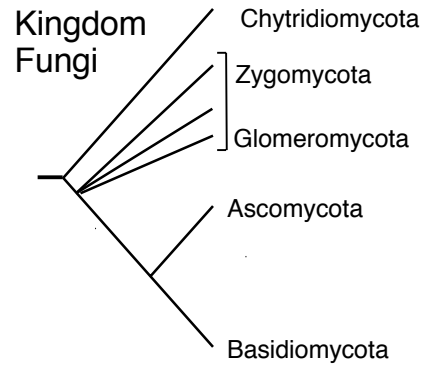


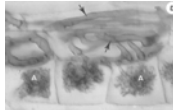
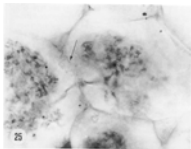
Arbuscular Mycorrhizae

- Introduction
- Anatomy
- Physiology
- Ecology

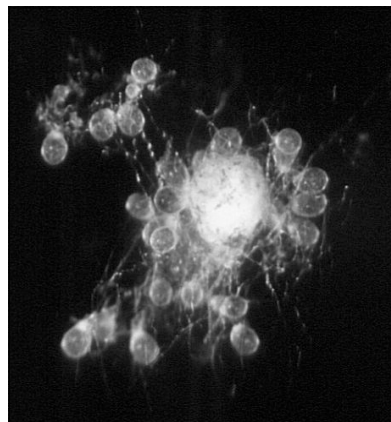
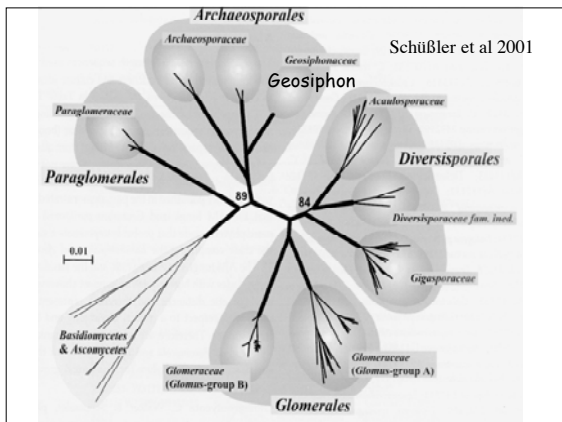
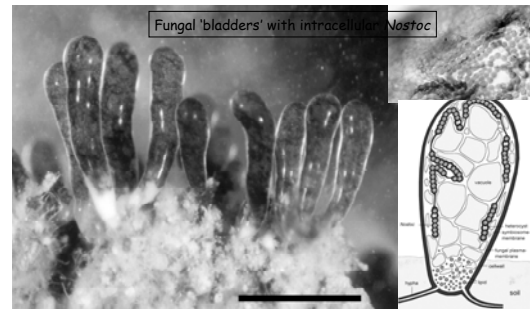


Early land plants with AM structures

Rhynie chert formation, 400-460 million years old.

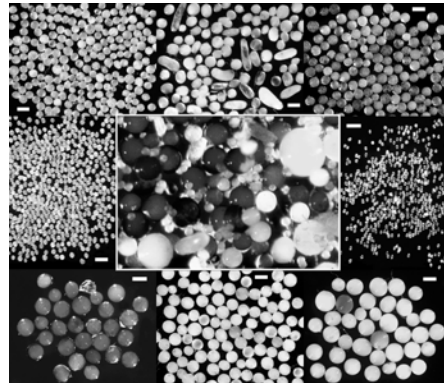
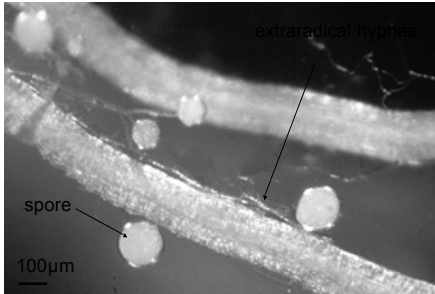


Geosiphon pyriforme -- work by Arthur Schüßler



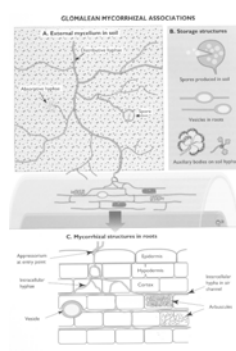
Spore formation by *Geosiphon*
Photo by Arthur Schüßler

Arbuscular mycorrhiza (*Plantago media* and *Glomus clarum*)

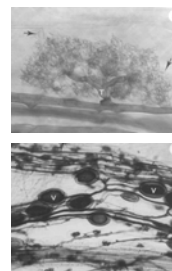


AM Structures

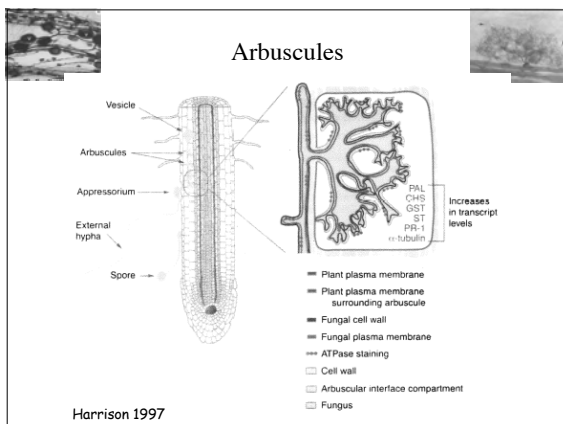
- Arbuscules/coils = site of exchange
- Vesicles = fungal storage (full of lipids)
- Spores = dispersal unit? Remember they are asexual.



Arbuscular Mycorrhizae

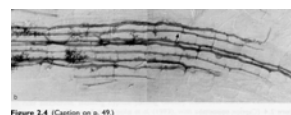


Arbuscules



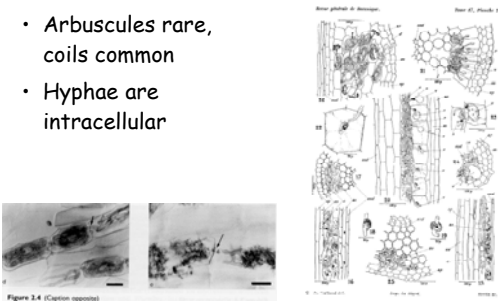
Arum Type AM

- Arbuscules diagnostic
- Hyphae remain intercellular except for arbuscules



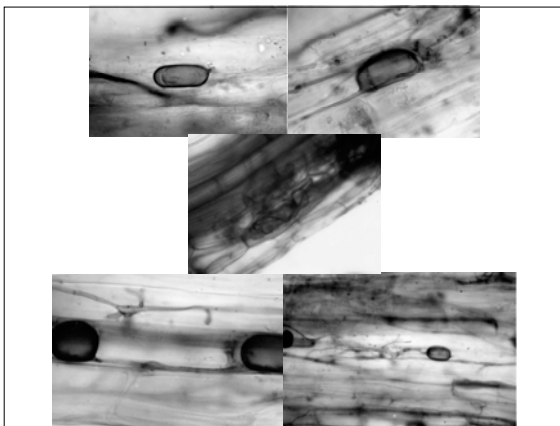
Paris Type AM

- Arbuscules rare, coils common
- Hyphae are intracellular



The players

- Fungi = Glomeromycota
- Plants = most herbs, grasses, bryophytes (mosses?), ferns, and many woody plants including maple, redwood, cherry, apple, and many tropical trees
- All of our agricultural crops are AM plants except Brassicaceae (mustards/broccoli) and Chenopodiaceae (quinoa, rumex, spinach)
- Many EM hosts will associate with AM fungi (but AM hosts typically do not associate with EM fungi)



Arbuscules increase plant/fungal interface

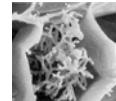


Table 2.2 The effect of development of arbuscules on the surface area of protoplasts and surface:volume ratios of cells of different plant species colonized by *Glomus fasciculatus*

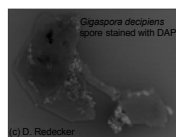
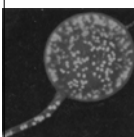
Plant species	Cell volume	S _{ij} (μm ²)	S _{ij} (p.c.) (μm ² μm ⁻³)	S _{ij} (μm ²)	S _{ij} (p.c.) (μm ² μm ⁻³)	Area of arbuscular interface per cell (μm ²)
Wheat	212 874	22 416	0.11	83 012	0.39	59 805
Oats	221 875	22 188	0.10	73 519	0.33	51 031
Maize	177 328	19 566	0.11	79 798	0.45	60 792
Mean for grasses			0.11	78 479	0.39	56 978
Onion	340 468	34 074	0.10	64 688	0.19	30 614
Bean	146 574	16 123	0.11	49 835	0.34	33 712
Tomato	147 910	16 370	0.11	42 894	0.29	28 424
Mean for non-grasses			0.11	43 472	0.27	30 316

S_{ij}, surface area of protoplast; S_{ij}(p.c.), surface:volume ratio of cells. Values are averaged over the whole cell cycle. Based on a table from Tarkenton et al. (1986).

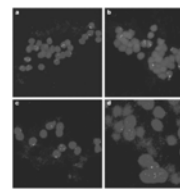
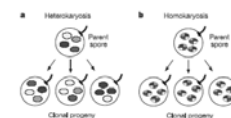
Nuclear counts in AM spores

Table 2.1 Numbers of nuclei per spore of a range of VA mycorrhizal fungi: counted directly (a) or estimated from the surface area of the spore and the presumed distribution of the nuclei (b) (see text)

(a) Direct counting				
Species	Diameter (μm)	Stain	Nuclei per spore	Reference
<i>Gigaspora decipiens</i>	400	DAPI	1000	Tommerup, in Viera and Glenn, 1990
<i>G. margarita</i>	250	Methylen-blue	2000	Bécard and Pfeiffer, 1993
<i>G. gigaspora</i>	350	Alexan-orange	3400	Coake et al., 1987
<i>Suillus spore cyathopa</i>	200	Alexan-orange	3850	Coake et al., 1987



Genetic Variation Within AM Spores: Inter or Intra-nuclear?



Spore	Single spore cultures (isolates)			
	3d-4	13-4-2	21-4-4	73-4-4
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
4	1	1	1	1
5	1	1	1	1
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	1	1
13	1	1	1	1
14	1	1	1	1
15	1	1	1	1
16	1	1	1	1
17	1	1	1	1
18	1	1	1	1
19	1	1	1	1
20	1	1	1	1
21	1	1	1	1
22	1	1	1	1
23	1	1	1	1
24	1	1	1	1
25	1	1	1	1
26	1	1	1	1
27	1	1	1	1
28	1	1	1	1
29	1	1	1	1
30	1	1	1	1
31	1	1	1	1
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33	1	1	1	1
34	1	1	1	1
35	1	1	1	1
36	1	1	1	1
37	1	1	1	1
38	1	1	1	1
39	1	1	1	1
40	1	1	1	1
41	1	1	1	1
42	1	1	1	1
43	1	1	1	1
44	1	1	1	1
45	1	1	1	1
46	1	1	1	1
47	1	1	1	1
48	1	1	1	1
49	1	1	1	1
50	1	1	1	1
51	1	1	1	1
52	1	1	1	1
53	1	1	1	1
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57	1	1	1	1
58	1	1	1	1
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73	1	1	1	1
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75	1	1	1	1
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82	1	1	1	1
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85	1	1	1	1
86	1	1	1	1
87	1	1	1	1
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90	1	1	1	1
91	1	1	1	1
92	1	1	1	1
93	1	1	1	1
94	1	1	1	1
95	1	1	1	1
96	1	1	1	1
97	1	1	1	1
98	1	1	1	1
99	1	1	1	1
100	1	1	1	1

Kuhn 2001

Pawlowska & Taylor 2004

Species effect on biomass and P

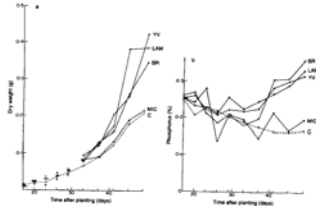


Figure 4.1. (a) Dry weight changes and (b) P contents of Allium cepa roots colonized by four VA mycorrhizal fungi, compared with controls (C). LY: Glomus mosseri; LAM: G. macrosporus var. gisparsus; MIC: G. microsporus; BR: Scutellospora (Gisparsus) colapsura. From Sanders et al. (1977), with permission.

Species effect on P inflow

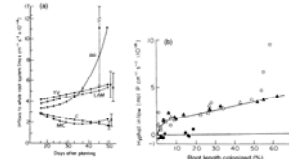


Figure 5.2. The effects of mycorrhizal colonization on inflow of P into roots of Allium cepa. (a) Inflow of P into whole root systems compared for each harvest date. C, non-mycorrhizal control; LAM, Glomus macrosporus var. gisparsus; BR, Scutellospora (Gisparsus) colapsura; MIC, Glomus microsporus; LY, Glomus mosseri. (b) Inflow attributable to the hyphae of: ▲, Glomus mosseri; △, Glomus macrosporus var. gisparsus; □, Gisparsus (Scutellospora) colapsura; ●, Glomus microsporus. Values calculated by subtracting inflow into non-colonized roots from inflow into mycorrhizal roots. Note that the ineffective fungus Glomus microsporus, which colonized roots very slowly, did not increase the P inflow over that of controls. From Sanders et al. (1977), with permission.

AM and nitrogen

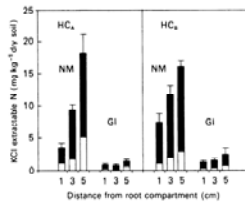


Figure 5.8. Effect of mycorrhizal hyphae of Glomus intraradices on depletion of KCl-extractable NH_4 and NO_3^- in the rhizosphere of plants of *Cucumis sativus* fertilized (HC_a), or not (HC_b), with added NO_3^- . GI, mycorrhizal plants; NM, non-mycorrhizal plants. Bars are standard errors of the means of four replicates. From Johansen et al. (1992), with permission.

Carbon transfer from green plant to green plant via AM fungal connection

Table 4.4. Effects of shade on C transfer from *Plantago lanceolata* to *Festuca ovina*

	Full light		Shade	
	Root	Shoot	Root	Shoot
Non-mycorrhizal	0.08	0.10	0.03	0.04
VA mycorrhizal	2.8***	0.44**	36.4***	0.32***

^{14}C supplied as $^{14}\text{CO}_2$ to the leaves of the donor plants. The receiver plants were either fully illuminated or shaded during the transfer period (48 h). Statistical significance of differences between mycorrhizal and non-mycorrhizal: *** $P < 0.001$, ** $P < 0.01$. Figures calculated from raw data in Table 4 of Read et al. (1985); statistical significance by Mann-Whitney U-test. Data of Read et al. (1985), recalculated by Newmann (1988).

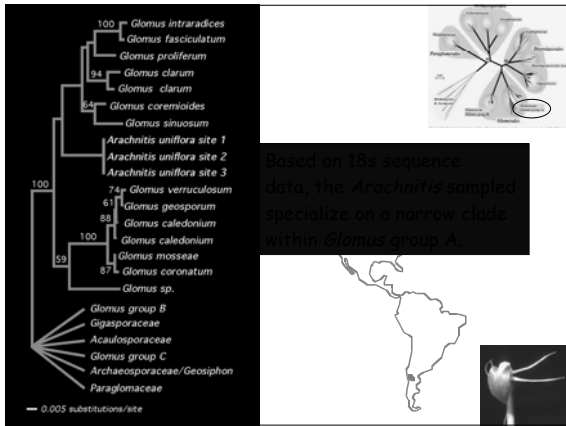
Translocation of C in AM Networks

- Fitter 1999: Myco-centric view
 - Labelled ^{14}C from a 'donor' plant shows up in roots, but not in leaves of 'receiver' plant.

- Arachnitis* grows in the understory of Andean forests
- It is a non-photosynthetic mycorrhizal "cheater"



Bidartondo Nature paper



Translocation of C in AM Networks

- Fitter 1999: Myco-centric view
 - Labelled ^{14}C from a 'donor' plant shows up in roots, but not in leaves of 'receiver' plant.
 - Exceptions include achlorophyllous plants...
 - Although Simard et al. showed C moved between birch and Douglas-fir, but that was in ECM networks

Next slide please....

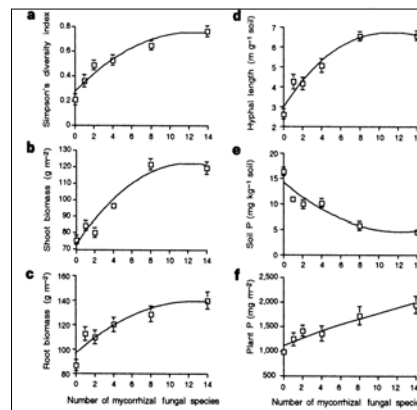
Carbon movement between green plants via AM networks

Oecologia 2002, 132:183-187
DOI 10.1007/s00442-002-0918-6

Sylvia Lorei · Rachel Gard · Josh G. Callard · Bernd Yerbberg · Yves Piché · Liane Lipshitz
 ^{14}C transfer between the spring ephemeral *Erythronium americanum* and sugar maple saplings via arbuscular mycorrhizal fungi in natural stands

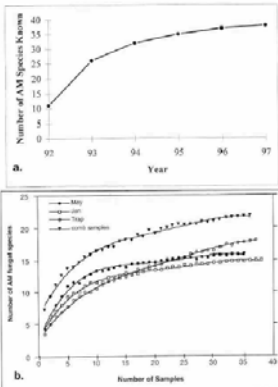


Ann Arbor Pioneer High School Ecology Club web page



AM fungal diversity affects plant diversity

Van der Heijden et al. 1998

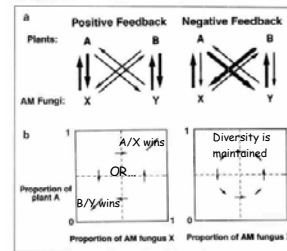


- Species richness is in the high 30s in a single field.
- Note that different approaches yield different species richness.

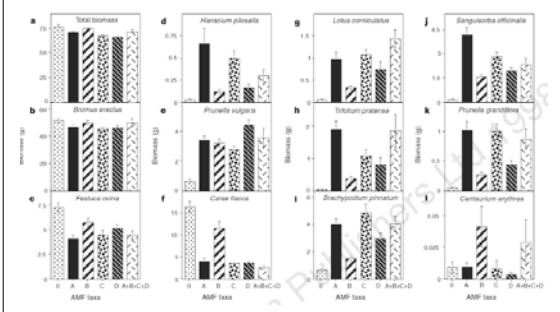
Why so many species???

BioScience • November 2001 / Vol. 51 No. 11

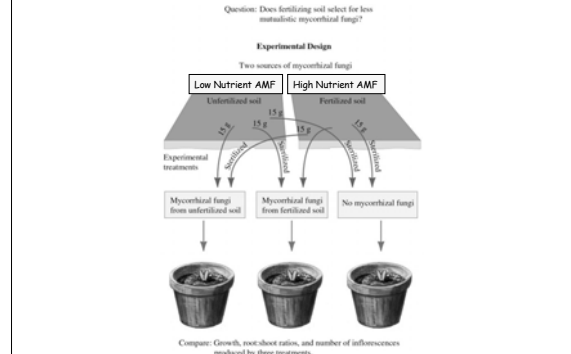
Negative Feedback Leads to Greater Species Richness



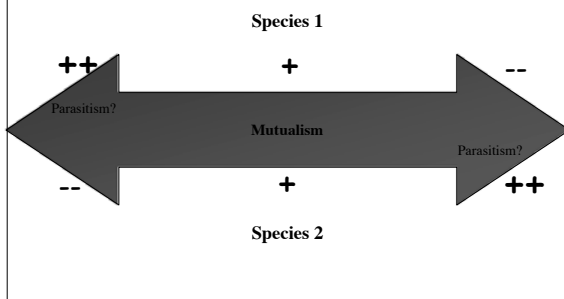
Van der Heijden et al. 1998



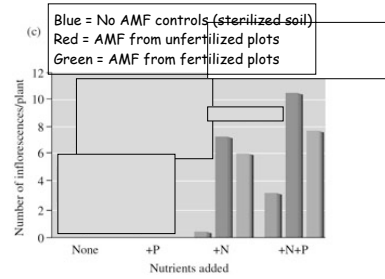
Mutualism-Parasitism Continuum



Mutualism-Parasitism Continuum



Fertilizing crops selects a less beneficial community of AM fungi



Three Components of Mycorrhizal Symbioses

