Control of other fungi, invertebrates, bacteria

Nematode trapping, bacteriophagy ("eating bacteria"), sporophagy ("eating spores")

relation to Nitrogen availability
frequency

Possible Bizarre interactions with plants -*Lupinus arboreus,* the moth *Hepialus californicus*, and an insect-parasitic nematode *Heterorhabditis sp***.** (*Oecologia* 104:85-92)

Soil structure and nutrient availability

Microaggregates, pH, Cation exchange capacity, breakdown of organics and release of nutrients

N fixation

Prokaryotes only - bacteria, Actinomycetes, cyanobacteria
symbiotic interactions Legumes (e.g.., lupines) *Rhizobium*, *Bradyrhizobium*
Alders, *Ceanothus, Ramnus* - "actinorhizal"*Frankia*
cost 16 moles of ATP/ 2 moles of NH_3

Carbon cycling

wood decay; organisms involved mostly Basidiomycetes and some Ascomycetes - without their presence we would accumulate woody debris and tie up the mineral nutrients contained in it.

Mycorrhizae (= fungus - root)

mutualism based on exchange of fixed carbon for nutrients (P,N, and others)
A comparison of the two main types of mycorrhizae Arbuscular and Ectomycorrhizae

	VAM (Endos)	Ectos
Plant hosts	Most vascular plants, including herbs, shrubs, trees. examples of tree you know: Maples, Ash, giant Sequoia, Sequoia, Incense Cedar association is not obligate in most hosts	Most temperate forest trees, some shrubs. examples you know: Pines, Douglas-fir, true firs, Oaks, Manzanita, Madrone association is obligate for the hosts
Fungi involved	ca. 150 known species **Glomeromycota** all obligate associates, little "apparent" specificity	ca. 6000 known species Basidiomycetes, Ascomycetes, (Zygomycetes) most obligately associated, some highly host specialized, most not.
Cost to hosts	moderate (<15% of C)	similar but perhaps higher (20% of C)
Longevity of individual associations	2-3 weeks	Several months (maybe) five years
Primary nutrients gathered	**P**, (N), trace elements,	**N**, P, trace elements, water (two directions, see (Querejeta et al. 2003)

Environment	Richer soils, lacking large accumulations of organic detritus	Poor soils, with large accumulations of organic detritus
Morphology	no obvious external signs of colonization, cortex cell are penetrated and arbuscules (highly branched haustoria) and sometimes vesicles are formed	roots are swollen, often branched, covered by a "mantel" of hyphae, intercellular hyphae (hartig net) but usually no penetration of cells

roughly 85% of all vascular plants form mycorrhizae in nature

"Minor" types: Ericoid (*Vaccinum* & others) and Orchidoid
fungi involved *Hymenoscyphus ericae*, and *Rhizoctonia* spp.
use of detritus by Hymenoscyphus
cheating by orchids

Ecologically important aspects of mycorrhizae

Seedling establishment - crucial, but inoculum rarely limiting

Types of inoculum: living mycelium, spores & sclerotia

a few examples of limited ecto inoculum - exotic plantings (Pines in southern hemisphere); strip mines,

Long fallow disease a limitation of AM - crop issue in Australia

Symbiont sharing, nutrient transfers between hosts, and the parasitic edge
extreme case - Monotropoideae - *Pterospora;* Achlorophyllus orchids

possible + and - scenarios, *Arctostaphylus* & *Pseudotsuga*

Antagonistic interactions
Truffles, oaks, and Brulé formation

AM meadows and non-AM weedy species
Francis and Read

Bacterial interactions
helper bacteria - assist or antagonize formation of Ectos (Jean Garbaye -many papers)
bacterial endocytobiosis - AM *Gigaspora* & *Burkholderia* (Paula Bonfante-Fasolo, recent Applied and Environmental microbiol.) - *Geosiphon pyriforme* & *Nostoc(* (Gehrig H. et al. J. mol. Evol.)

And now for some pathogens - canker fungi:

What is a canker? - necrosis of stem tissue - sometimes a visible canker is formed other times shoots are killed too quickly and the only symptom is branch "flagging"

How is one formed? - **death of cambium**

via direct colonization of cambium by pathogen - Ex: mostly ascomycetes or imperfect stages, many of which are weak or opportunistic pathogens; colonization mostly via wounds, perhaps endophytic colonization?, more rarely though leaves and into twigs (*Discula)*

via colonization of cambium or sapwood following by secondary infections - ex: rusts followed by ascomycetes like *Nectria*,

via decay of sapwood resulting in death of adjacent cambium - Ex: canker rots - some *Phellinus sp*., *Fomitopsis cajanderi*, many others

Importance of canker fungi

very common on all types of trees, but usually of little consequence. Often become a problem as other stress factors activate them: other pathogens, insects, damage, and **climatic stress** (especially correlated with the limits of host geographic range) - best example cypress canker

Exceptions: **introduced canker fungi** are some of most virulent pathogens (Chestnut blight, dogwood anthracnose, pitch canker, beach bark disease, SOD)

General characteristics of canker causing fungi

Usually causes by ascomycetes, and mitotic spore states are often important
cankers are especially common outside the range of a host
they may interact with other "predisposing" organisms that weaken the branch or tree

often they show up first as flagging branches, which may or may not spread into main stem

secondary decay fungi are often introduced - causing defects and structural weakness at canker

Atropellis canker - *Atropellis pinicola* - very common cause of branch death (flagging) on Sugar pine. - often mistaken for blister rust because of canopy flagging.

Cypress canker - *Seiridium cardinale*

Host range - *Cupressus spp*. (& *Sequoia*?) seen almost exclusively in trees planted outside natural range - **and this range is very finely defined**.

Signs and symptoms - flagging, resinous "diffuse" cankers, small black fruitbodies (acervuli). Distinctive conidia

Disease is spread short distance by rain splashed conidia, and long distance by wind-borne ascospores. Transmission by the cypress moth may also occur.

Cytospora spp - asexual states of *Leucostoma* and *Valsa*

many spp involved - both hardwood and conifers are hosts usually associated with damaged or stress limbs or trunks (e.g. frost damage, mistletoe) *C. abietis* on red fir with mistletoe

Best sign distinctive asexual spore stage - yellow to orange tendrils of stick spores. The sexual state (clustered black perithecia) is common on some hosts.

Hypoxylon mammatum - Aspen canker. causes a canker rot which can result in snapping of main stem. cankers are often associated with branch stubs; serious losses in Lake states,

References:

Your book has a very short section on mycorrhizae pp 266-273. The classification they use in table 11.1 (p 267) is dated by the use of the term "endomycorrhizae" and wrong by inclusion of Arbutoid mycorrhizae as an example of endo.

See canker diseases pp341-347 in your text

A good general reference about global pattern of mycorrhizae

Read D J 1991 Mycorrhizas in ecosystems. Experientia 47, 376-391.

Other specific references

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Deacon J W and Flemming L V 1992 Interactions of ectomycorrhizal fungi. *In* Mycorrhizal functioning an integrative plant-fungal process. ed. M. F. Allen, 249-300. Chapman and Hall, New York.

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