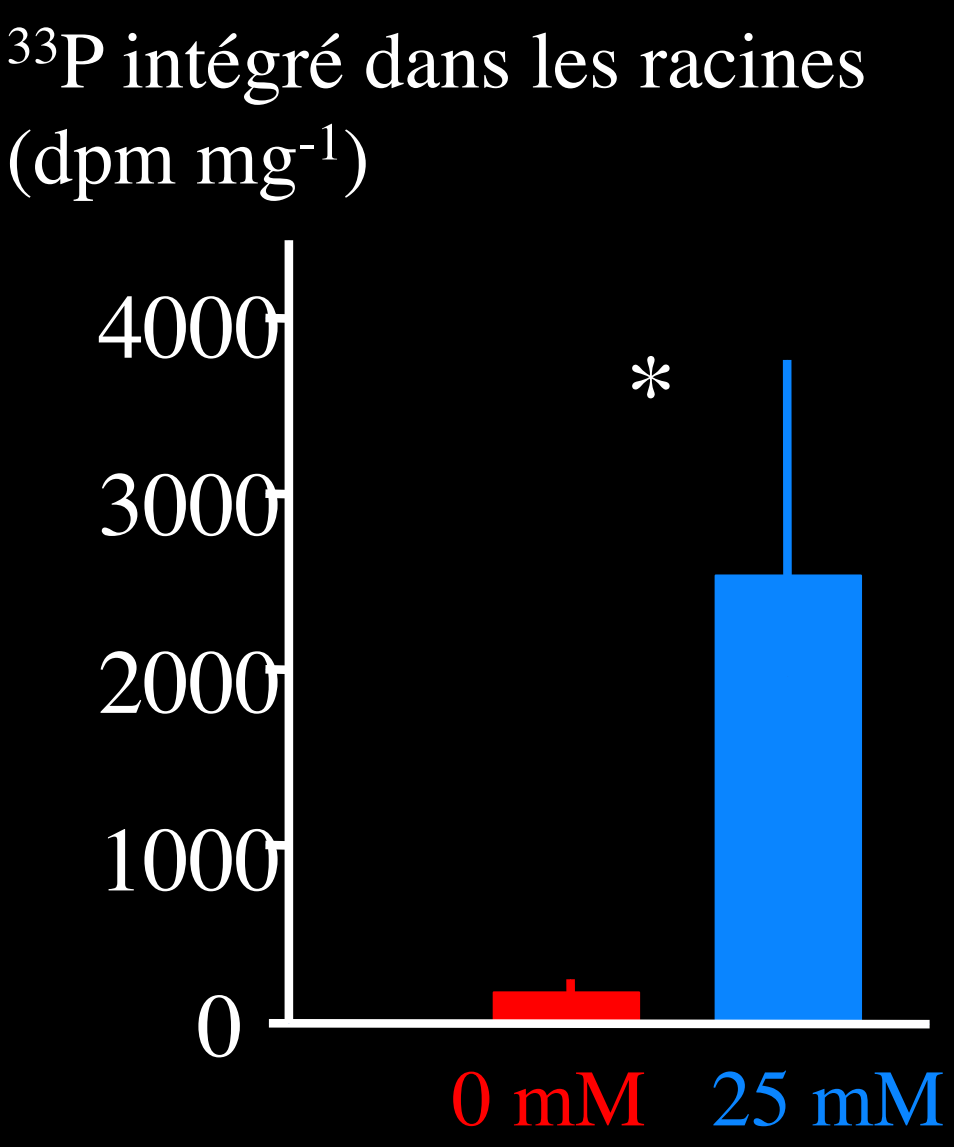


^{14}C alloué à chaque champignon
(% du total transféré)



Kiers *et al*. 2011, *Science* 333, 880
Selosse & Rousset 2011, *Science* 333, 828





Kiers *et al*. 2011, *Science* 333, 880
Selosse & Rousset 2011, *Science* 333, 828

Microbiotique par essence

Microbiote et nutrition

Microbiote et défense

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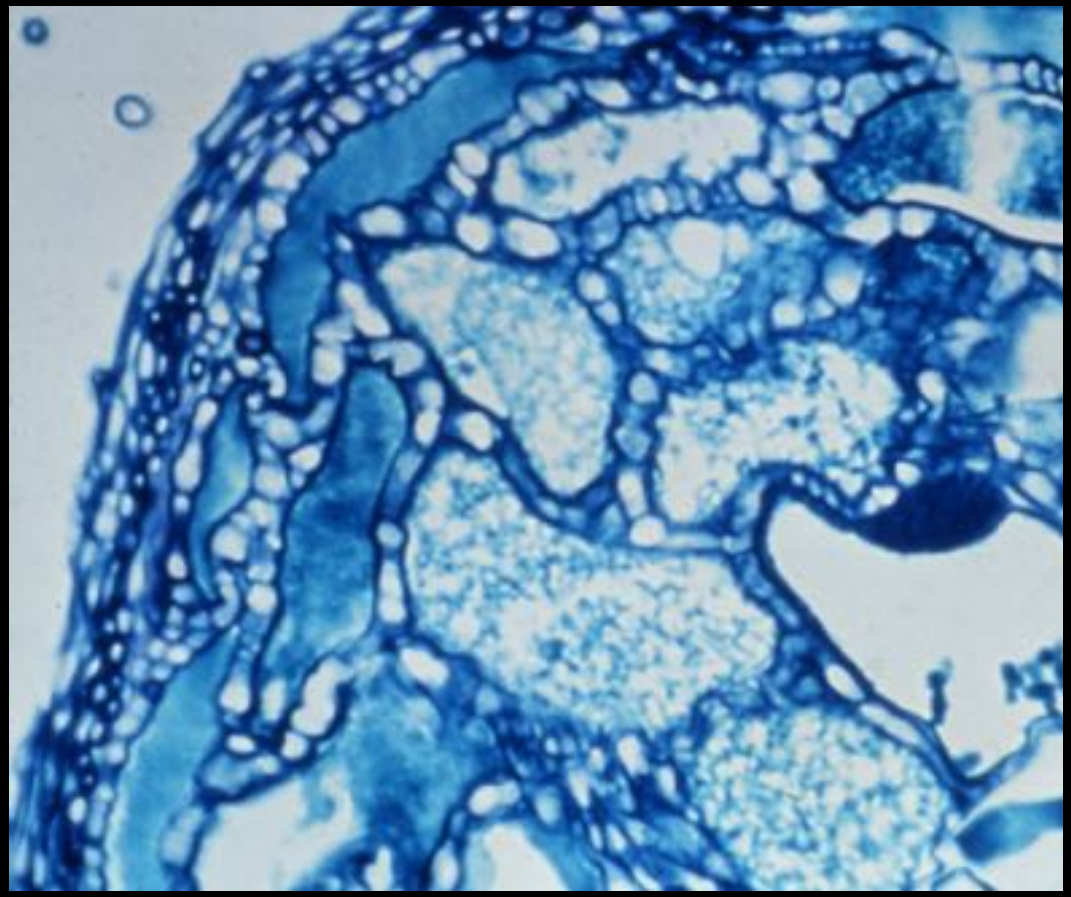
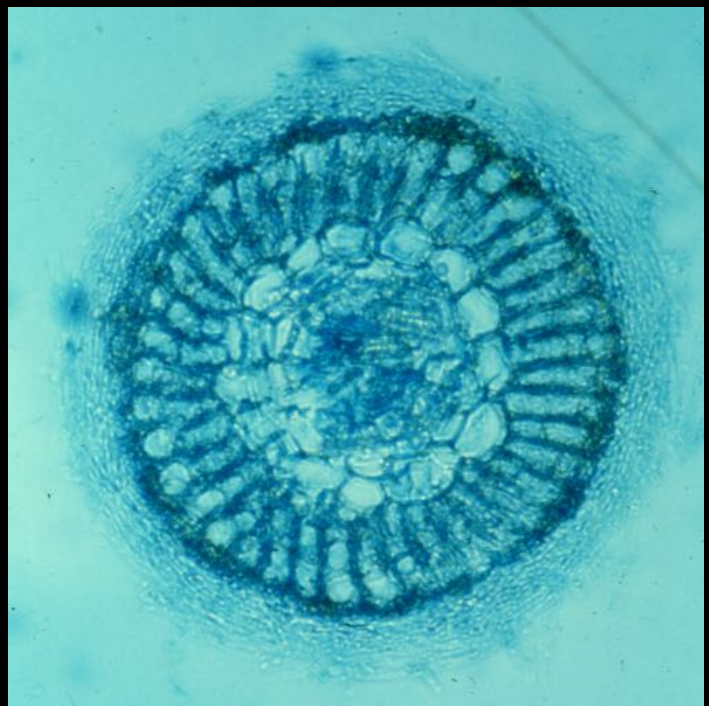
Protection contre *Botrytis cinerea*





Protection contre *Botrytis cinerea*

Non mycor.

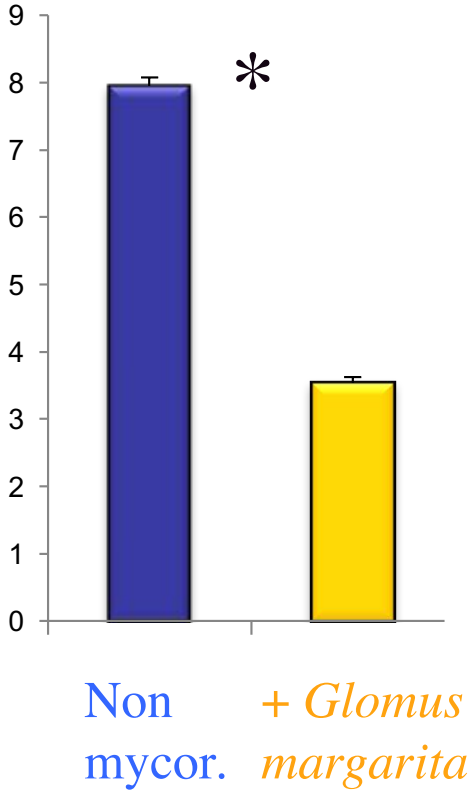
+ *Glomus margarita*

Protection contre *Botrytis cinerea*

Non mycor.

+ *Glomus margarita*

Dégâts
(% feuilles abimées)

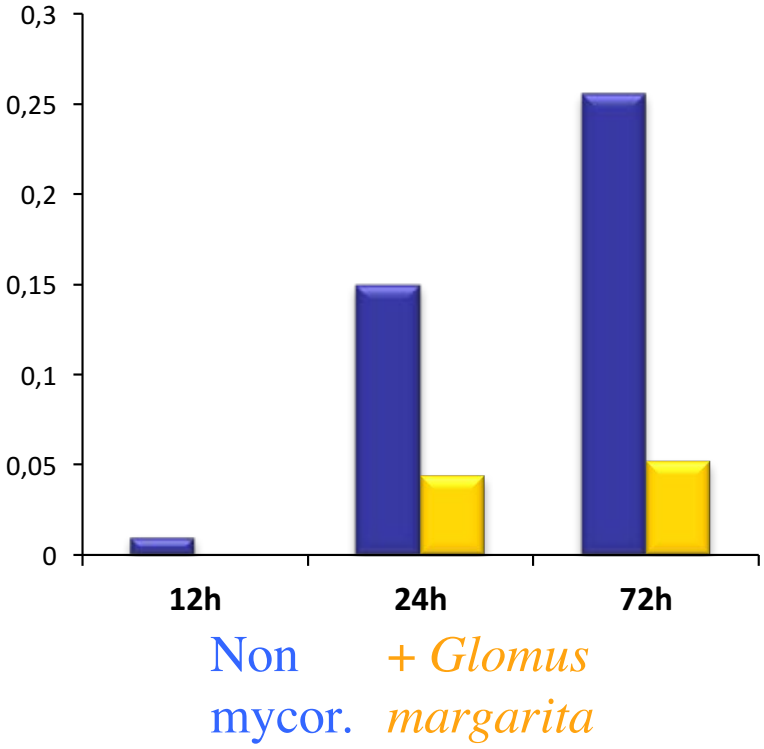


Protection contre *Botrytis cinerea*

Non mycor.

+ *Glomus margarita*

Expression du gène de tubuline de *Botrytis* (colonisation)

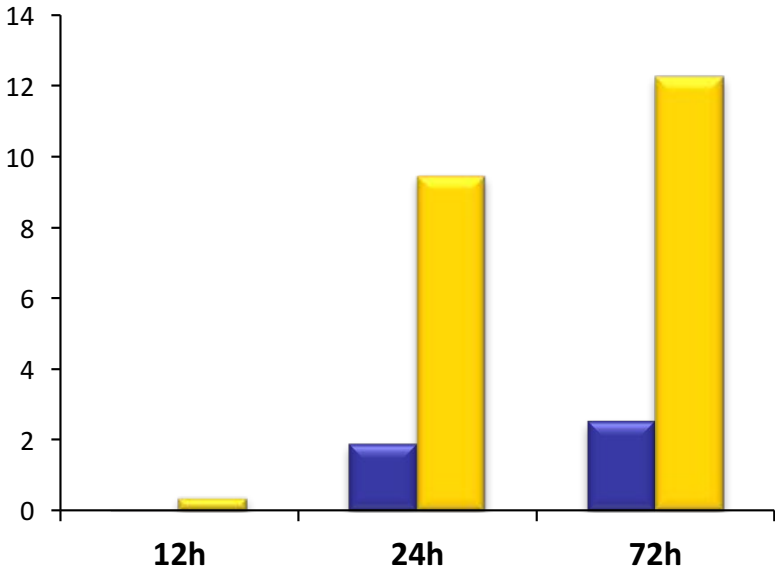


Protection contre *Botrytis cinerea*

Non mycor.

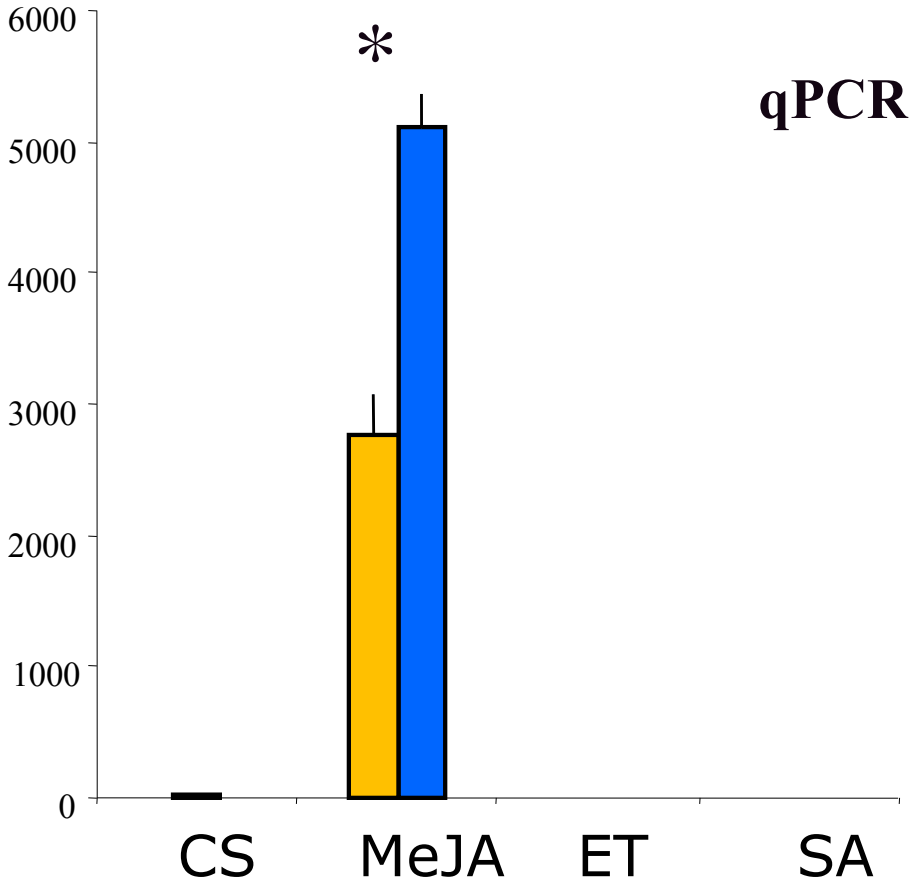
+ *Glomus margarita*

Expression de la protéase de défense *Pin II*



Protection contre *Botrytis cinerea*

Fold induction after exogenous hormone application



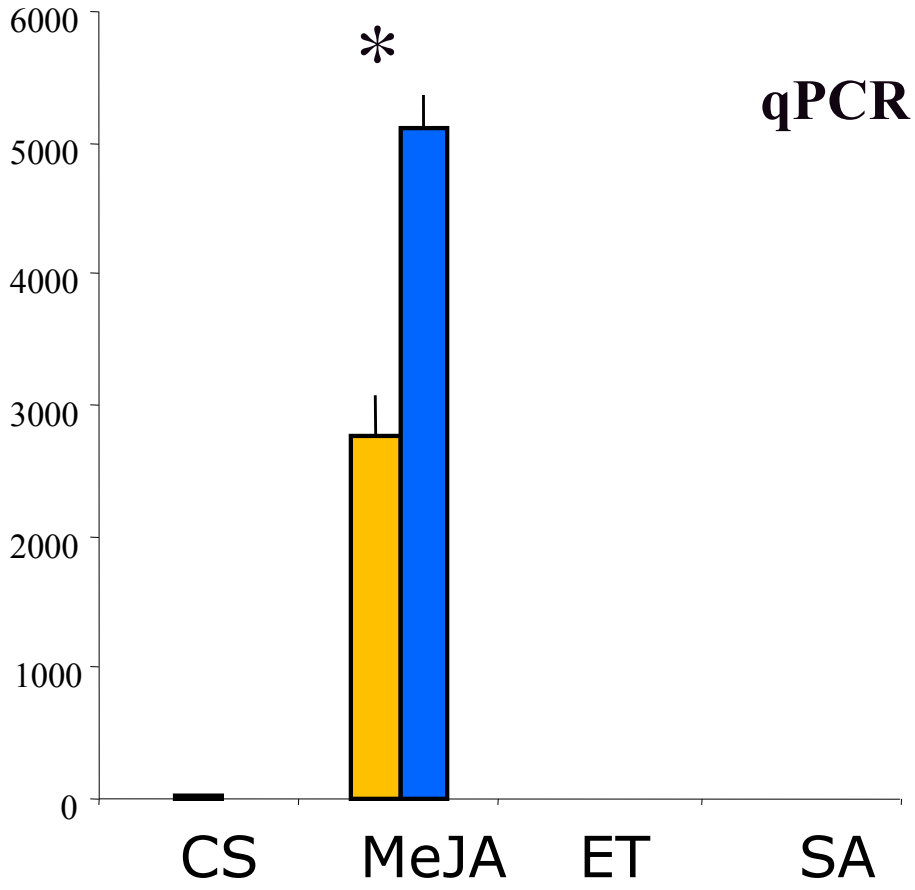
qPCR: *PinII* expression

Non mycor.

+ *Glomus margarita*

Protection contre *Botrytis cinerea*

Fold induction after exogenous hormone application

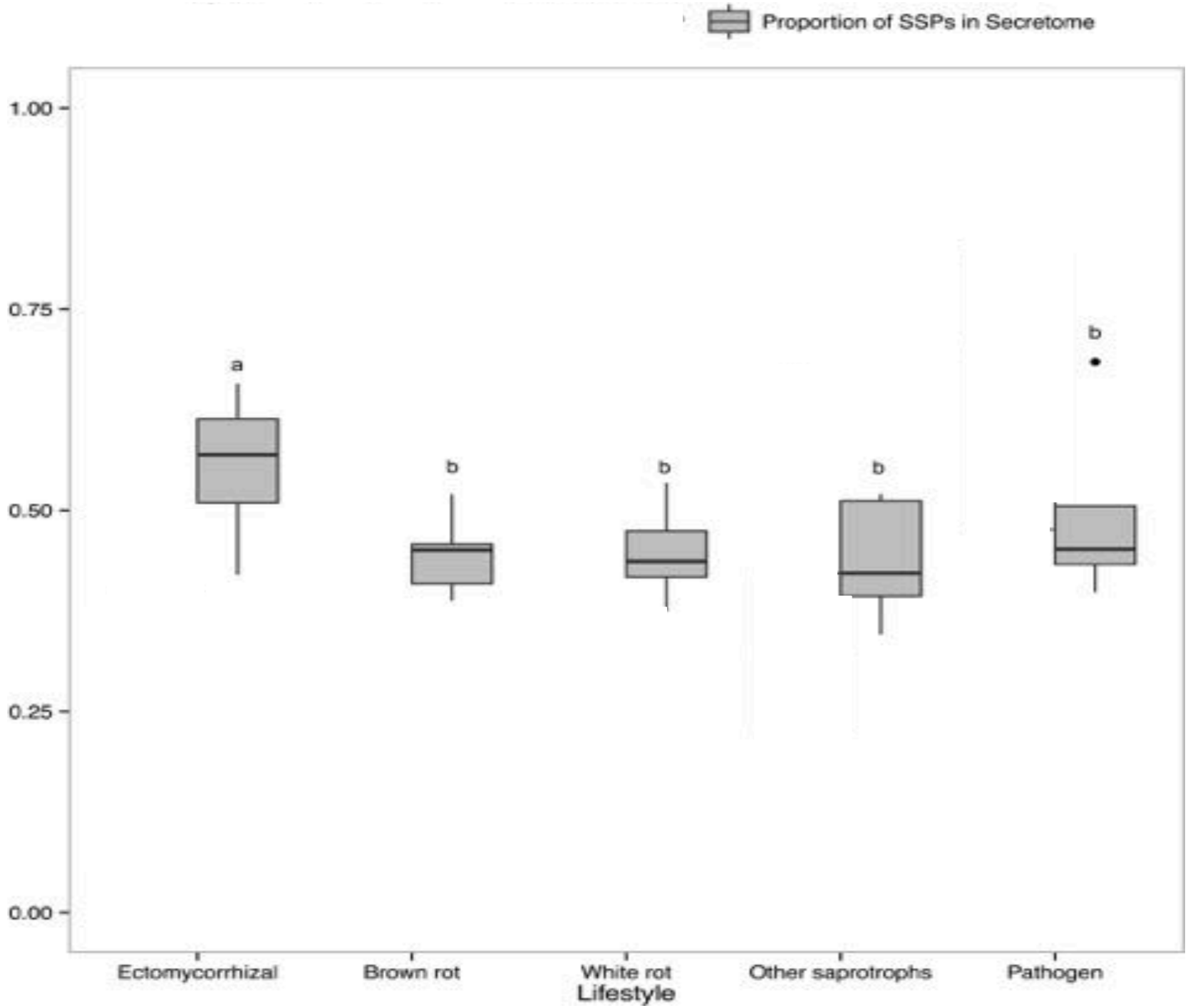


qPCR: *PinII* expression

Non mycor. + *Glomus margarita*

>> mycorrhizal colonization is associated to a

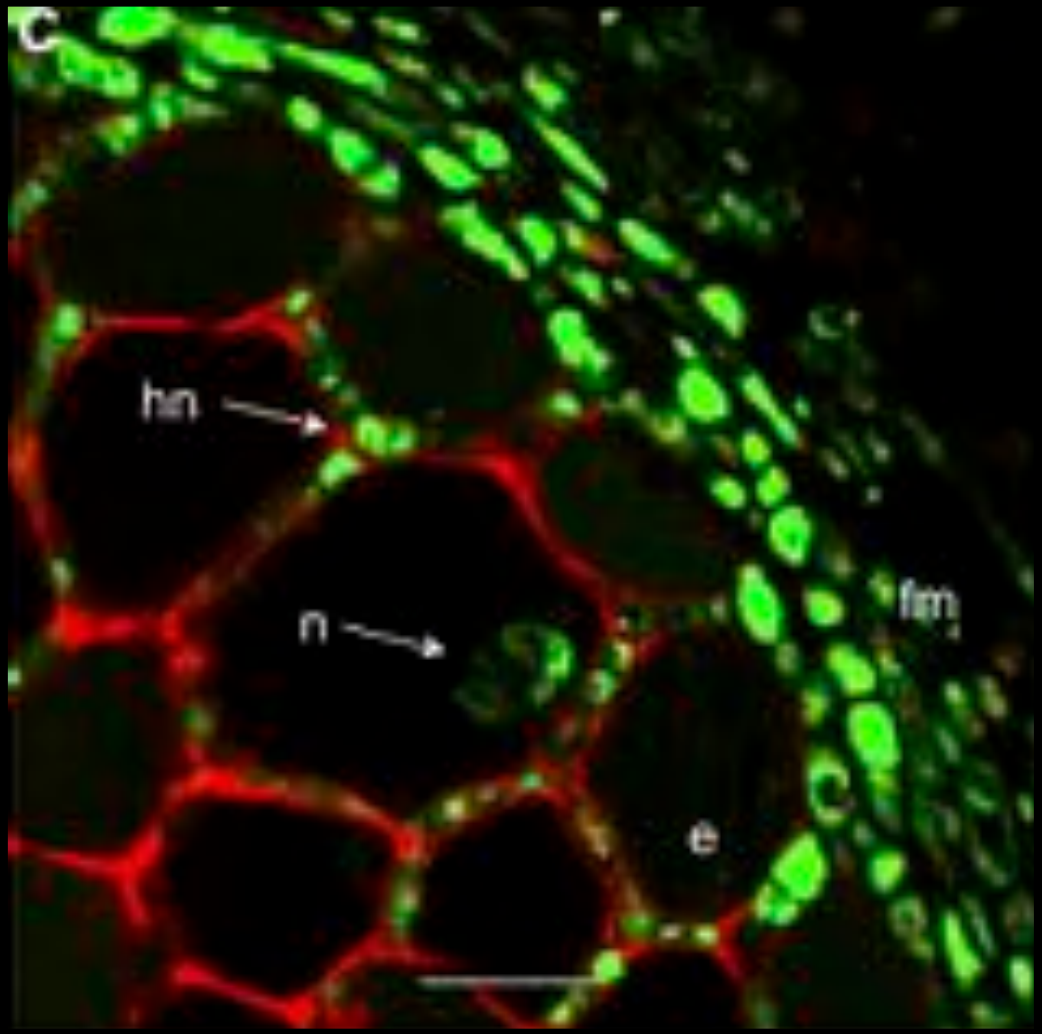
potentiation of JA-dependent defences



Pellegrin *et al*. 2015, Font. Microbiol. 6: 1278

Laccaria MiSSP7 entre dans les noyaux cellulaires racinaires

5,6-carboxyfluorescein (FAM)-t
agged synthetic MiSSP7 protein

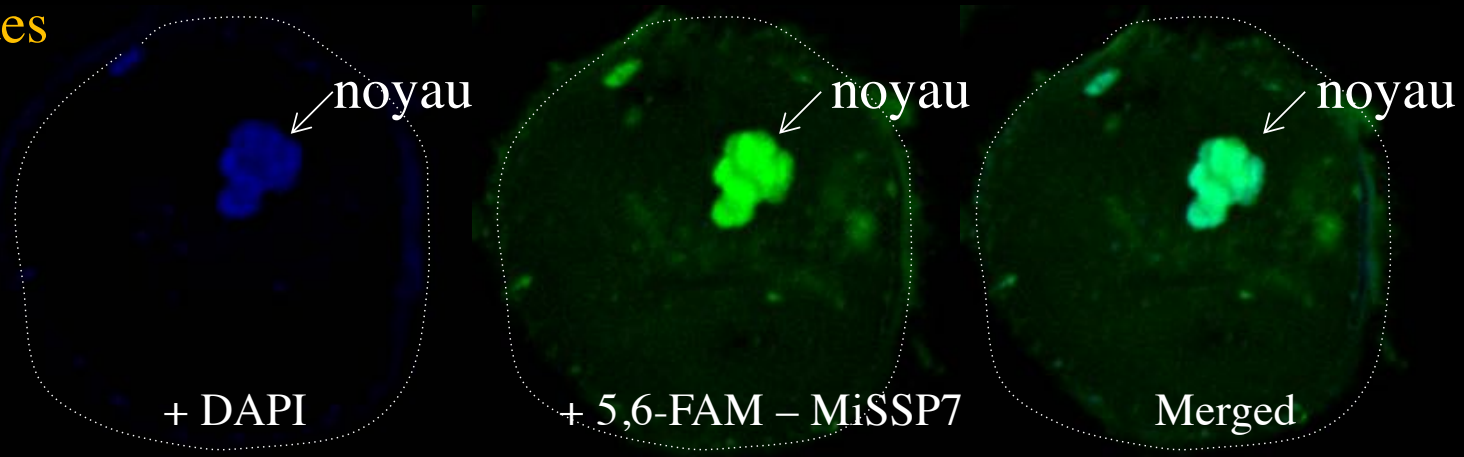


Plett *et al*. (2011) Current Biology 21, 1197-1203

Laccaria MiSSP7 entre dans les noyaux cellulaires racinaires

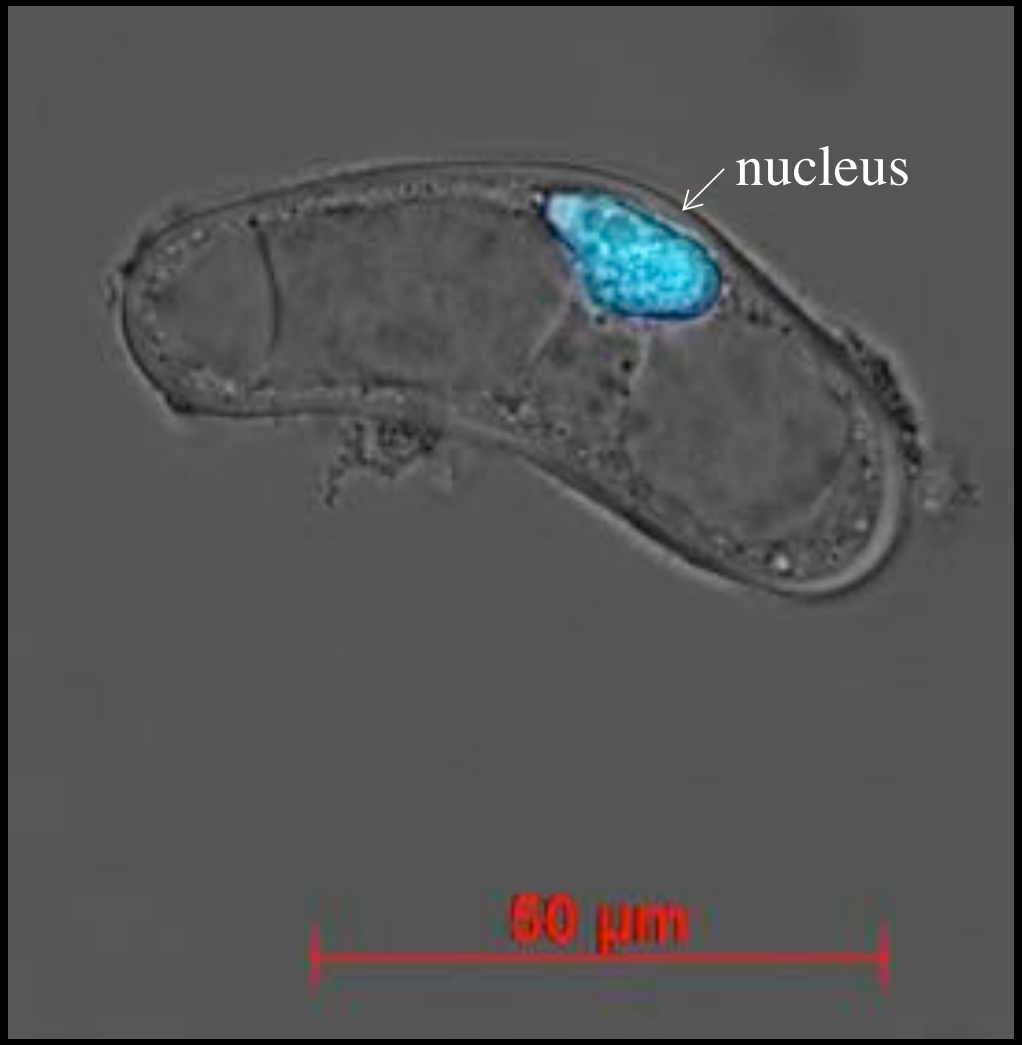
5,6-carboxyfluorescein (FAM)-t
agged synthetic MiSSP7 protein

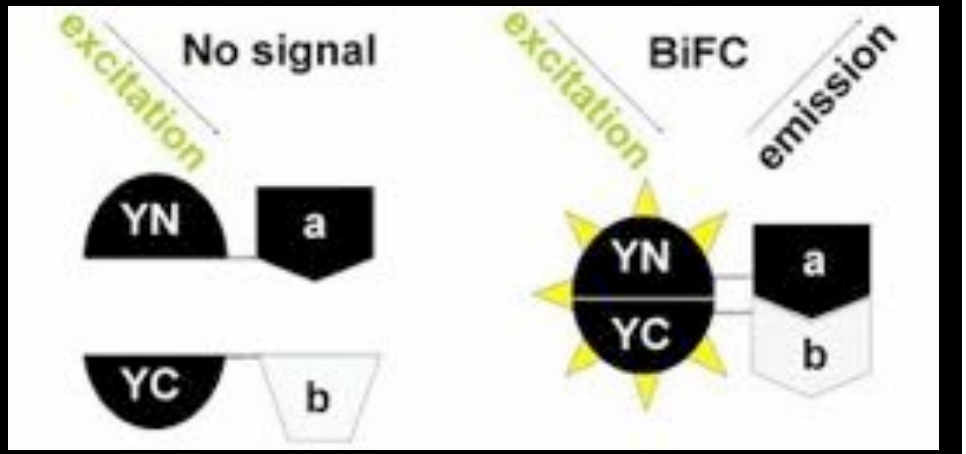
Suspension
de protoplastes
de Peuplier



Plett *et al*. (2011) Current
Biology 21, 1197-1203

Laccaria MiSSP7 bloque le co-receptor du jasmonate

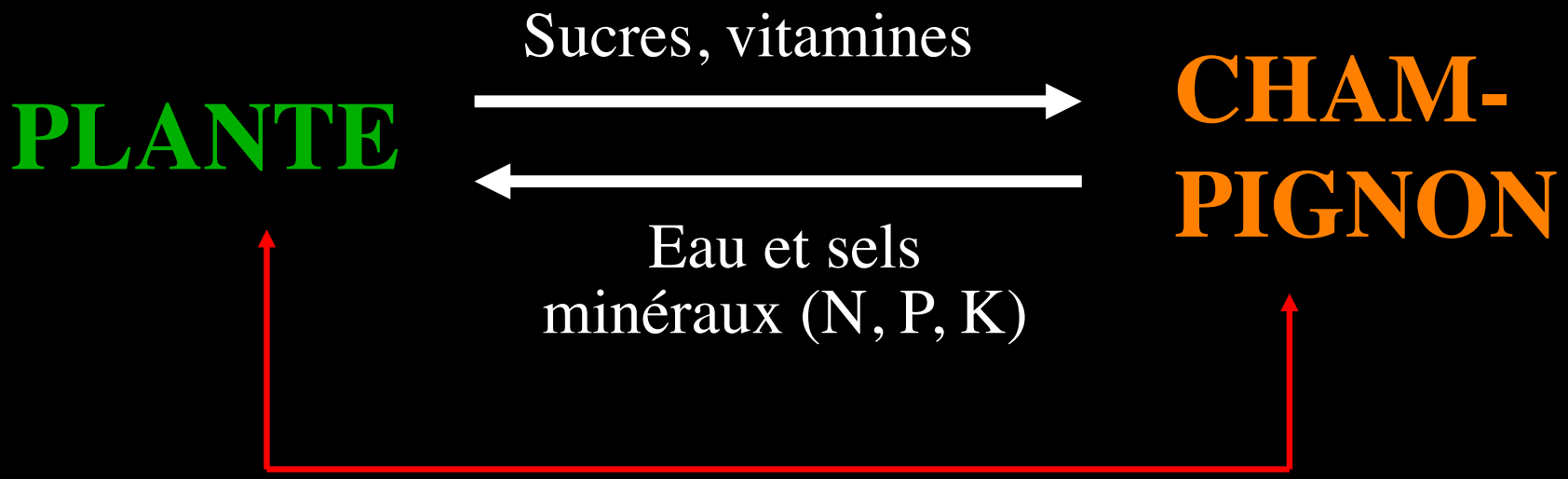




Martin *et al*. (2011) PNAS 111, 8299-8304

Bimolecular Fluorescence Complementation
MiSSP7 + JAZ6 in Poplar Protoplasts

LA RHIZOSPHERE



Protection contre les agressions
physiques et biologiques

Survie à la chaleur de *Dichanthelium lanuginosum* sur les sols volcaniques

Curvularia sp.

Redman *et al*. (2002), *Science* 298, 1581

Survie à la chaleur de *Dichanthelium lanuginosum* sur les sols volcaniques

40° C

C+

C-

28g

21g

Vue : en place déraciné

Curvularia sp.

Redman *et al*. (2002), *Science* 298, 1581

Survie à la chaleur de *Dichanthelium lanuginosum* sur les sols volcaniques

45° C

C+ *15g*

C- *0g*

40° C

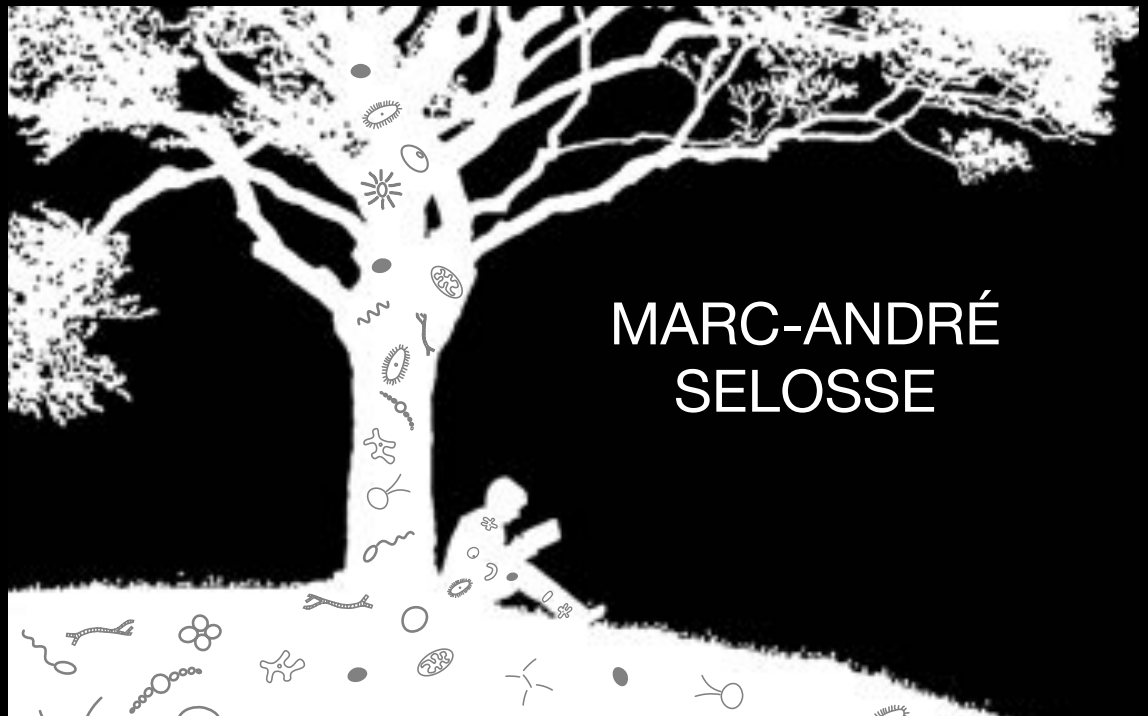
C+ *28g*

C- *21g*

Vue : en place déraciné

Curvularia sp.

Redman *et al*. (2002), *Science* 298, 1581



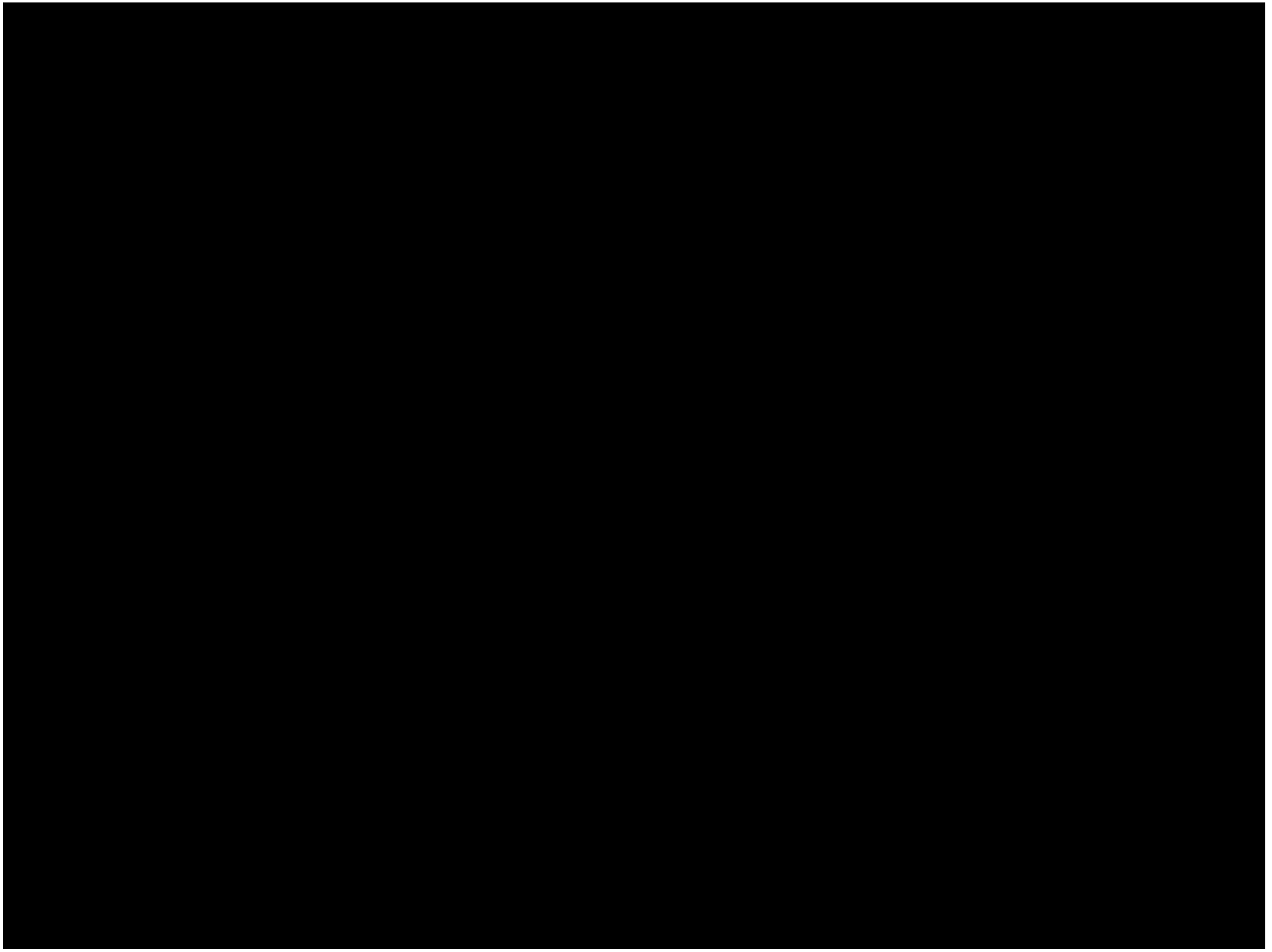
MARC-ANDRÉ
SELOSSE

JAMAIS SEUL

Ces microbes qui construisent les plantes, les animaux et les civilisations

postface de Francis Hallé

ACTES SUD



Microbiotique par essence

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De l'holobionte au réseau


Chêne vert
+ arbousier

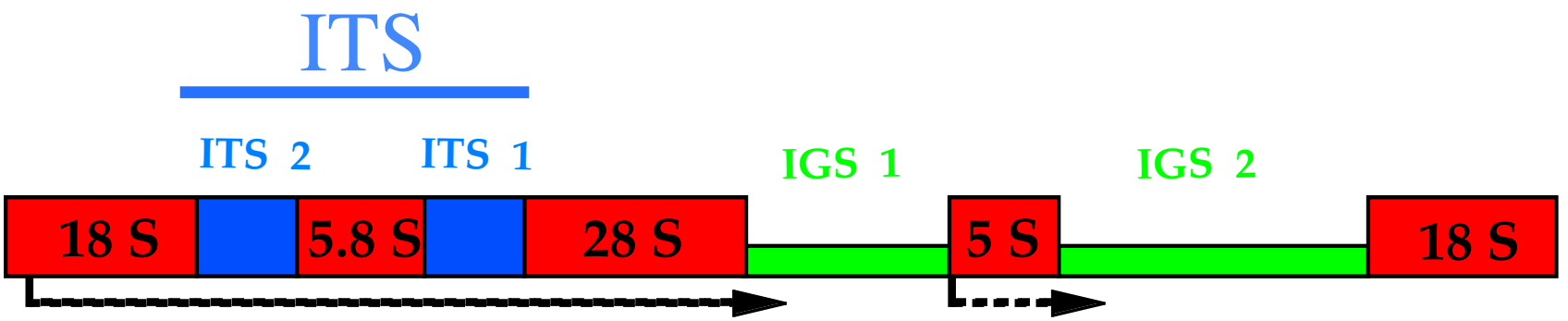
Chêne vert + arbousier

BARCODE ITS

Genus / order

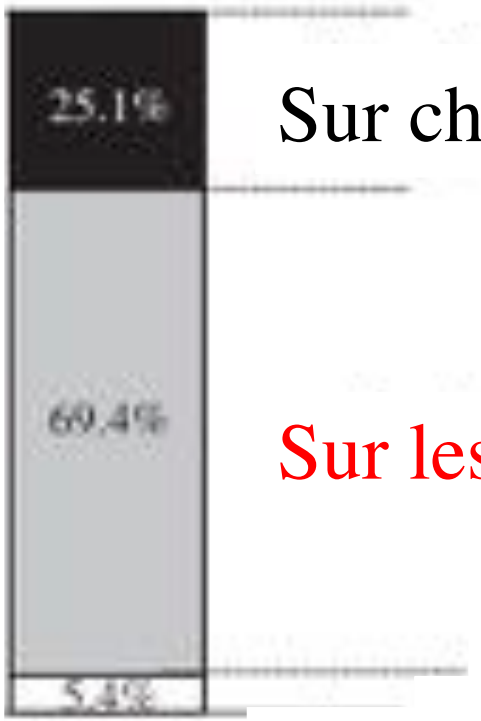
Species / sub-species

Sub-species / genet



Ribosomal DNA sub-unit in fungi: *circa* 10 kpb

Plus de 520 espèces ectomycorhiziennes…



Sur chêne vert seulement

Sur les deux partenaires !

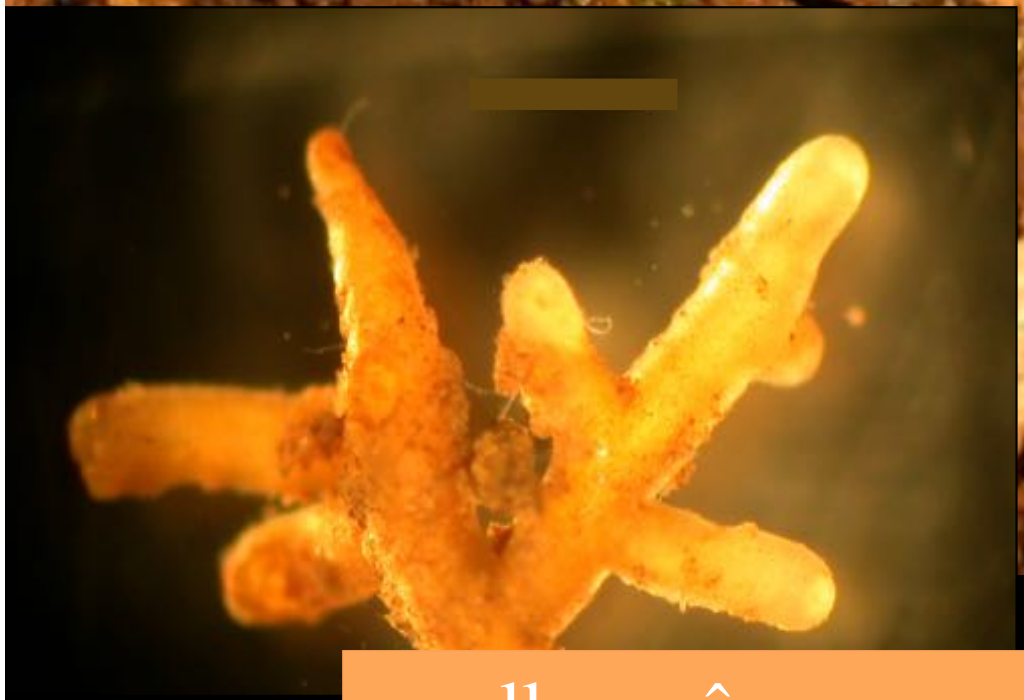
Sur arbousier seulement

Diversité fongique de la Chênaie du Fango en Corse (Richard *et al.* New Phytol. 2004)

Neottia nidus-avis


… associé avec des *Sebacina*…
5 mm

… associé avec des *Sebacina*…

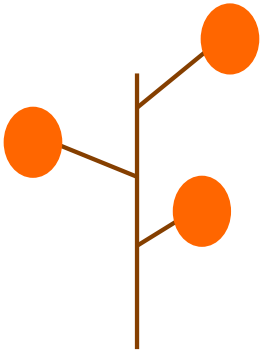


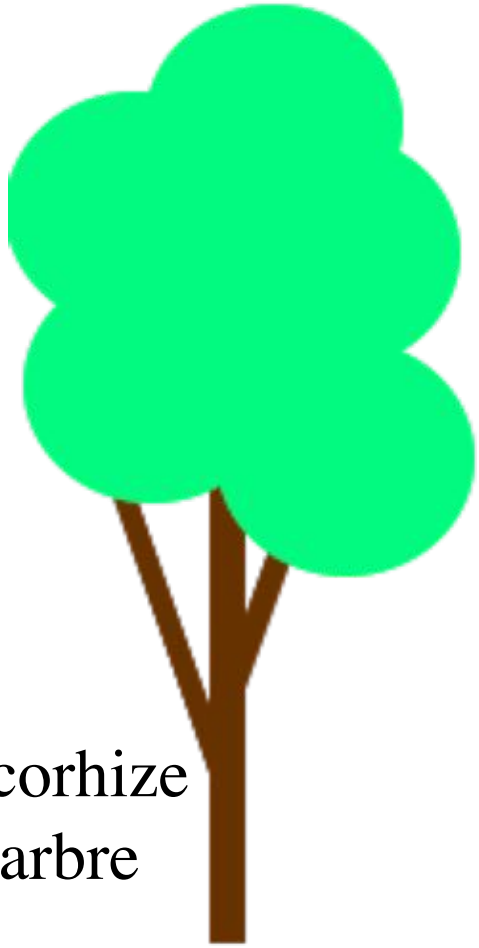
… elles-mêmes associées aux arbres voisins

UN RESEAU !

ARBRE

PLANTE NON CHLOROPHYLLIENNE

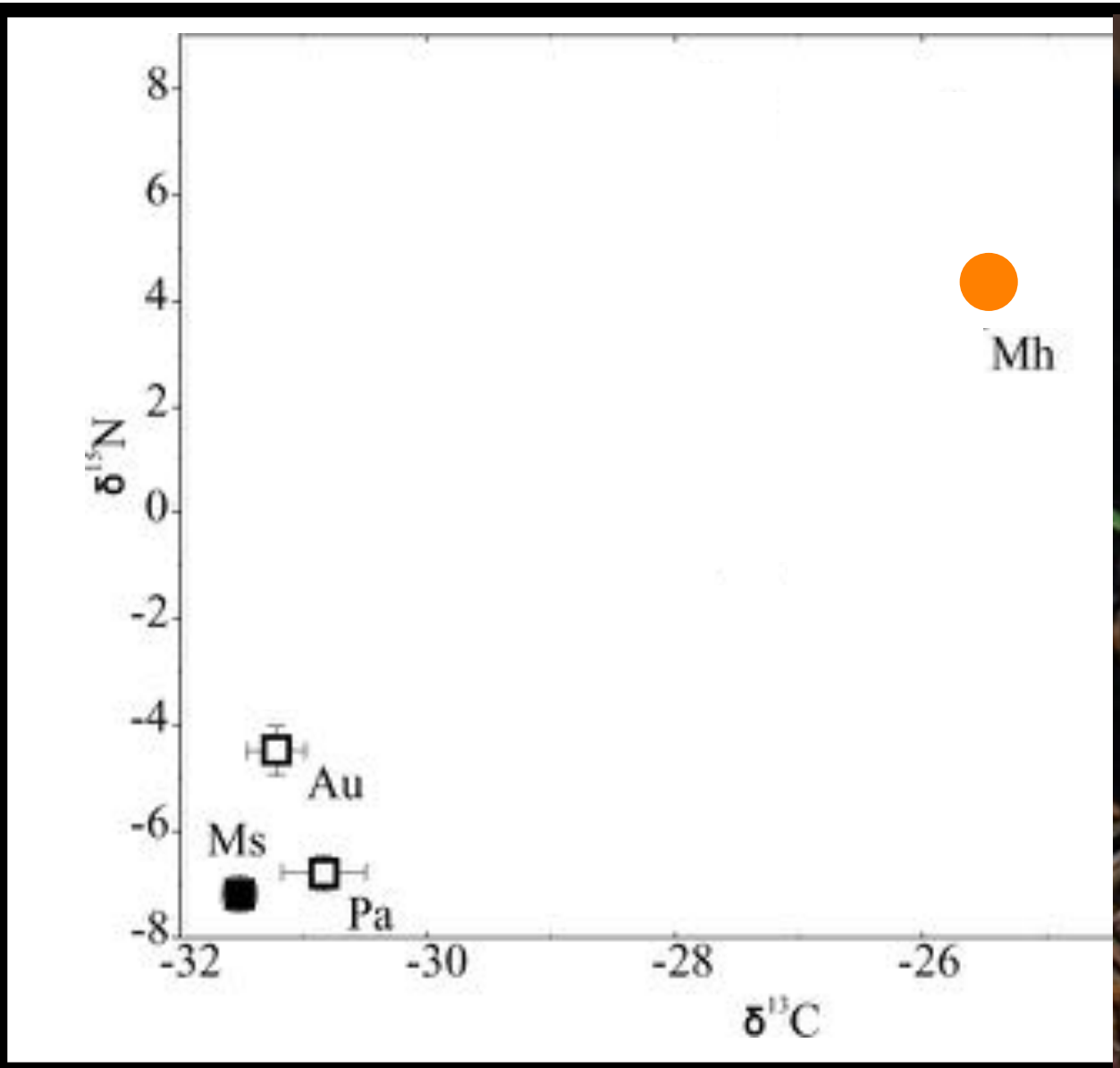




Mycorhize d'orchidée ← **Cchampignon** ← Mycorhize d'arbre

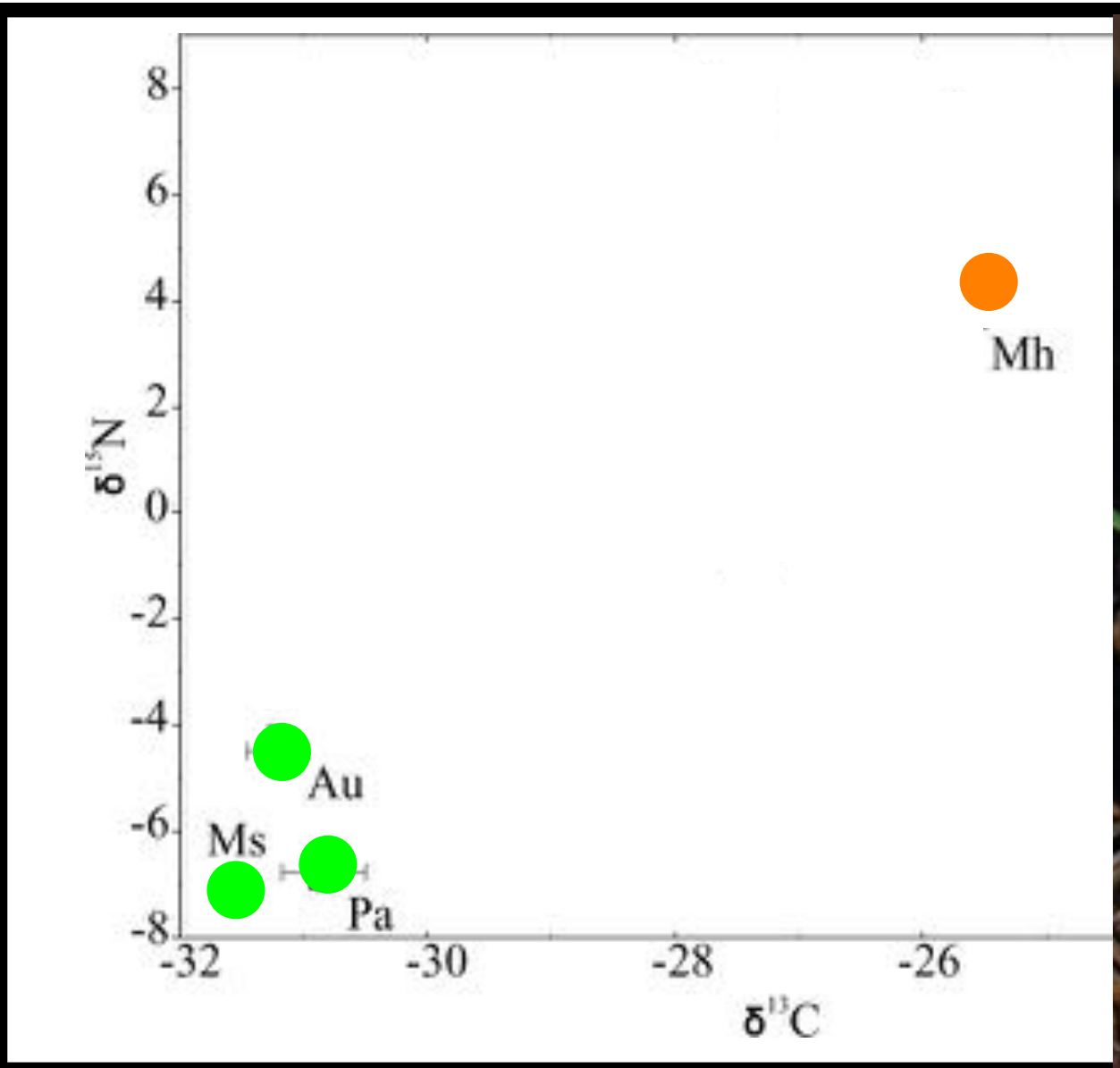
Flux de sucre

Selosse & Roy (2009), *Trends in Plant Sciences* **14**: 64-70



Mycoheterotrophic Ericaceae:
Hypopitys monotropa

al., 2007)

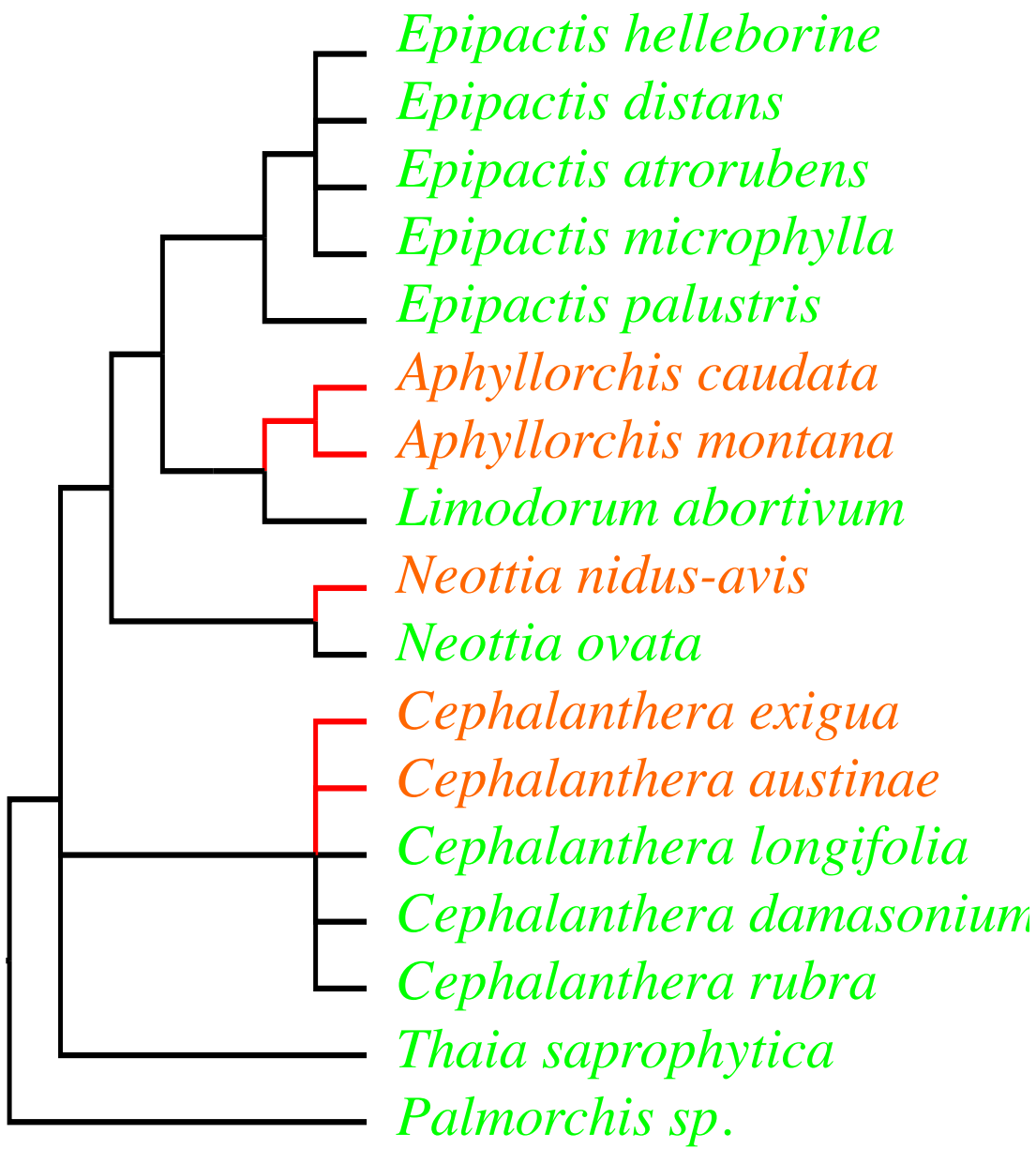


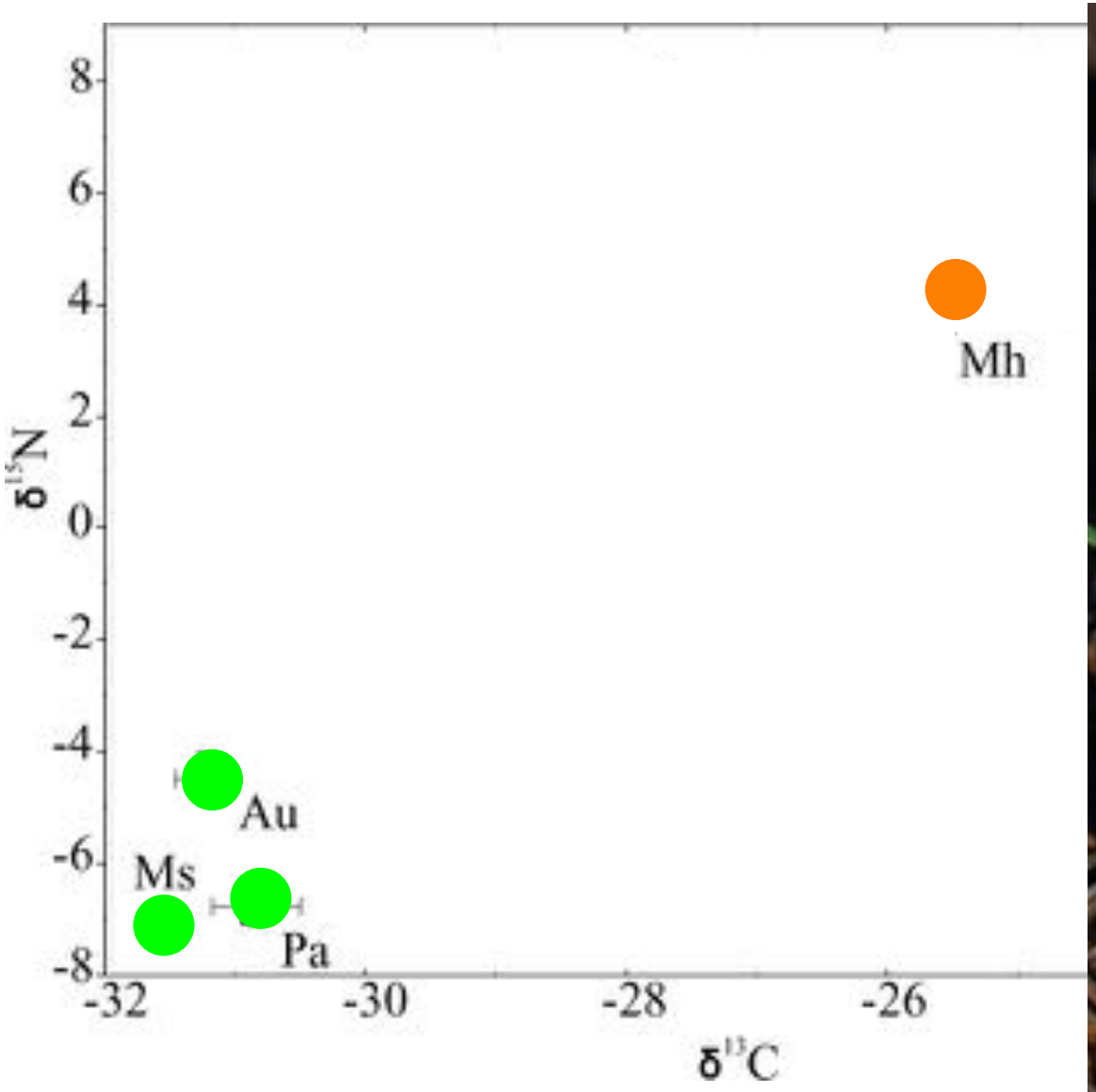
Autotrophs: *Arctostaphylos uva-ursi*, *Picea abies*, *Melampyrum sylvaticum*

Green orchids related to mycoheterotrophs

E.g. the Neottieae tribe, mycoheterotrophy arose repeatedly, by convergent evolution among green species

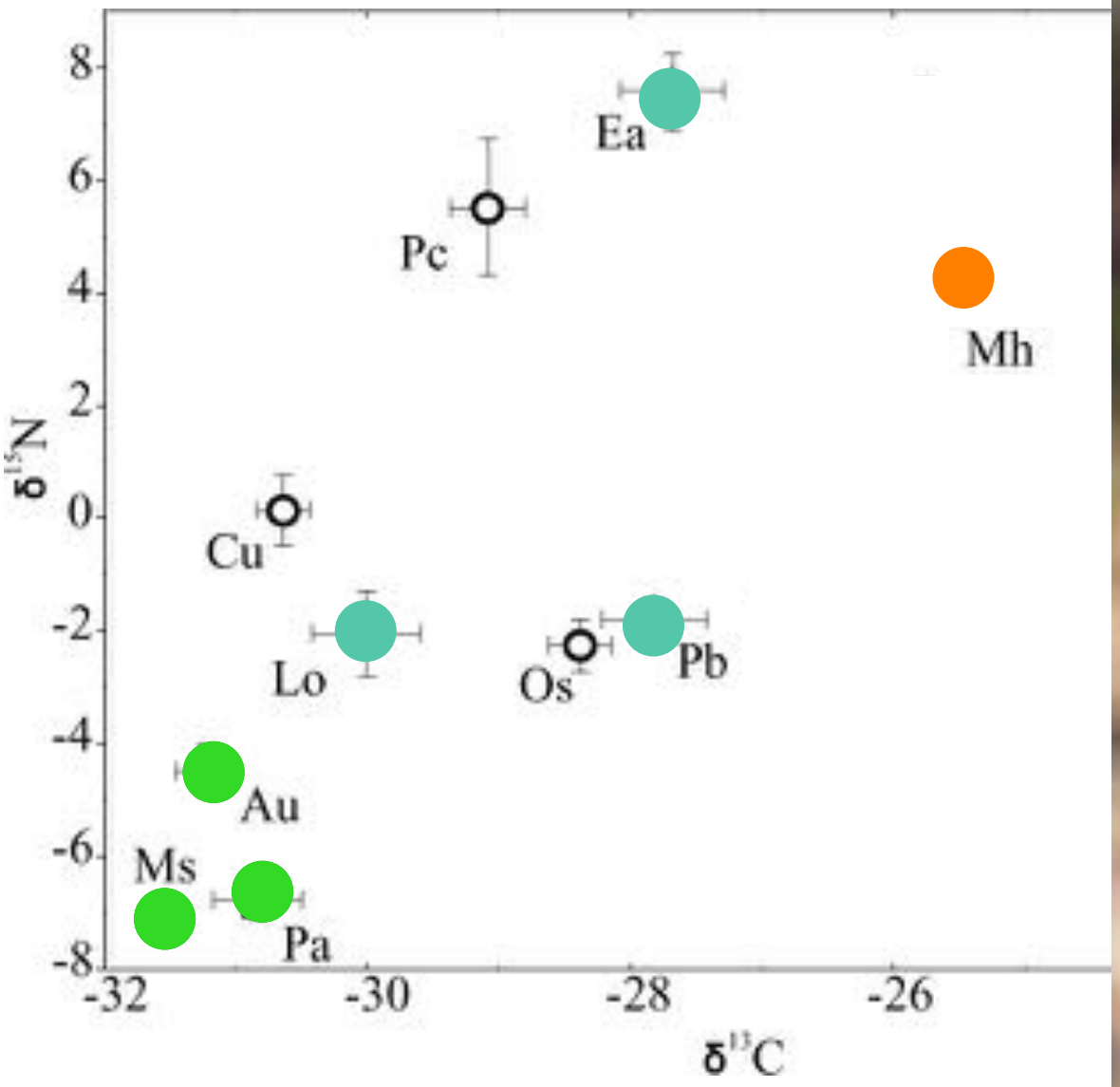
… predisposition ?





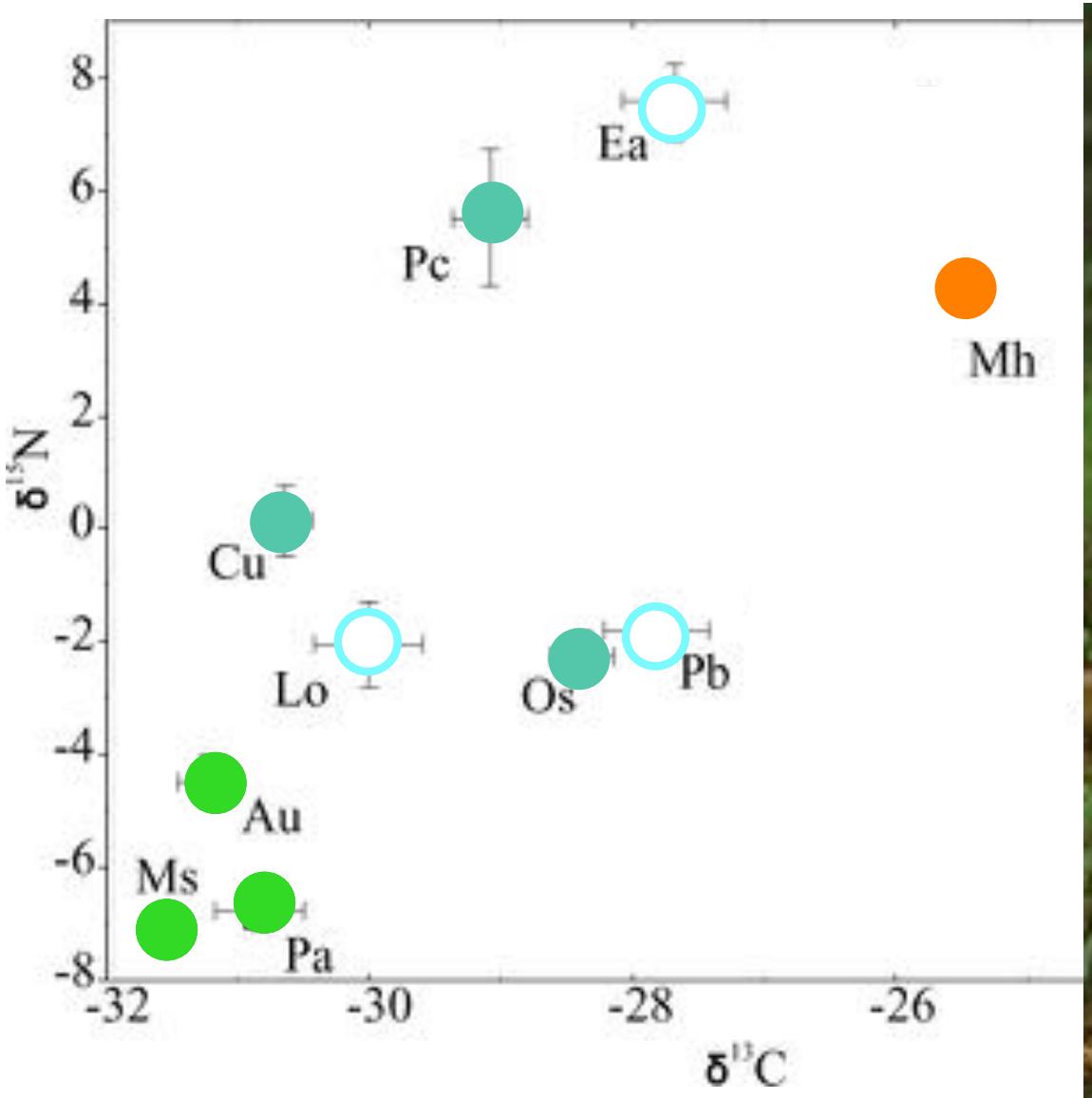
A look at green plants phylogenetically close to mycoheterotrophs

Tedersoo *et al*., 2007, *Oecologia*



« Green » orchids: *Listera ovata, Platanthera bifolia, Epipactis atrorubens*

Tedersoo *et al.*, 2007, *Oecologia*



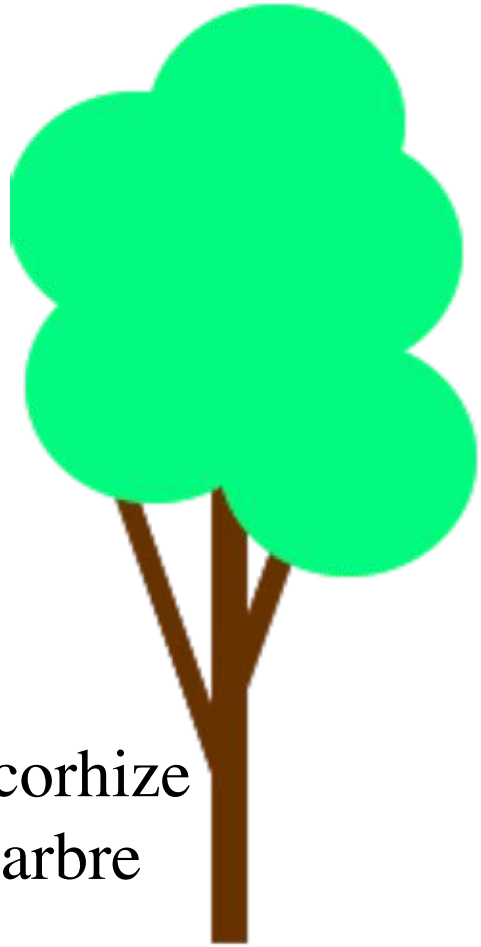
« Green » Ericaceae: *Orthilia secunda*, *Chimaphila umbellata*, *Pyrola chlorantha*

Tedersoo *et al.*, 2007, *Oecologia*

UN RESEAU !

ARBRE

PLANTE CHLOROPHYLLIENNE



Mycorhize d'orchidée ← **CHAMPIGNON** ← Mycorhize d'arbre

→

→

Flux de sucre

Selosse & Roy (2009), *Trends in Plant Sciences* **14**: 64-70
Selosse *et al*. (2017) *Ecology Letters* **20**: 246-263

In mixotrophic orchid species, achlophyllous variants, the albinos,

… survive as mycoheterotrophs!

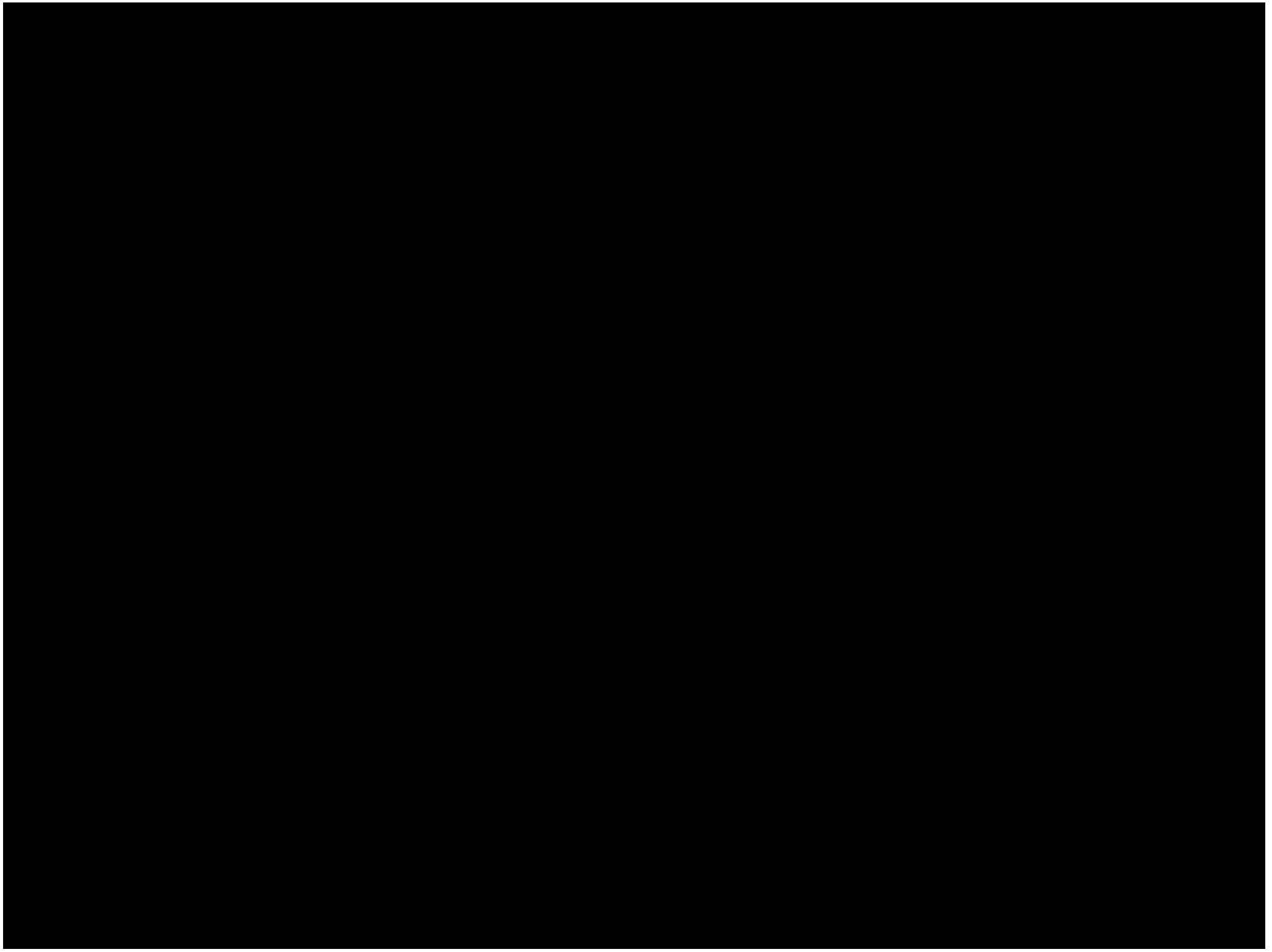
Cephalanthera damasonium

Roy *et al*., (2013) *Ecol. Monographs* **83**: 95

Epipactis purpurata

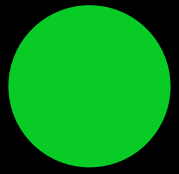
(A. Hasenfratz)


UN RESEAU !

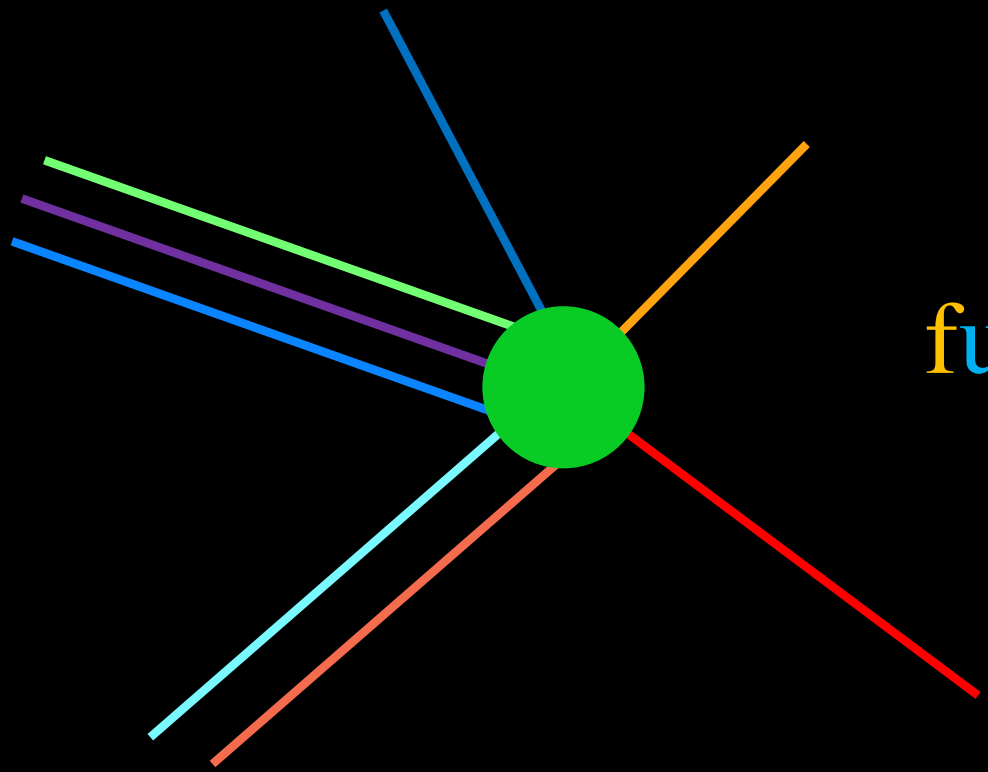


Holobionte…

plant

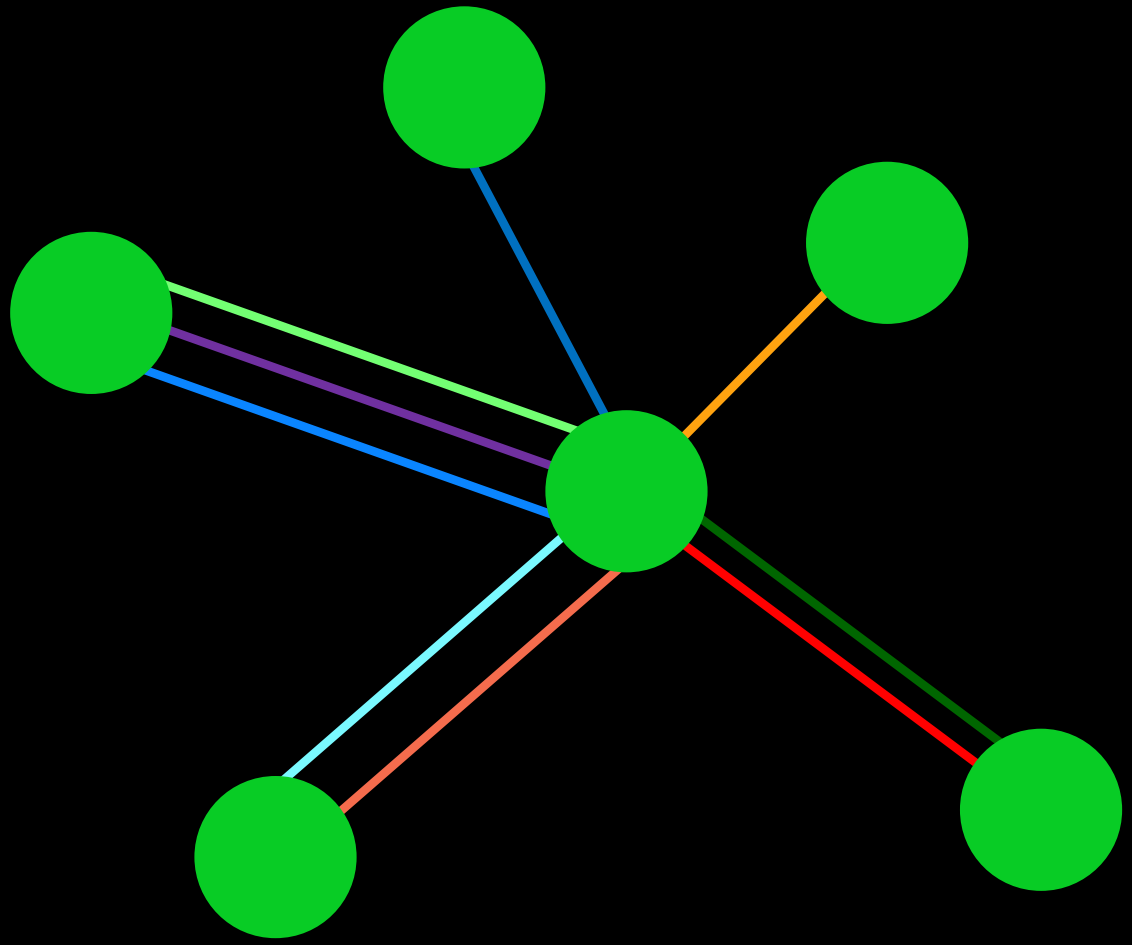


Holobionte…

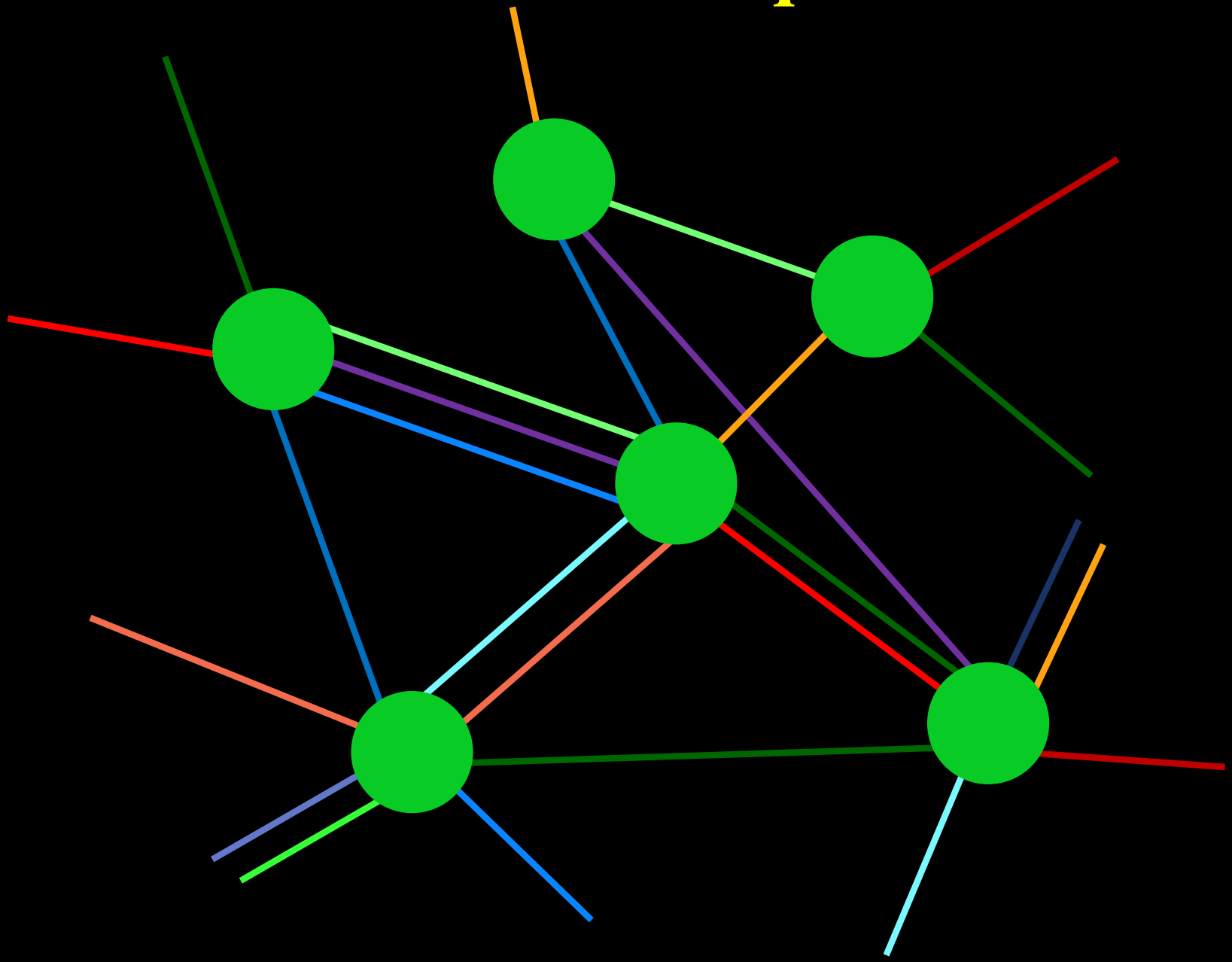


fungi

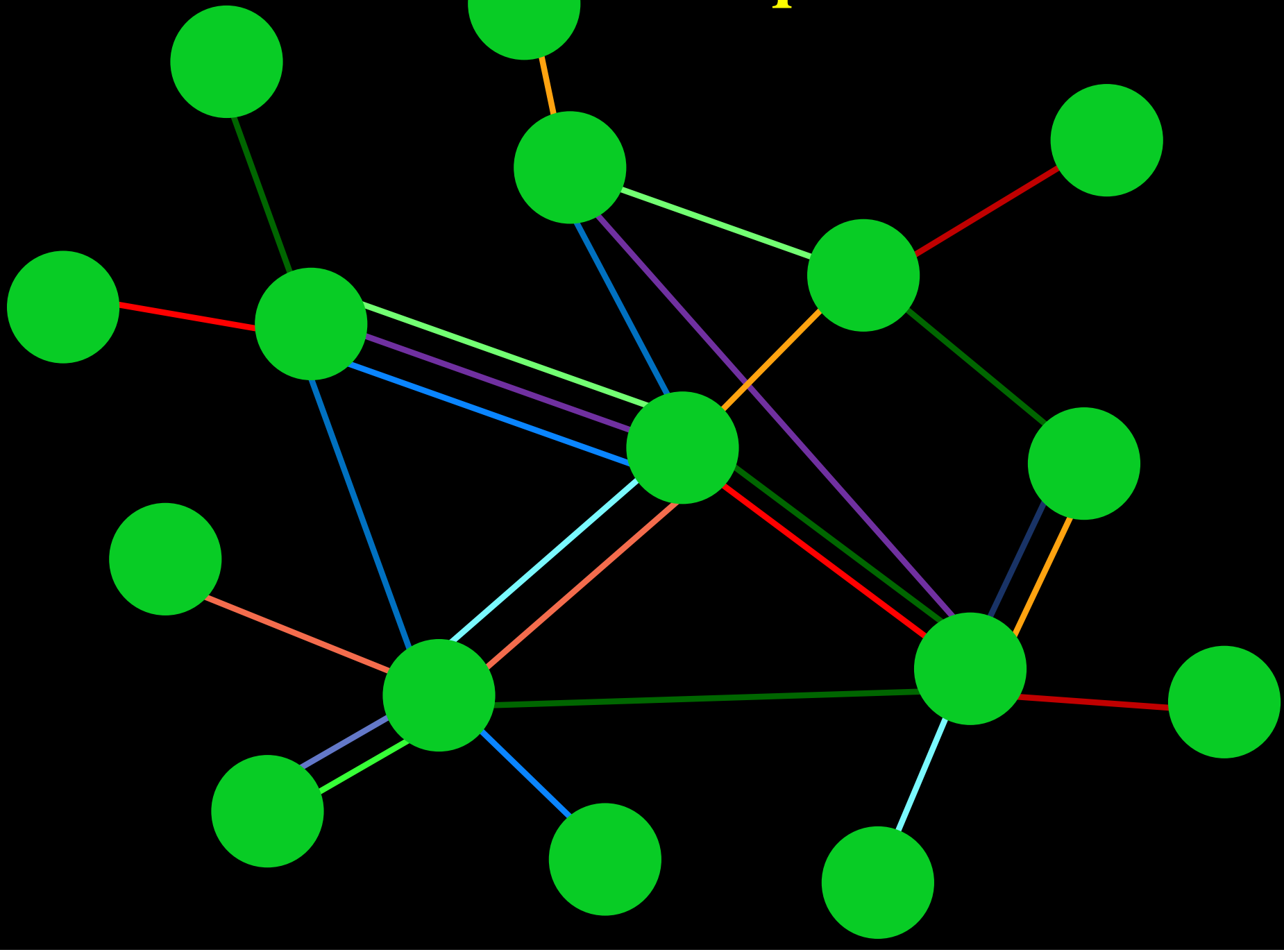
Holobionte… mais quelles limites ?



Holobionte… mais quelles limites ?

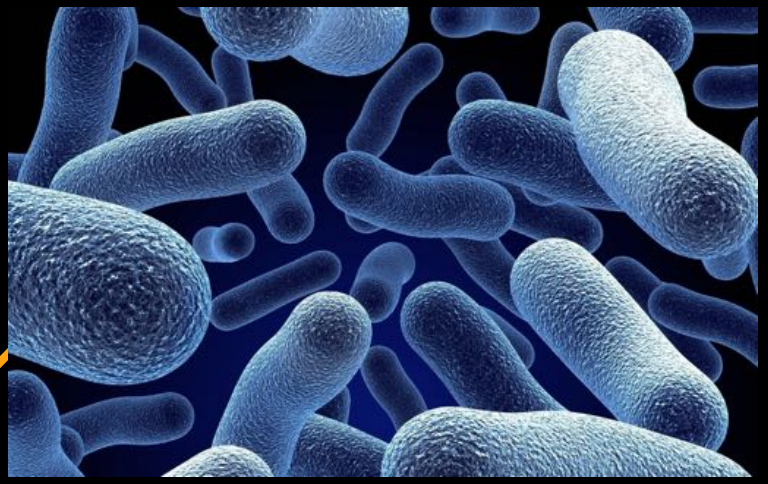


Holobionte... mais quelles limites ?



Holobionte… mais quelles limites ?

Mycorhizes

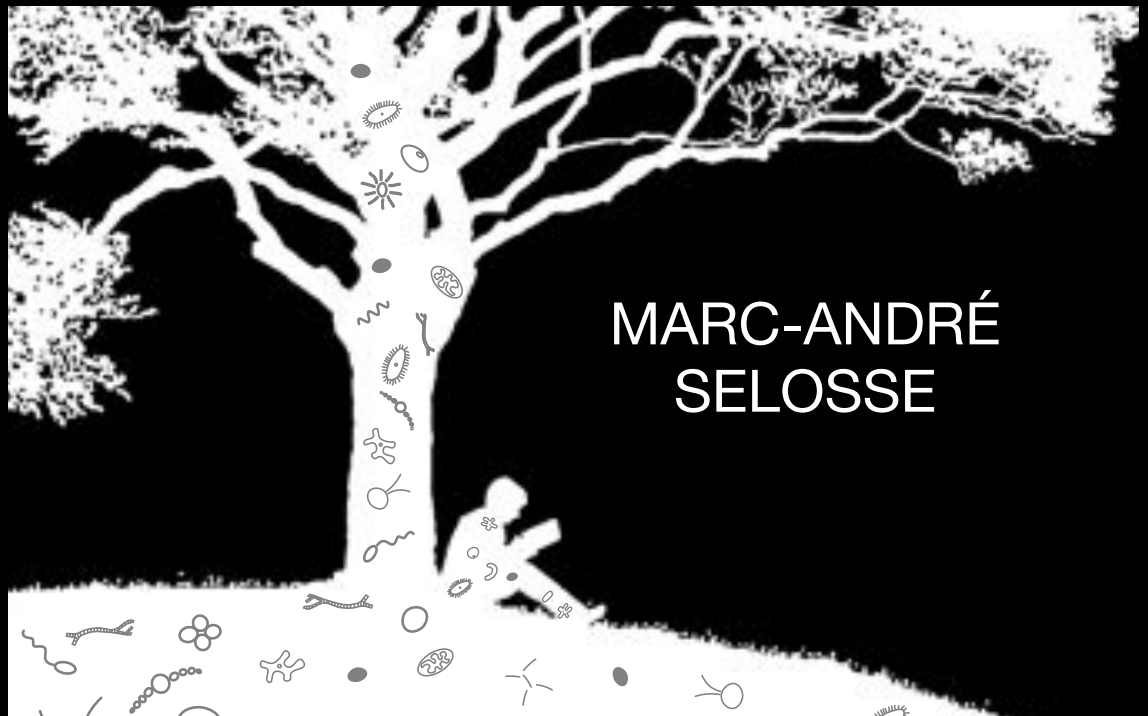


Clones rhizobactériens

Acariens protecteurs

Pollinisateurs

UN RESEAU !



MARC-ANDRÉ
SELOSSE

JAMAIS SEUL

Ces microbes qui construisent les plantes, les animaux et les civilisations

postface de Francis Hallé

ACTES SUD