Urban Tree Management

Fungal Growth & Tree Health

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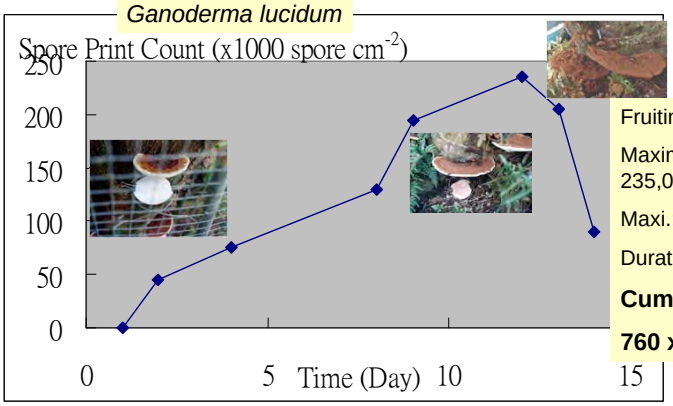
Nutrition on FUNGI

- **Heterotrophic**
- Secrete extracellular enzymes
- Absorptive nutrition
- **Saprobes**: decay dead organic matter
- pathogens: biotroph, necrotroph
- symbionts: parasites - commensals - mutualists

Fungi are Spore-ific!!!

Penicillium hyphae with conidia

Ganoderma lucidum



Mean:

141 x 10^3 spores / cm^2. d

Fruiting Body (450 cm^2):

Maximum spore print count: 235,000 spores/ cm^2 . d

Maxi.: **6 x 10^5 spores/cm^2. d**

Duration: more than 12-14 d

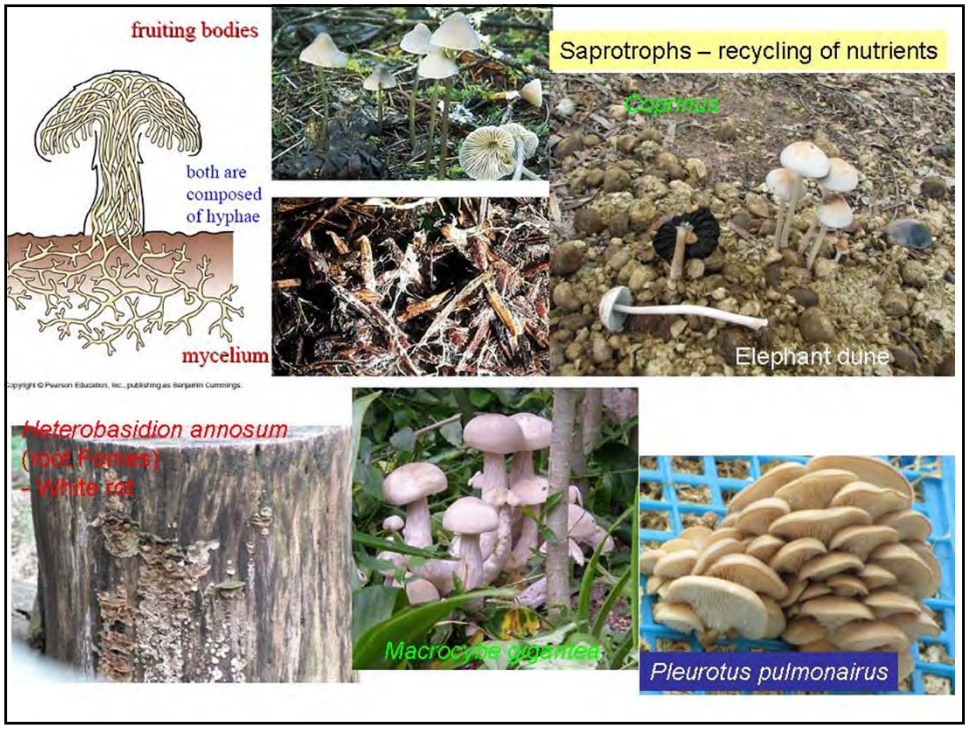
Cumulative Total:

760 x 10^6 spores/cm^2 in 12 d

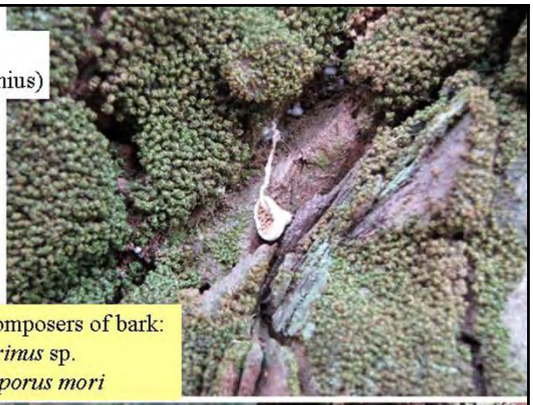
Spore production of individual fruiting bodies (Buller, 1909, 1922; Gregory et al., 1953; Ingold, 1971)

Species	Production unit	Spore production
Serpula lacrimans	Fruiting body	3x 10^3 spores cm^{-2} d^{-1}
Ganoderma applanatum	bracket	3 x 10^{10} spores d^{-1}
Daldinia concentrica	perithecial stroma	1 x 10^8 spores d^{-1}
Langermannia gigantea	puffball	7 x 10^{12} spores total
Sclerotinia sclerotiorum	apothecium	3 x 10^7 spores total
Tilletia caries	infected wheat grain	1.2 x 10^7 spores total
Penicillium sp.	colony 2.5 cm in diam	4 x 10^8 spores total

Lacey, J. (1996) Spore dispersal - its role in ecology and disease: the British contribution to fungal aerobiology. Mycological Research 100, 641-660.



Decomposer of Litter:
Marasmius purpureostriatus (violet Marasmius)

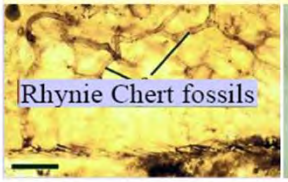


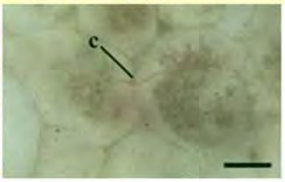
Decomposers of bark:
Coprinus sp.
Polyporus mori

Beneficial Fungi - Mycorrhizae

a. Arbuscular mycorhizae (AM)
b. Ectomycorrhizae (EM)

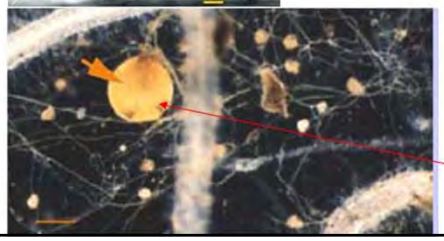
Fossil plants (416-359.2 million yrs ago) contain AM fungi

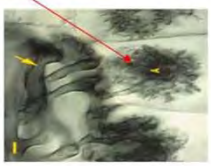


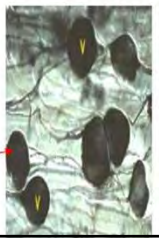


Arbuscular Mycorrhizae

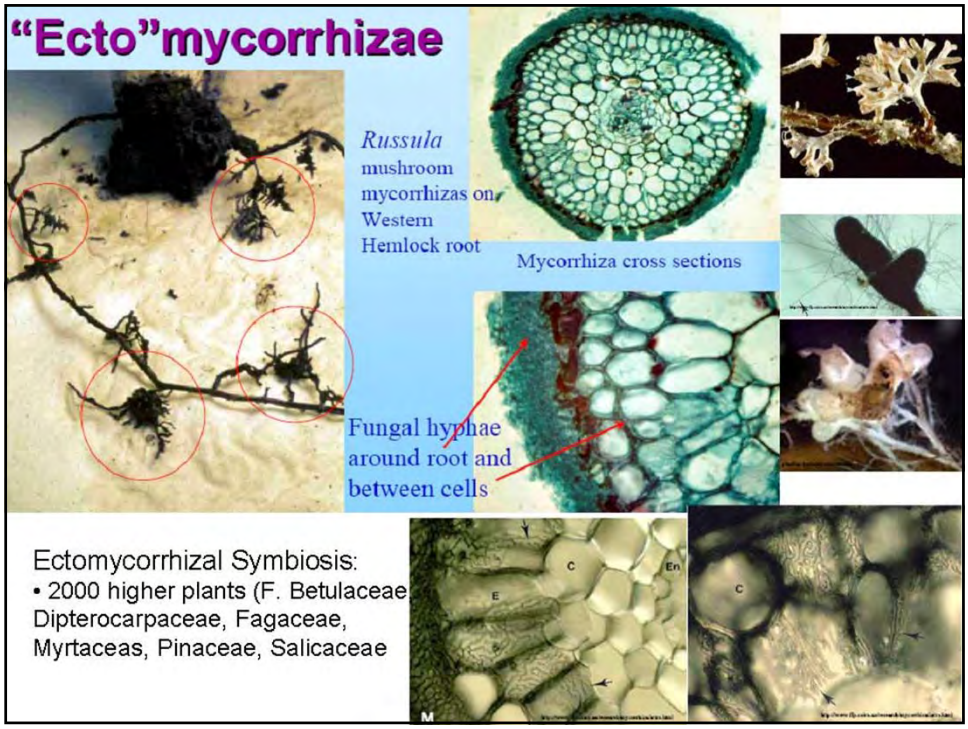
Arbuscules

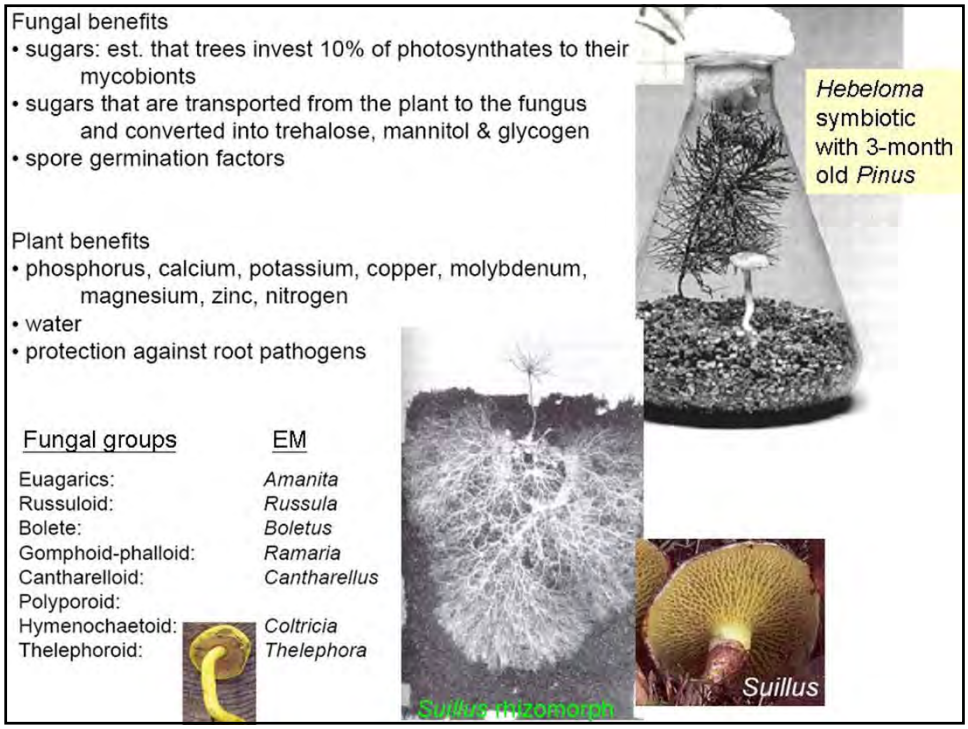


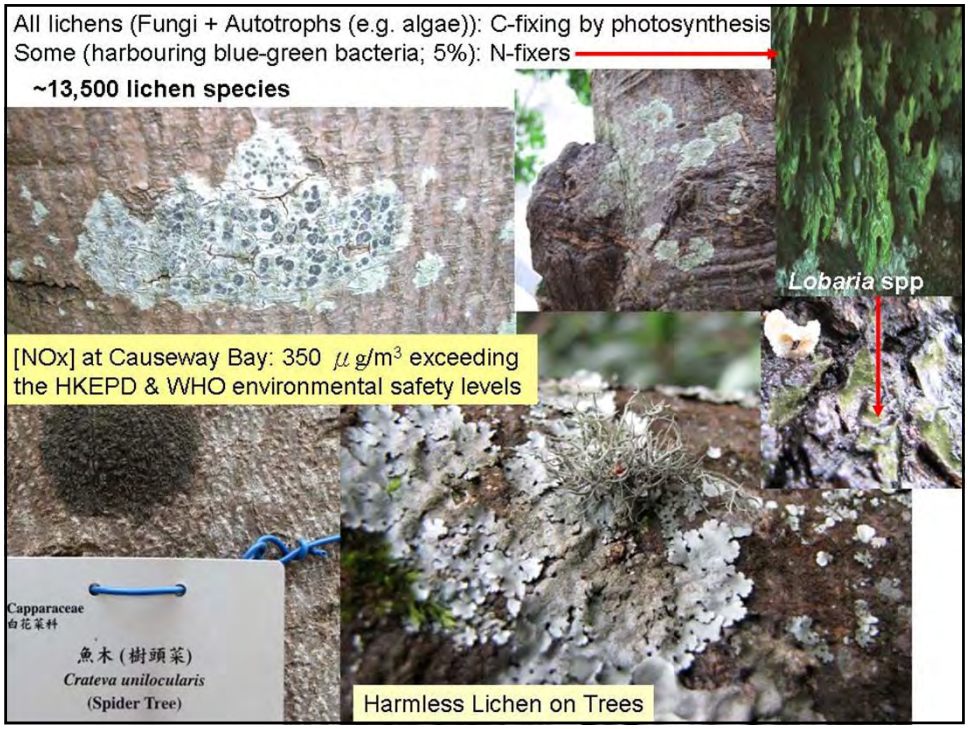


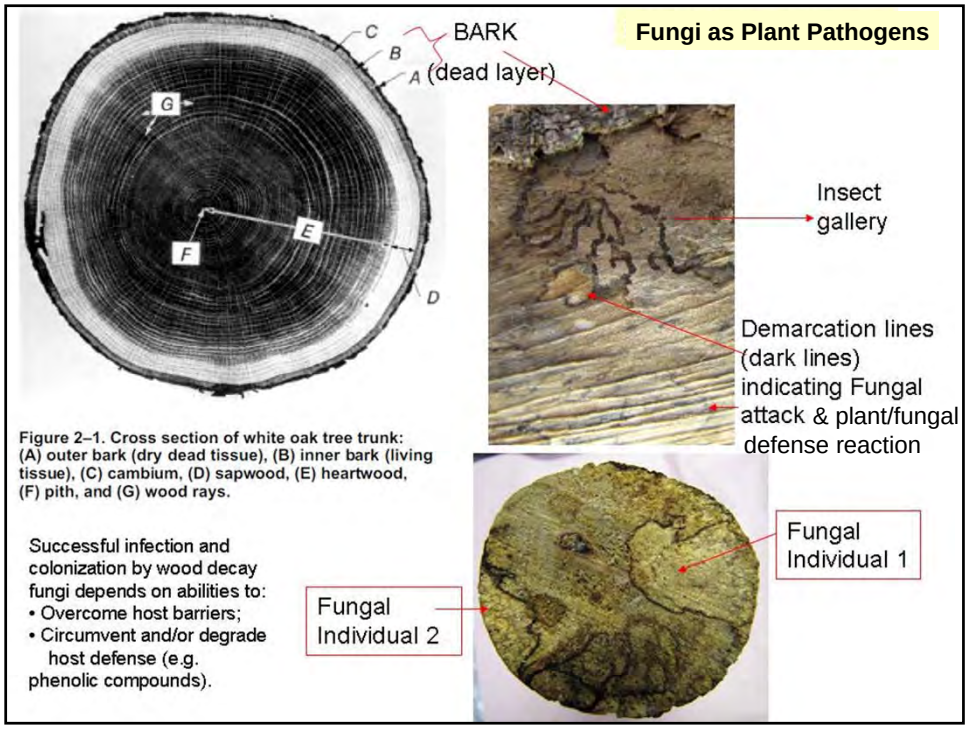


Vesicles

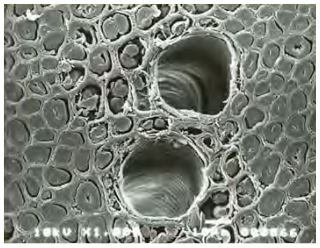

"Ecto"mycorrhizae
Russula mushroom mycorrhizas on Western Hemlock root
Mycorrhiza cross sections
Fungal hyphae around root and between cells
Ectomycorrhizal Symbiosis:
• 2000 higher plants (F. Betulaceae Dipterocarpaceae, Fagaceae, Myrtaceas, Pinaceae, Salicaceae
C
En
E
M

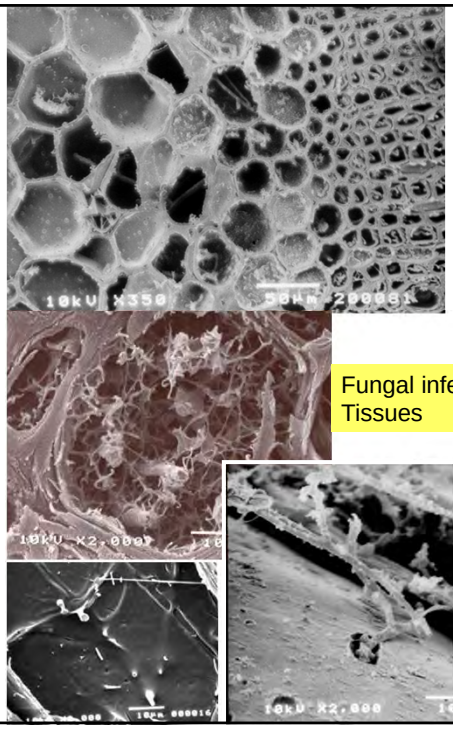

Fungal benefits
• sugars: est. that trees invest 10% of photosynthates to their mycobionts
• sugars that are transported from the plant to the fungus and converted into trehalose, mannitol & glycogen
• spore germination factors
Plant benefits
• phosphorus, calcium, potassium, copper, molybdenum, magnesium, zinc, nitrogen
• water
• protection against root pathogens
Hebeloma symbiotic with 3-month old Pinus
Fungal groups
EM
Euagarics: Amanita
Russuloid: Russula
Bolete: Boletus
Gomphoid-phalloid: Ramaria
Cantharelloid: Cantharellus
Polyporoid:
Hymenochaetoid: Coltricia
Thelephoroid: Thelephora
Suillus rhizomorph
Suillus


All lichens (Fungi + Autotrophs (e.g. algae)): C-fixing by photosynthesis
Some (harbouring blue-green bacteria; 5%): N-fixers
~13,500 lichen species
Lobaria spp
[NOx] at Causeway Bay: 350 μg/m3 exceeding the HKEPD & WHO environmental safety levels
Capparaceae
白花菜科
魚木 (樹頭菜)
Crateva unilocularis
(Spider Tree)
Harmless Lichen on Trees


Fungi as Plant Pathogens
BARK
(dead layer)
C
B
A
G
F
E
D
Insect gallery
Demarcation lines (dark lines) indicating Fungal attack & plant/fungal defense reaction
Figure 2–1. Cross section of white oak tree trunk: (A) outer bark (dry dead tissue), (B) inner bark (living tissue), (C) cambium, (D) sapwood, (E) heartwood, (F) pith, and (G) wood rays.
Successful infection and colonization by wood decay fungi depends on abilities to:
• Overcome host barriers;
• Circumvent and/or degrade host defense (e.g. phenolic compounds).
Fungal Individual 2
Fungal Individual 1

Normal vascular tissue



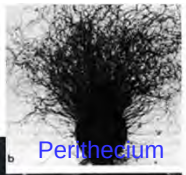


Fungal infected Tissues

Wood Decay by Fungi
1. **Soft Rot**
2. **Brown Rot**
3. **White Rot**

Fungal as Pathogens

Soft Rot
Decay WET wood
Decay cellulosic & hemicellulosic material in soil and estuaries,
Non-lignin degrader

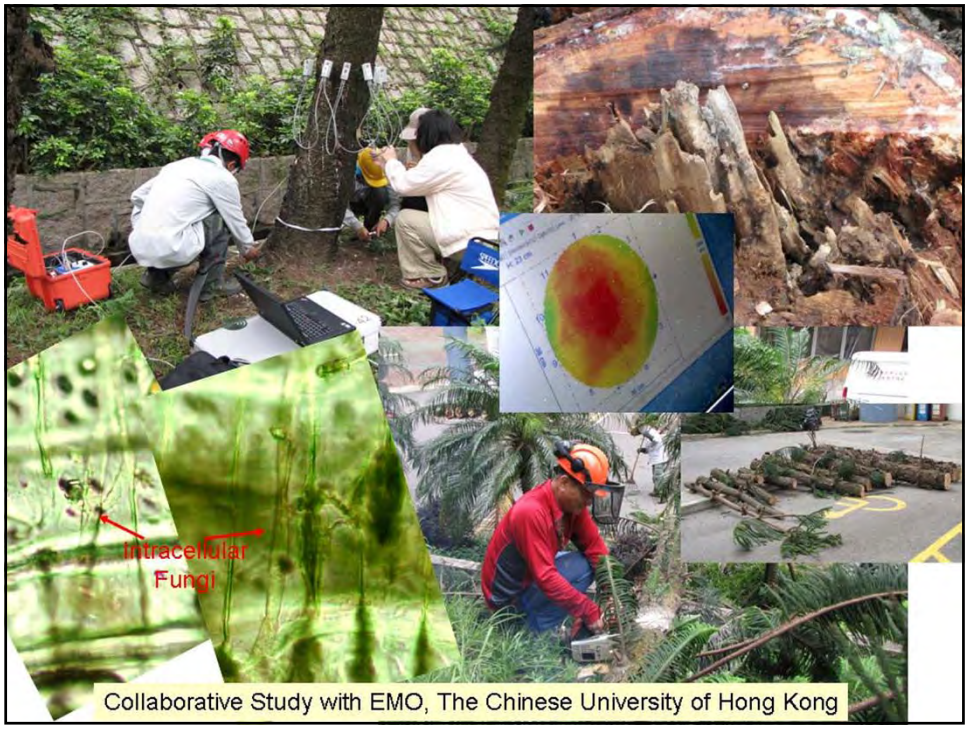


Ascomycetes and Fungi Imperfecti.
e.g. *Phialophora*, *Chaetomium globosum*
Soft Rot decay occurs when the timber is saturated with water .

Phialophora richardsiae is a soft rot fungus of wood and is an uncommon cause of human infection. However, cases of subcutaneous phaeohyphomycosis have been reported.

Phialophora species possess a variable capacity for growth on either copper, arsenic or copper-chrome-arsenic (CCA) supplemented media.


Mold & Bacteria intensify the decay initiated by Termite attack
南洋杉 Araucaria heterophylla
Bleeding Canker
Wilt
Foilar Abnormalities
Collaborative Study with EMO, The Chinese University of Hong Kong


Intracellular Fungi
Collaborative Study with EMO, The Chinese University of Hong Kong

Brown Rot - cubicle brown rot

- 10% of all wood-decay fungi
- 80% of these occur on conifers
- mostly members of the Polyporaceae
- degrade cellulose and hemicellulose but not much lignin
- the major component of humus
- degrade cellulose via oxidative process involving production of H_2O_2 during breakdown of hemicellulose

Brown rot blossom blight is a common and destructive disease of all stone fruits including flowering cherry and plum as well as their fruit bearing relatives.

Initial typically deep brown-red discoloration and wood become more soft and brittle.
Shrinking of wood caused by degradation of cellulose and hemicellulose.
The infected wood cracks transversely and longitudinally on drying. Final stage: typical cubical rot with white mycelium lying in between (BROWN rot).
The mycelium is soft and fluffy, not tough and leathery.

- A parasite and satrotroph of Conifer and broad-leaved trees

Heart Rot

Bark injuries, pruning cuts, branch stubs or injured roots: infection courts for the basidiospores.
Also grow saprotrophically.

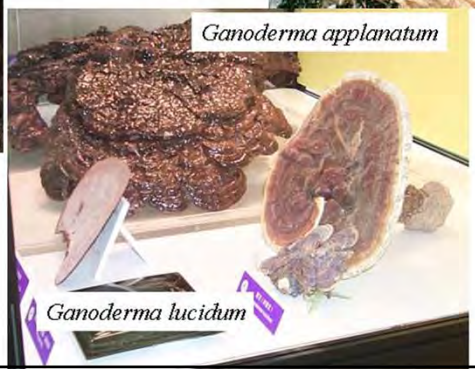
Fungus: *Laetiporus sulphureus* (sulfur shelf, chicken of the woods)
Tree: 樟 *Cinnamomum camphora*

Chicken of the woods is a yellow tree fungus, often layered like roof tiles, which causes a lumpy brown rot in the heartwood. It enters through wounds. Infected trees rapidly lose their stability. Chicken of the woods has a relatively large range of hosts.

White Rot Fungi

- largest group of wood rot fungi; Basidiomycota, Ascomycota
- degrade cellulose, hemicellulose and lignin
- produce a white stringy decay of wood
- 3 classes of enzymes for cellulose & hemicellulose degradation
  - Hydrolytic: cellulase, glucanases, glucosidases
  - Oxidative enzymes: cellobiose (=hemicellulose)
  - Oxidoreductase: cellobiose reductase

Ganoderma applanatum species complex



Ganoderma applanatum species complex

Ganoderma lucidum
Host: *Acacia confusa* 台灣相思

Phaeolus schweinitzii - butt-rot

attacks the roots of living trees
host becomes more susceptible to wind-throws

Host: conifers

Tree host:木麻黃 *Casuarina equisetifolia*

White rot fungus
Fomes fomentarius

Phellinus spp
- causing agent of laminated root rot
- important in the decline of the Douglas-fir stage of succession in cedar-hemlock forests
- affects other conifers as well (e.g., *Pinus* spp.)

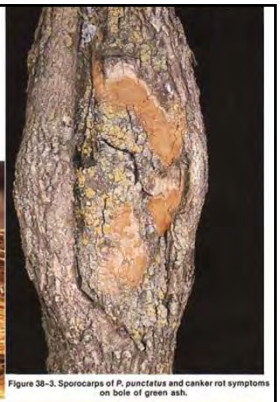


Figure 38–3. Sporocarps of *P. punctatus* and canker rot symptoms on bole of green ash.

The different species of *Phellinus* may form shelf-like fruitbodies (Conk) or just coat the wood underside (crust form: bolster shaped, dark red-brown, very tough, firm)

Brown root rot

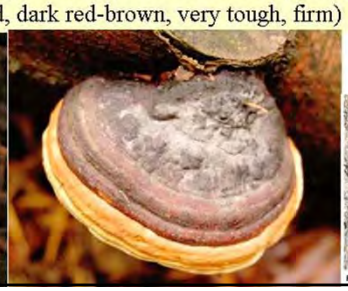
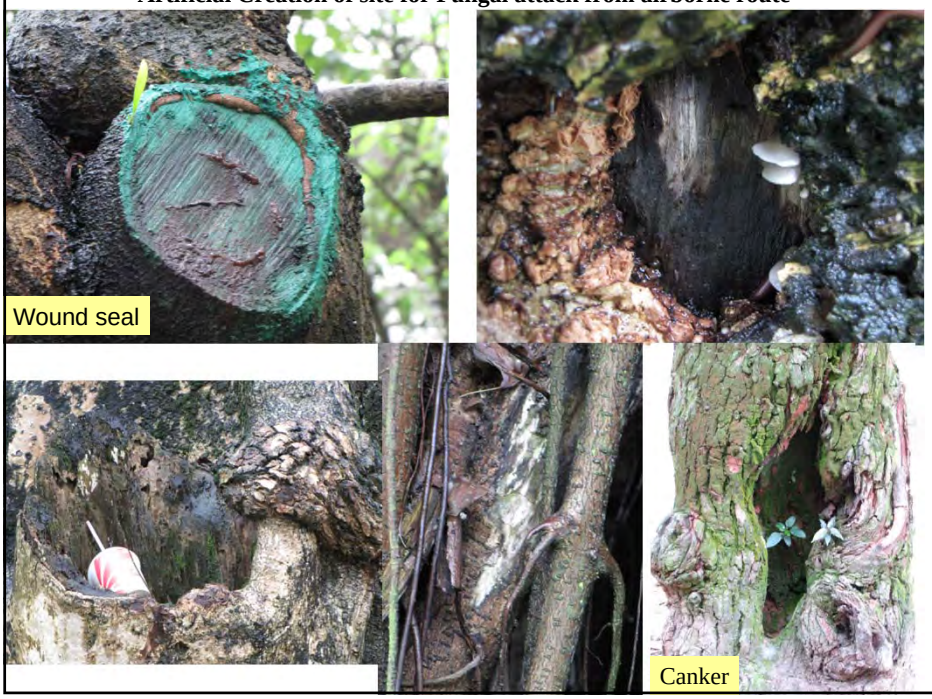


Figure 38–4. Sporocarps of *P. robineae* on bole of black locust.

Longan (*Dimocarpus longan*) Infected by *Phellinus noxius*. Upper root showing network of brown lines; upper right: white to brown fungal mat on inner bark surface; Lower right: developing crust.

Mature fruiting bodies (Crust) of *Phellinus noxius* produced on a declining flame tree (*Delonia regia*). (courtesy J. H. Huang)

Artificial Creation of site for Fungal attack from airborne route



Crust fungus

Stereum rugosum

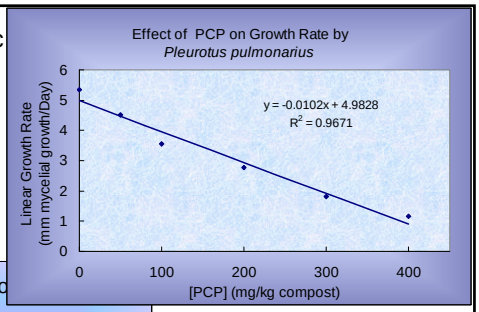
Wound increases susceptibility to fungal attack

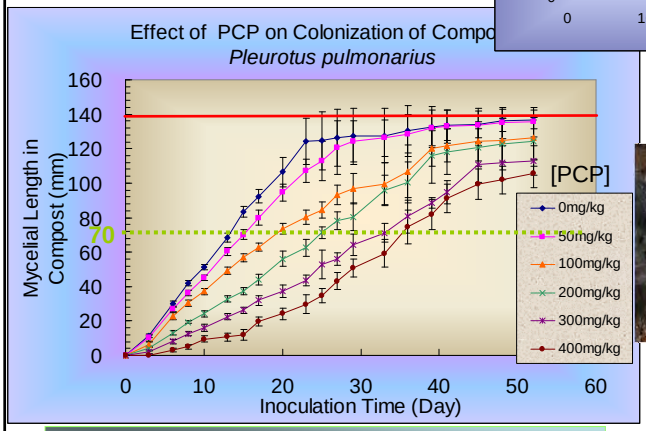
Polyporus alveolaris
White rot fungus

It causes a white rot of dead hardwoods. Found on sticks and decaying logs.

White Rot Fungi Degrade Persistent Organic Compounds, e.g. Fungicides, Wood Preservatives, via the biosynthesis of the natural Fenton reagents, the lignolytic enzymes.

Pentachlorophenol: a wood Preservative

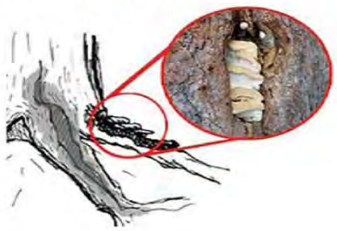




Data presented in mean ± SD of 10-12 replicates

Pictorial Guide for Tree Maintenance to Reduce Tree Risks
減低樹木風險的樹木護養簡易圖解

Fungal fruiting bodies
呈現菌類子實體



Recommendation 建議

More detailed investigation of extent of decay is required

需要對腐爛狀況作更詳盡檢查

…… What guidelines?

- What about those MUSHROOMS which are seasonal, annual not perennial? – The inspector does not encounter 'mushrooms' at the right time, right place..
- What about those MUSHROOMS which are at early stage of infection?
- What about those fungi which do not form MACROSCOPIC mushrooms?

Foliar diseases

***Taphrina* occurs on a wide variety of hosts including some economically important species**

- ***Taphrina deformans*, the cause of peach and almond leaf curl**
- ***T. caerulescens* cause of leaf blister of oak**

Leaf curl

Taphrina

- saprobic haploid uninucleate yeast phase
- Dikaryotic hyphae in infecting host

Taphrina typically grow as yeasts during one phase of their life cycles, then infect plant tissues in which typical hyphae are formed, and ultimately they form a naked layer of asci on the deformed, often brightly pigmented surfaces of their hosts. No discrete fruit body is formed outside of the gall-like or blister-like tissues of the hosts. The asci form a layer lacking paraphyses, and they lack croziers. The ascospores frequently bud into multiple yeast cells within the asci.

http://www.caf.wvu.edu/kearneysville/disease_descriptions/omplfcrl.html

Anthracnose – dead areas/ blotches on leaves

Figure 1: *Marssonina* leaf spot on cottonwood.

Figure 2: *Marssonina* leaf spot on aspen, late symptoms.

Anthracnose on sycamore

Figure 3: *Septoria* leaf spot showing tan circular spots.

Figure 4: *Septoria* leaf spot showing irregular brown to black spots.

Figure 5: Ink spot disease on aspen in early summer.

Tar spot on maple

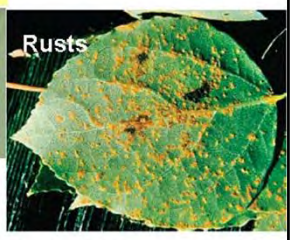
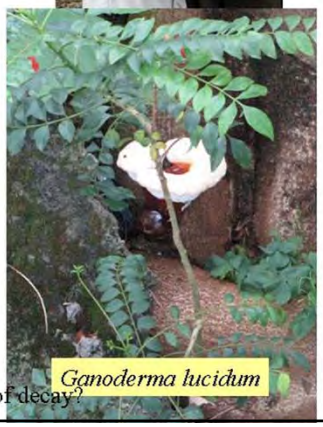


Figure 8: Leaf rust.

Insect & Fungal Galls

Leaf gall (blisters) caused by the fungus *Exobasidium vacinii.* Round, dark brown blisters form on the upper leaf surface; a white fungus growth forms on the underside



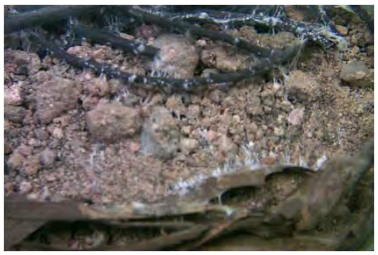
鳳凰木 *Delonix regia*

Ganoderma lucidum

Is *Ganoderma lucidum* the causative agent of decay?

Beside the Seasonal Spore dispersal, *Ganoderma lucidum* walks in soil.

No bait, no mycelial strands



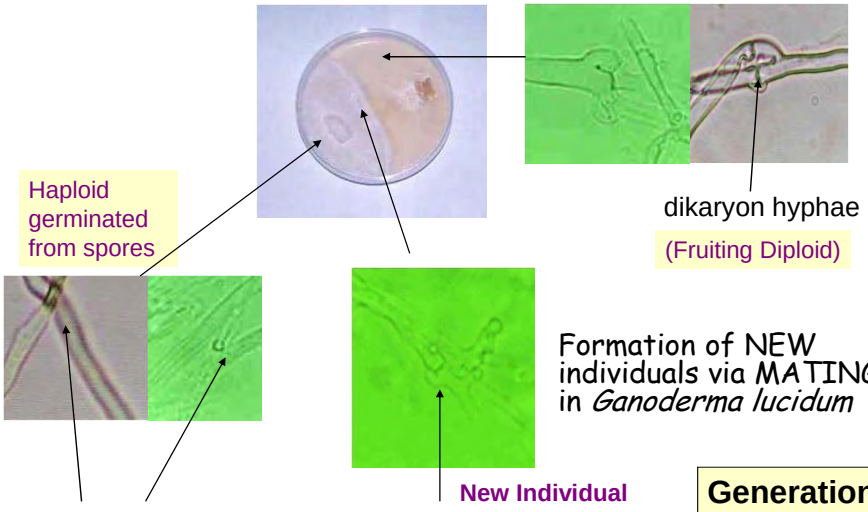
Bait, mycelial strands

Soil walking for FOOD.

Growth Rate of *Ganoderma lucidum* on soil

Time (Day)	10	20
Unsterile Soil	2.25±0.50 cm	5.28±0.65 cm
Sterile Soil	5.8 ±0.27 cm	6.00 cm *

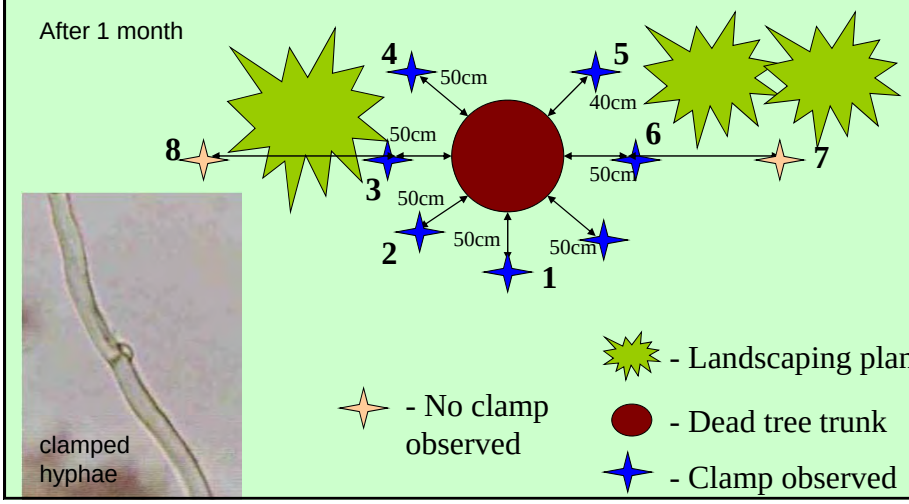
Di – Mon Mating Test



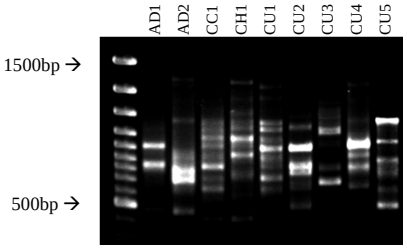
Soil walking for MATE

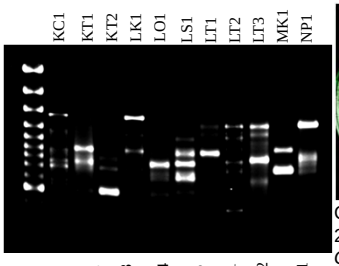

'Bait' of monokaryon

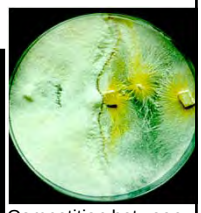

bait inserted in soil



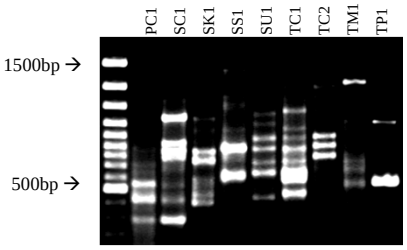
Confirmation of Fungal Individuals by Arbitrarily primed PCR using primer M13R

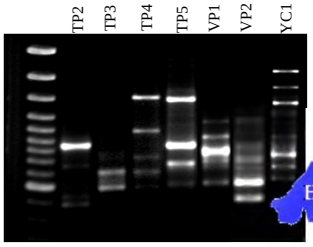


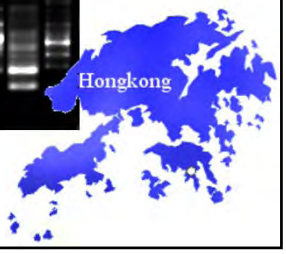




Competition between 2 individuals of *Ganoderma lucidum*



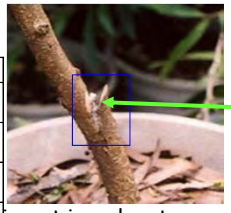




Ganoderma lucidum is found throughout Hong Kong

Artificial Pathogenesis

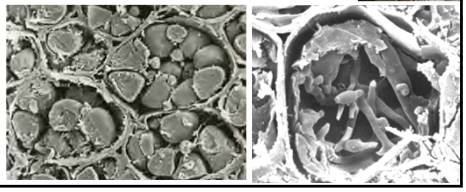
species	Treatment					control				
Pyrenria championi (石筆木)	++	++	-	-	-	-	-	-	-	-
Lithocarpus glaber (石櫟)	++	+	-	-	-	-	-	-	-	-
Quercus myresinaefolia (細葉青剛櫟)	++	+	+	+	+	-	-	-	-	-
Quercus championi (黃背櫟)	+	+	+	+	+	-	-	-	-	-
Litsea cubeba (山蒼樹)	++	++	+	++	++	-	-	-	-	-
Machilus breviflora (短花楠)	++	+	+	+	+	-	-	-	-	-
Dospyros morridiana (羅浮柿)	+	+	-	-	-	-	-	-	-	-
Aporusa chinesis (銀柴)	+	+	+	++ +	+	-	-	-	-	-
Acacia confusa (台灣相思)	+	+	-	-	-	-	-	-	-	-



insert inoculum to wound

3 months

Remark : Positive result is "+", more '+' means more mycelial growth.
Negative result is "-". *T. conferta*: 5 +



- Tree host specificity
- Individual tree health affects infection result

Ganoderma lucidum found in urban & protected areas

Conclusion

Using *Ganoderma lucidum* as a plant pathogen example,

The persistence in soil as a sink.

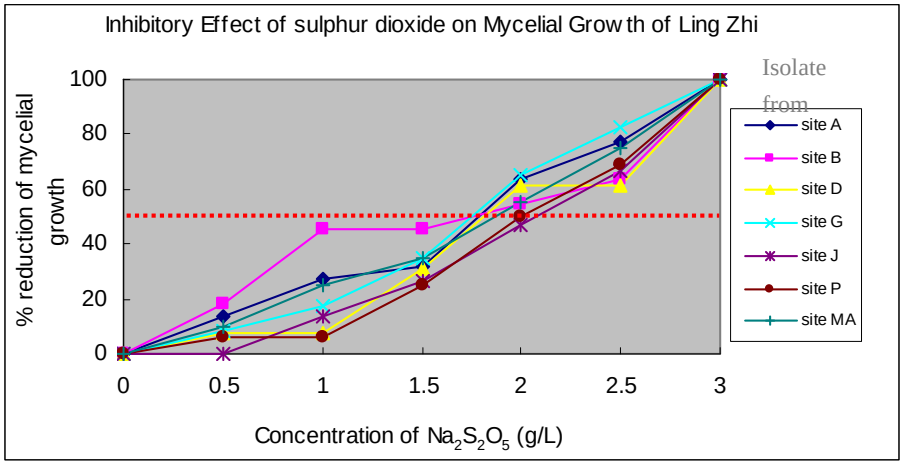
1. It 'walks' in soil and 'bites' on the wounded tree roots.
2. It disperses spores in air to infect trees annually.
   Billions of spores are produced from one *G. lucidum* mushroom.
3. It continuously generates genetic variation by 'mating' between two haploid spore germlings and 'di-mon' mating between a haploid spore germling and a diploid fruiter.
4. As a white rot fungus, it efficiently degrades wood to cause heart rot and litter to recycle nutrients. Mushrooms are borne on stem and root of the infected tree as well as on ground.
5. Host specificity was observed, e.g. *Acacia confusa*, leading to wide distribution in Hong Kong.
6. It is an OPPORTUNISTIC pathogen; Wound is the entrance for fungal infection.

Beside the wood degraders, there are other fungi which:

a. Beneficial to tree growth,
b. Neutral to the tree health,
c. Parasitize a tree host but the site of attack is at leaves.

Acknowledgement
The collaboration from Landscape Section, EMO, The Chinese University of Hong Kong

Tolerance to Pollutants

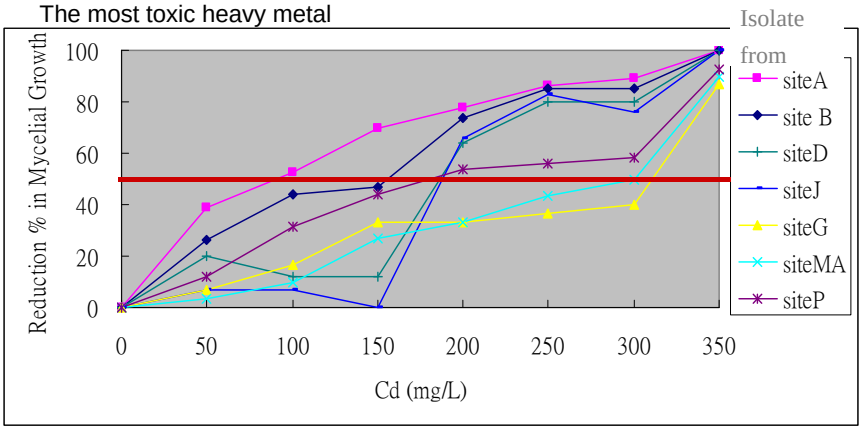


- High doses of SO_2 inhibit growth of *Ganoderma lucidum*
- Average EC_{50} ranges between 1800-2100 ppm of $Na_2S_2O_5$
- Many seedlings were killed by < 1 g/L $Na_2S_2O_5$
- *G. lucidum* cultures were highly tolerant to SO_2
- Different strains have similar sensitivity towards SO_2

Tolerance of Pollutants

Cadmium

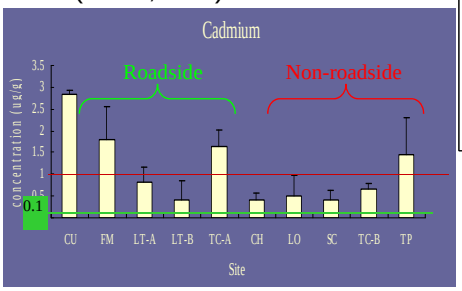
polyphosphate fertilizer and sewage sludge
build up of cadmium in agricultural soil
The most toxic heavy metal



Growth of *G. lucidum* was inhibited by high doses of Cd
The EC50 of Cd on mycelial radius ranges from 50-250 ppm
Different strains will have different sensitivities towards Cd

Metal Concentrations in Field Collected *G. lucidum*

- Concentrations of Cd in fruiting bodies from all sites exceed the maximum permitted concentration in food (WHO,1993)



maximum permitted concentrations in foods (WHO)