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 arbores*, 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*
*Alder*, *Ceanothus, Rhamnus* - "actinorhizal" *Frankia*
cost 16 moles of ATP / 2 moles of NH₃

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

<table>
<thead>
<tr>
<th></th>
<th>VAM (Endos)</th>
<th>Ectos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant hosts</td>
<td>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</td>
<td>Most temperate forest trees, some shrubs. examples you know: Pines, Douglas-fir, true firs, Oaks, Manzanita, Madrone association is obligate for the hosts</td>
</tr>
<tr>
<td>Fungi involved</td>
<td>ca. 150 known species <em>Glomeromycota</em> all obligate associates, little &quot;apparent&quot; specificity</td>
<td>ca. 6000 known species Basidiomycetes, Ascomycetes, (Zygomycetes) most obligately associated, some highly host specialized, most not.</td>
</tr>
<tr>
<td>Cost to hosts</td>
<td>moderate (&lt;15% of C)</td>
<td>similar but perhaps higher (20% of C)</td>
</tr>
<tr>
<td>Longevity of individual associations</td>
<td>2-3 weeks</td>
<td>Several months (maybe) five years</td>
</tr>
<tr>
<td>Primary nutrients gathered</td>
<td>P, (N), trace elements,</td>
<td>N, P, trace elements, water (two directions, see (Querejeta et al. 2003)</td>
</tr>
</tbody>
</table>
Beneficial microorganisms and canker fungi (our first pathogenic group of fungi)

<table>
<thead>
<tr>
<th>Environment</th>
<th>Richer soils, lacking large accumulations of organic detritus</th>
<th>Poor soils, with large accumulations of organic detritus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphology</td>
<td>no obvious external signs of colonization, cortex cell are penetrated and arbuscules (highly branched haustoria) and sometimes vesicles are formed</td>
<td>roots are swollen, often branched, covered by a &quot;mantel&quot; of hyphae, intercellular hyphae (hartig net) but usually no penetration of cells</td>
</tr>
</tbody>
</table>

Roughly 85% of all vascular plants form mycorrhizae in nature.

"Minor" types: Ericoid (Vaccinium & 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)


**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
Beneficial microorganisms and canker fungi (our first pathogenic group of fungi)

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
Beneficial microorganisms and canker fungi (our first pathogenic group of fungi)

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


Other specific references