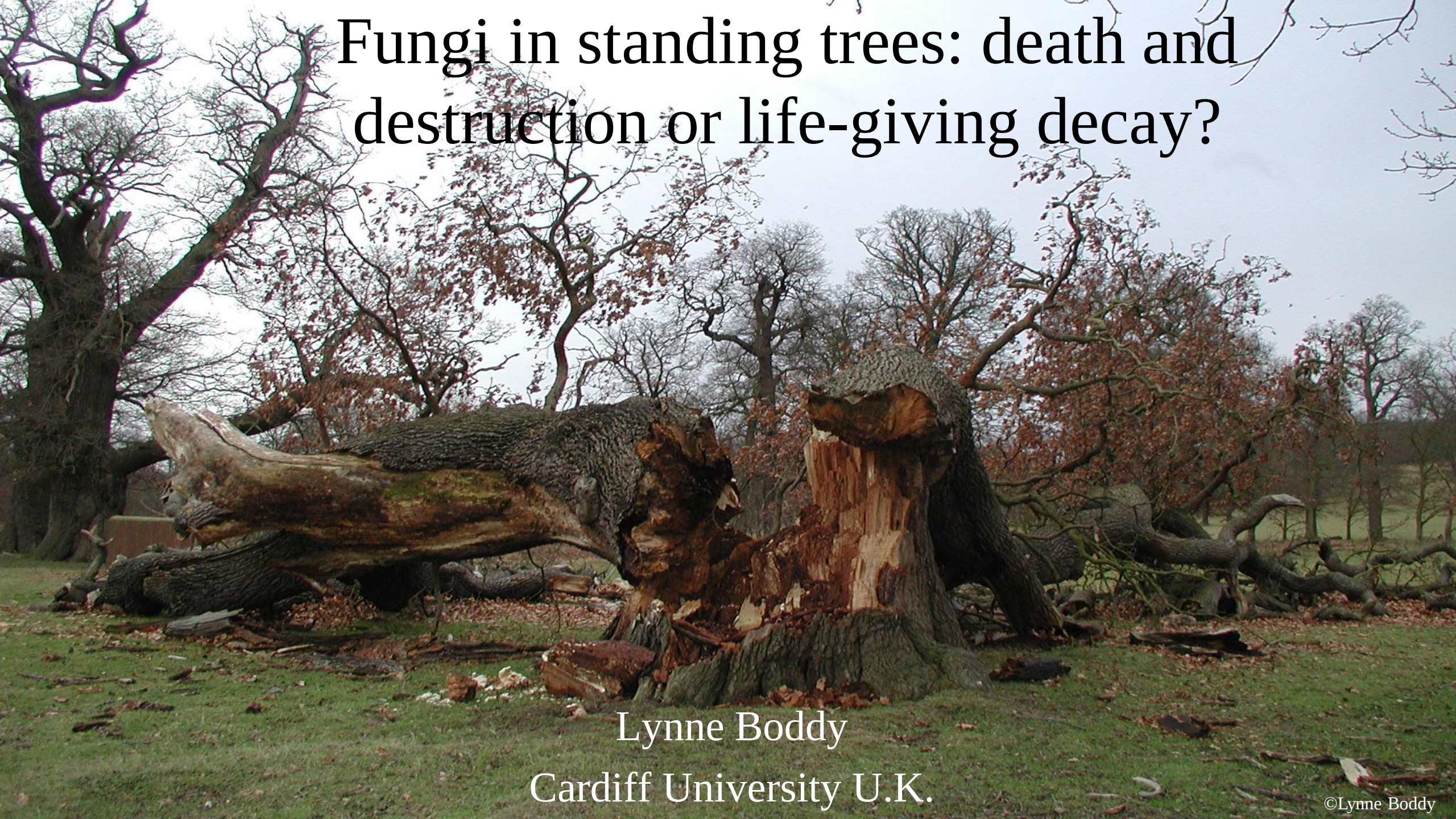


Fungi in standing trees: death and destruction or life-giving decay?



Lynne Boddy
Cardiff University U.K.

Tree holobiont

Foliar pathogens



Leaf epiphytes feeding on exudates

Leaf endophytes

Saprotrophs of dead leaves

Epiphytic lichens



Saprotrophs of dead twigs

Saprotrophs performing natural pruning of non-functional branches



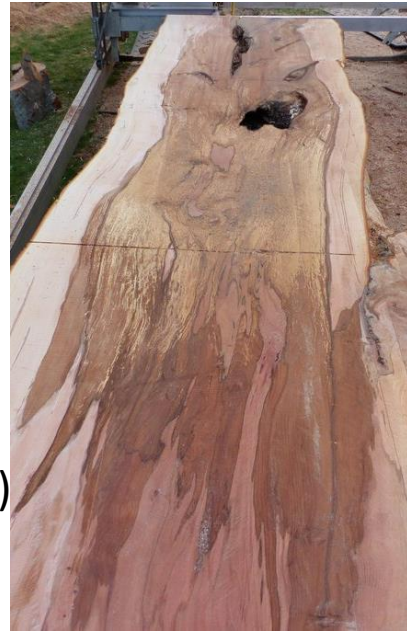
Saprotrophs causing heart-rot (top rot)

Latent fungi in functional sapwood

Fungi causing heart-rot (butt rot)

Bark-killing, canker-causing fungi

Wound colonisers



Pathogens of woody roots

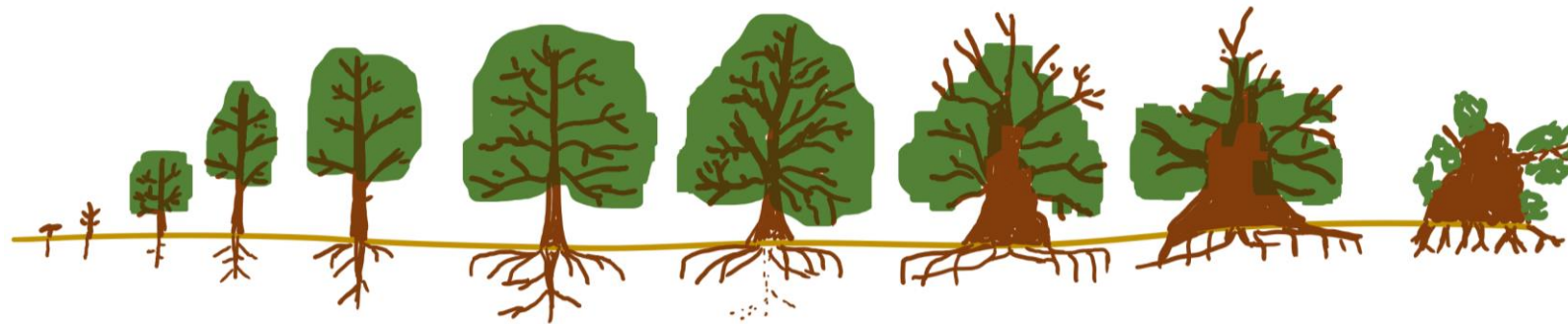
Pathogens of fine roots

Endophytes of roots

Saprotrophs decaying woody roots

Mycorrhizal fungi



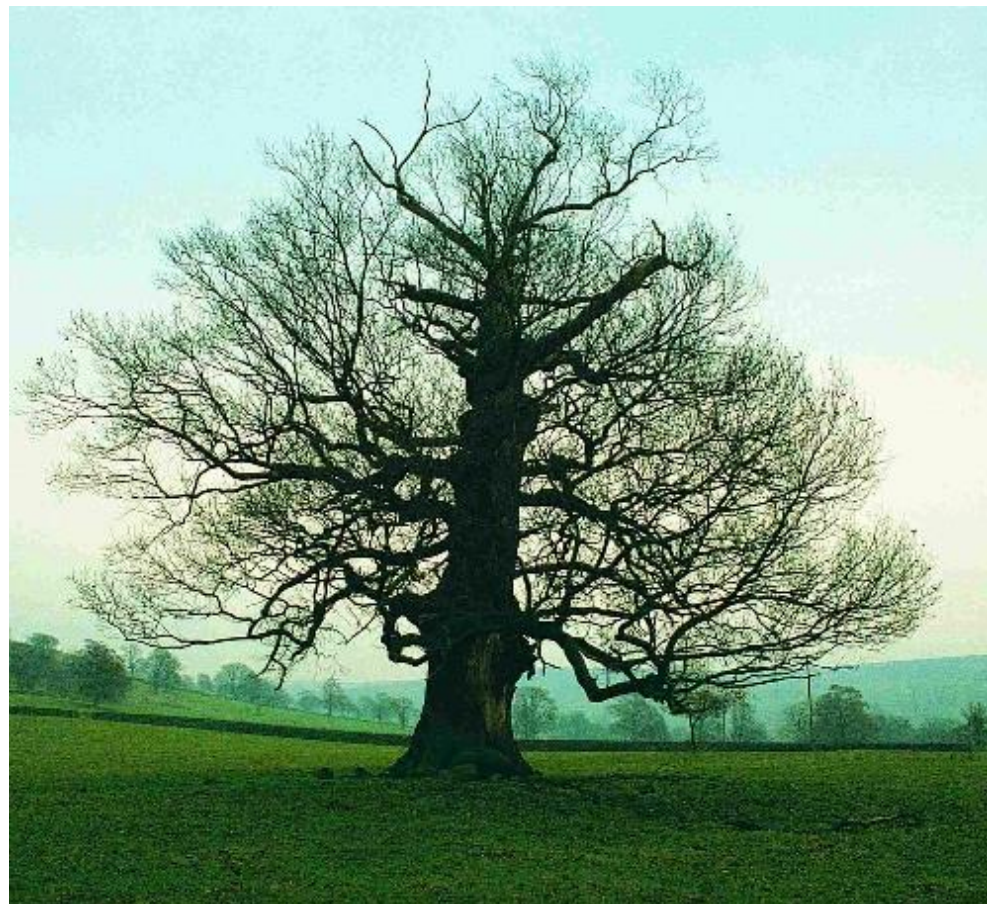


Trunk cross section



Life stage	<u>Seedling to early mature</u>		<u>Full – late mature</u>		<u>Early ancient</u>	<u>Mid ancient</u>	<u>Late ancient</u>
Apical dominance	Dominant		Lower functional units are free of dominance		Branch system operates in functional units		
Trunk ring width	Increases in early years, then decreases, then becomes constant		Decreases		Decreases	Decreases	Minimum sustainable
Current annual increment (CAI)	Increases		Constant		Decreases	Active in local regions of re-iterative growth	Can remain active in individual trunk columns
Growth/dieback /decay balance	Minimal dysfunctional tissue		Dysfunctional limbs/twigs due to shading, natural pruning		Crown starts to retrench; increased lower canopy growth; branch decay and heart-rot	Advanced crown retrenchment; branch dieback; branch breakage and epicormic growth; heart-rot	Dominated by decay of trunks and woody roots; tree may die or rejuvenate as phoenix growth

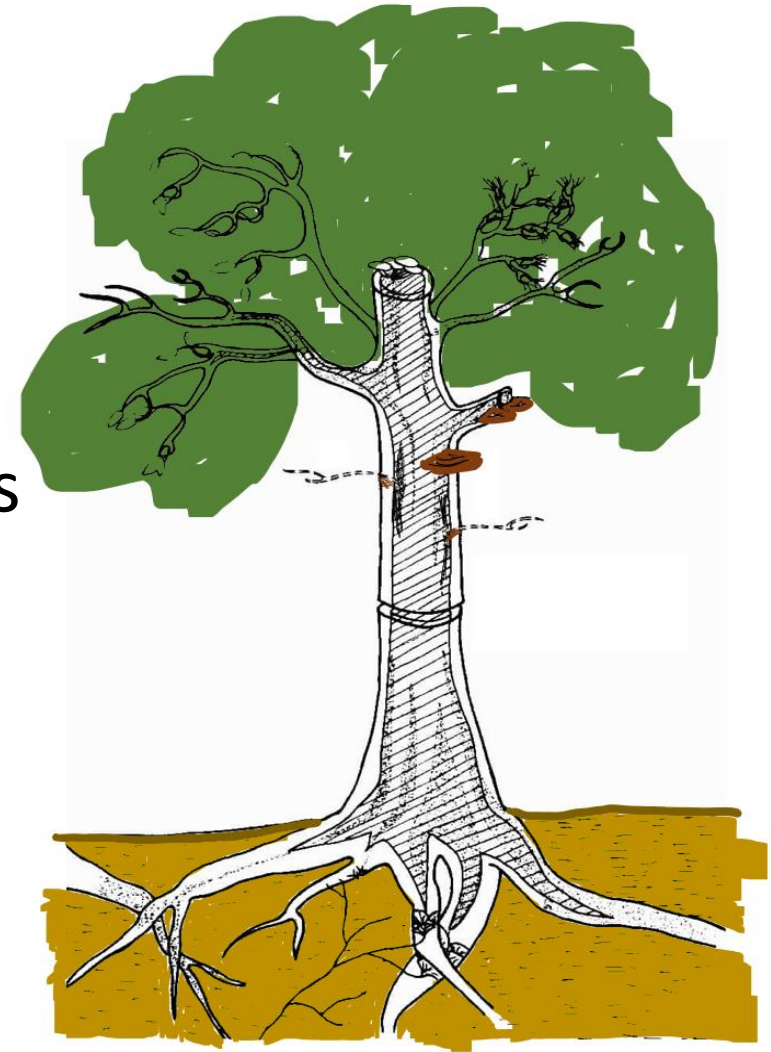






Colonization strategies

1. Heart rots
2. Active pathogenesis
3. Unspecialized opportunism - wound colonizers
4. Specialized opportunism – latency
5. Secondary colonizers





© L Boddy

Heart rot: Importance

Safety

Nutrient cycling

Fungal habitat

Vertebrate habitat: 1000 birds and mammals worldwide

Invertebrate habitat: 1700 spp. (6%) in UK; 15% rarest insects e.g. Violet Click Beetle *Limoniscus violaceus*



Buglossoporus quercinus

©Martyn Ainsworth



© L Boddy



Hericium coralloides

©Martyn Ainsworth



Hericium erinaceus

©Martyn Ainsworth

A paradox?

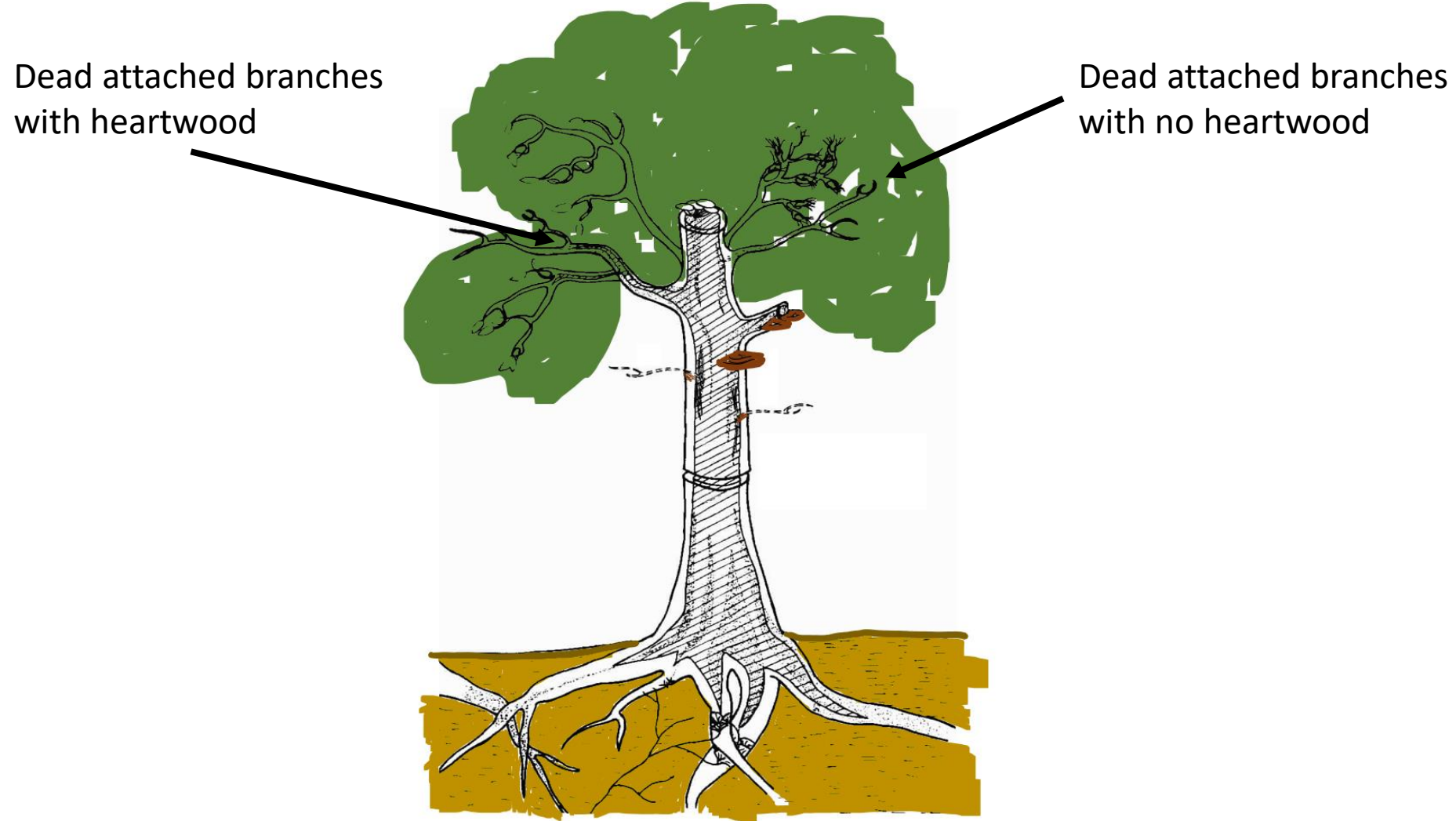
- In standing tree trunks most decay occurs in heartwood
- In felled/fallen tree trunks most rapid decay occurs in sapwood

The paradox explained

Functional sapwood v Heartwood

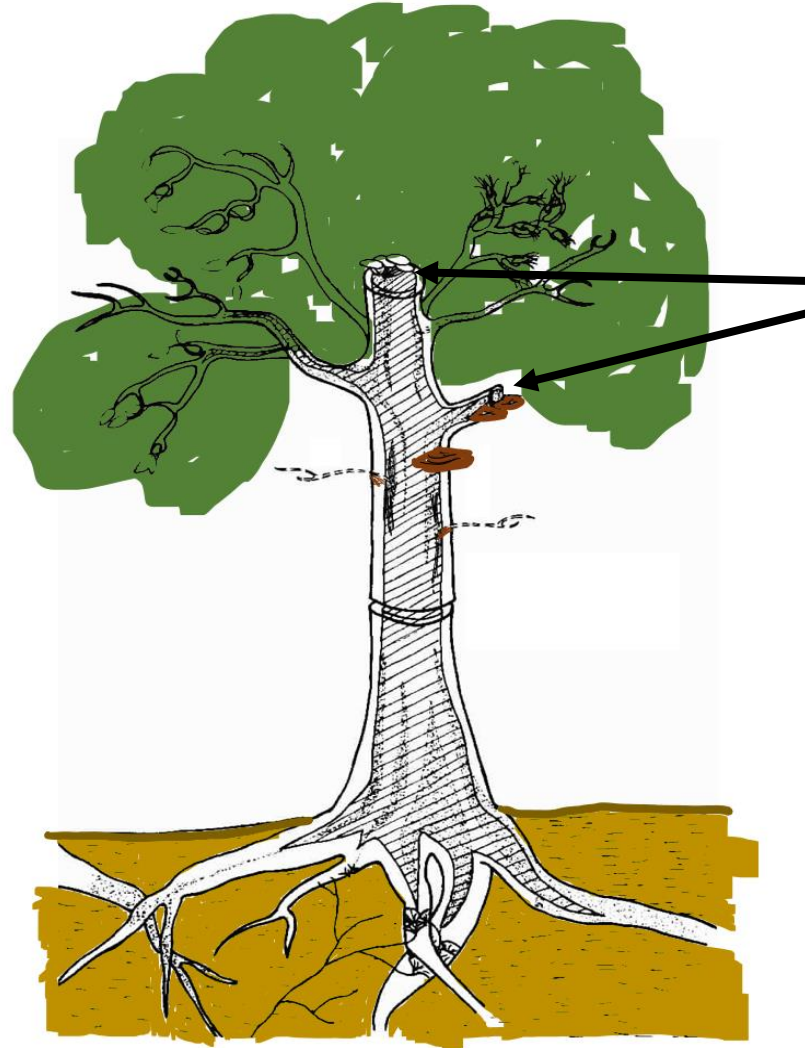
- Living cells
- High water content
- Low O₂
- High CO₂
- Low nutrient *availability*
- Inhibitory chemicals
- Lower water content
- Variable O₂ /CO₂ (but worse than ambient)
- C and nutrients available in wood cell walls

Heart-rot fungi: how do they establish in and leave standing trees?





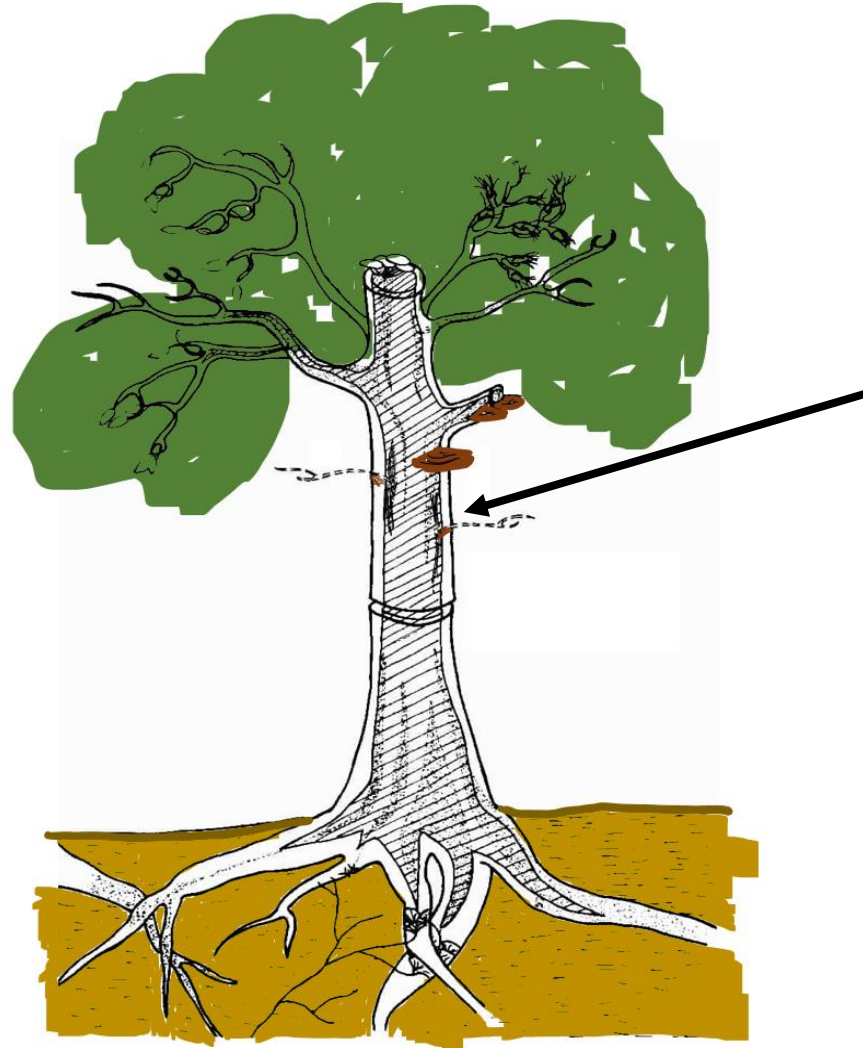
Heart-rot fungi: how do they establish in and leave standing trees?



Large wounds
exposing heartwood



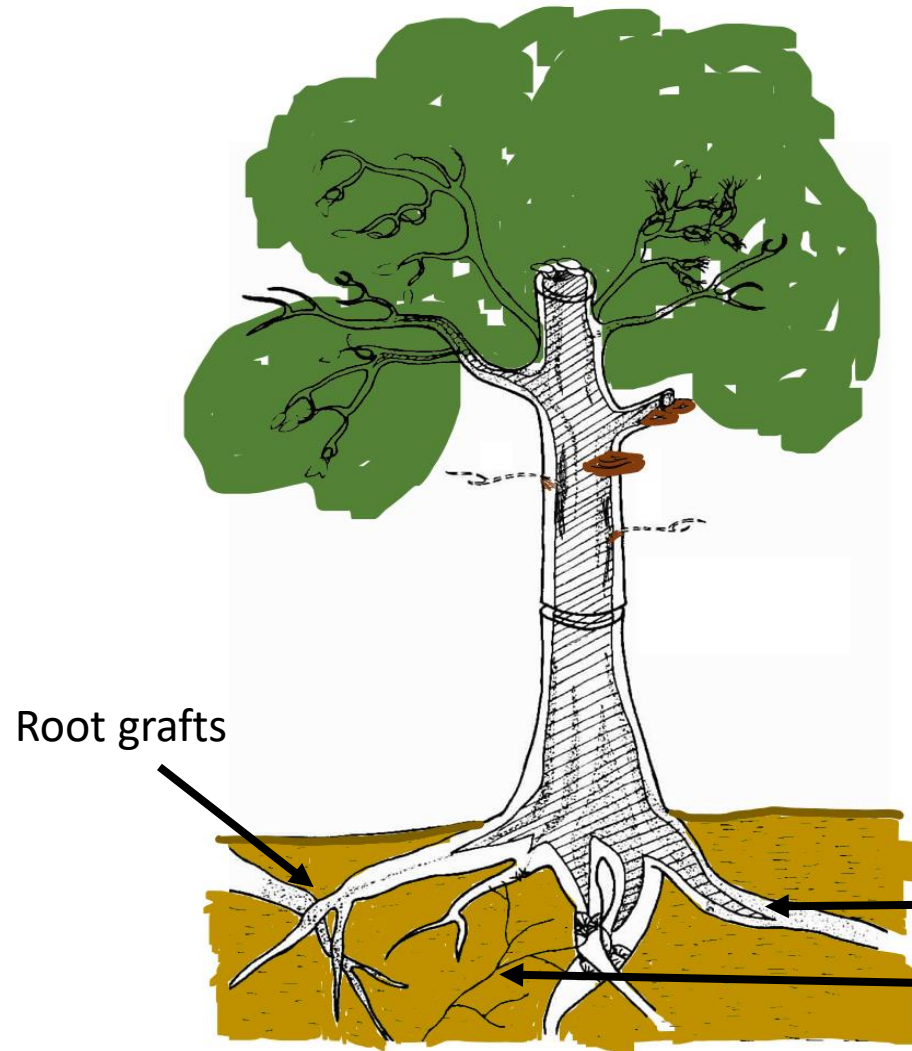
Heart-rot fungi: how do they establish in and leave standing trees?



Embedded stubs of
branchlets containing
established fungi

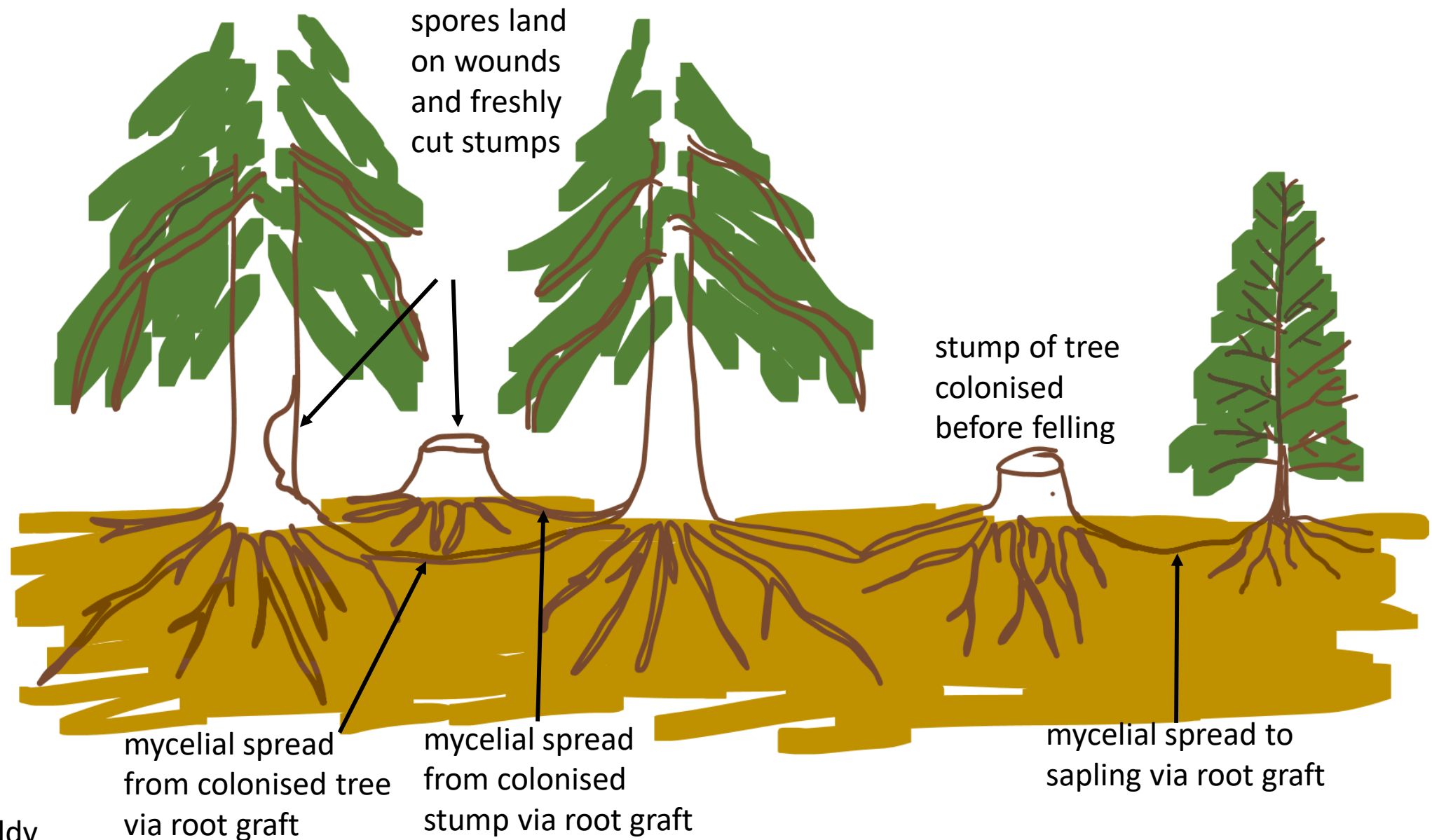


Heart-rot fungi: how do they establish in and leave standing trees?



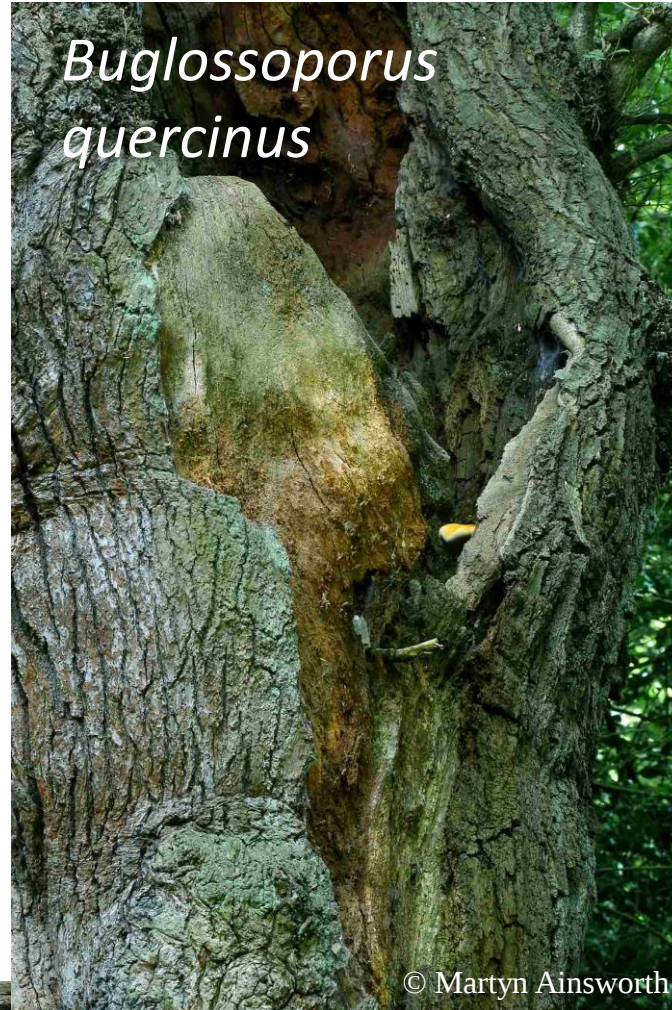
Sapwood of roots

Mycelial cords and
rhizomorphs



Heartrot fungi exhibit a range of selectivity

- Extremely selective
- Strongly selective for tree genera, but do occur on others
- Widely occurring





Heart-rotters of oak



Armillaria species
Daedalea quercina
Fistulina hepatica
Ganoderma lucidum
Ganoderma resinaceum
Hericium species
Laetiporus sulphureus
Inonotus dryadeus
Perennipora fraxinea
Phellinus robustus
Stereum gausapatum



Trametes versicolor

Laetiporus sulphureus

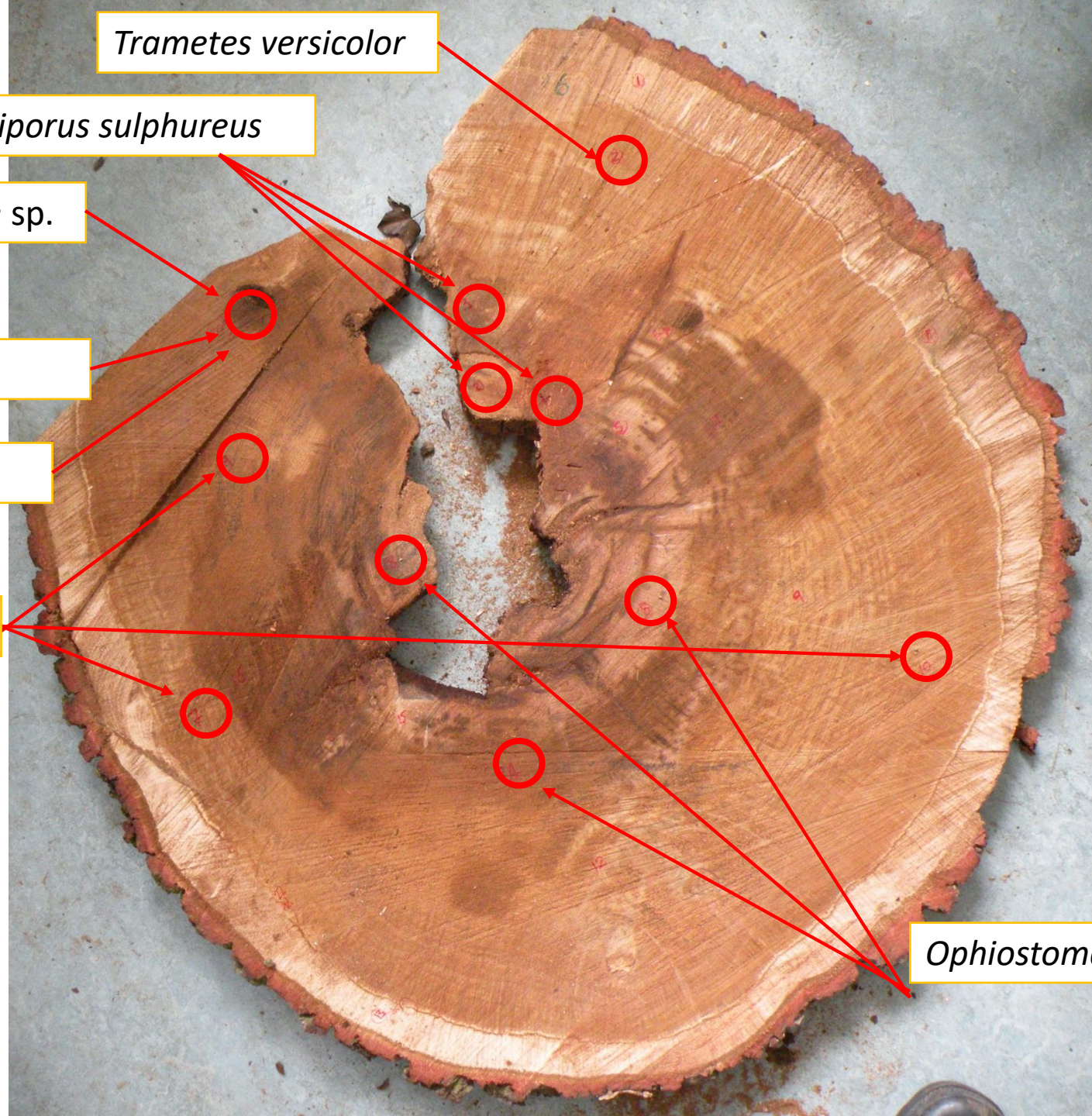
Ascocoryne sp.

Peniophora sp.

Eutypella sp.

Fistulina hepatica

Ophiostoma sp.



Heart-rotters of beech



Armillaria spp.

Aurantiporus alborubescens

Bjerkandera adusta

Fomes fomentarius

Fomitopsis pinicola

Ganoderma applanatum

G. adpersum, *G. pfeifferi*

Hericium spp.

Heterobasidion annosum

Inonotus cuticularis

Laetiporus sulphureus

Meripilus giganteus

Oudemansiella mucida

Perenniporia fraxinea

Rigidoporus ulmarius

Pholiota spp.

Pleurotus ostreatus

Podoscypha multizonata

Polyporus squamosus

Spongipellis delectans

Volvariella bombycina

Eutypa spinosa

Kretzschmaria deusta

Beech heart-rot survey

Cores at 1.3m from 55 trees (50 – 90 cm dbh)

20 had heart-rot

Basidiomycota	Ascomycota
<i>Armillaria gallica</i>	<i>Ascocoryne</i>
<i>Aurantiporus fissilis</i>	<i>Kretzschmaria deusta</i>
<i>Coprinellus disseminatus</i>	<i>Neobulgaria</i>
<i>Ganoderma australe</i>	<i>Nodulisporium</i>
<i>Ganoderma pfeifferi</i>	©Gilmartin, Boddy et al.
<i>Laetiporus sulphureus</i>	
<i>Phanerochaetaceae</i>	
<i>Pholiota adiposa</i>	
<i>Psathyrella cernua</i>	

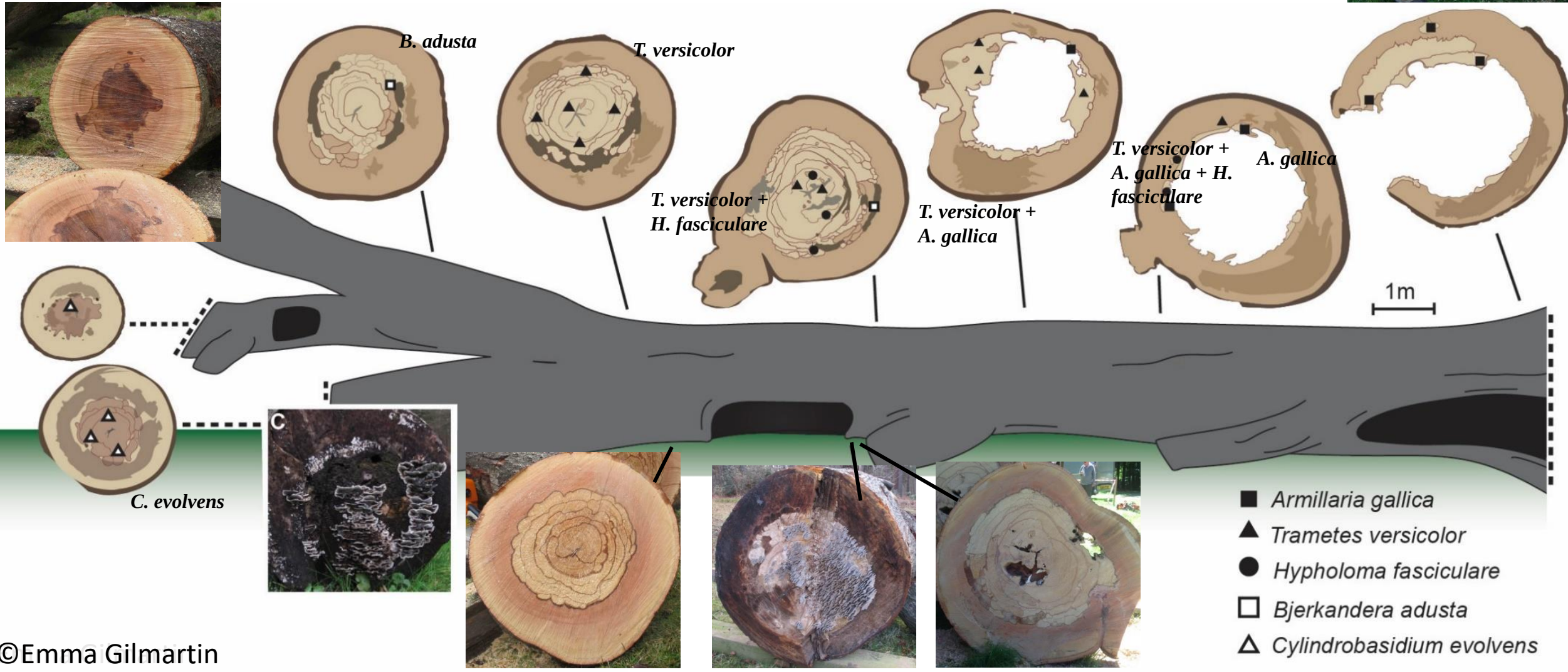


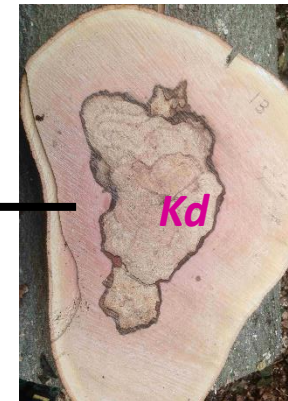
Heart Rot of Beech



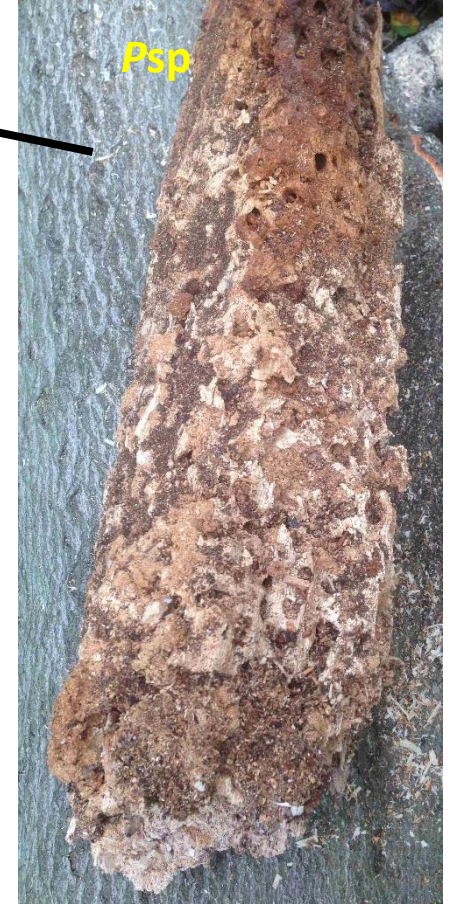


Heart-rot fungal community in a hollowed beech





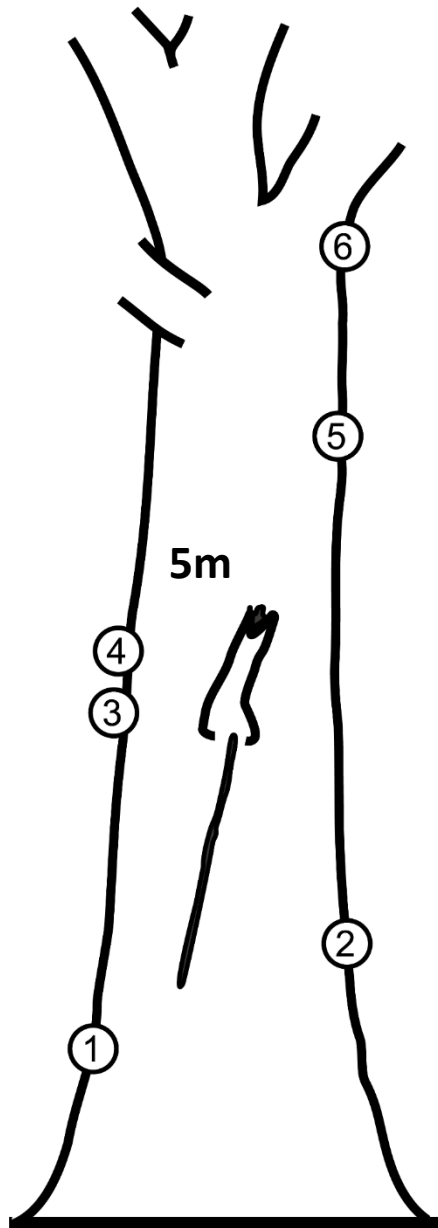
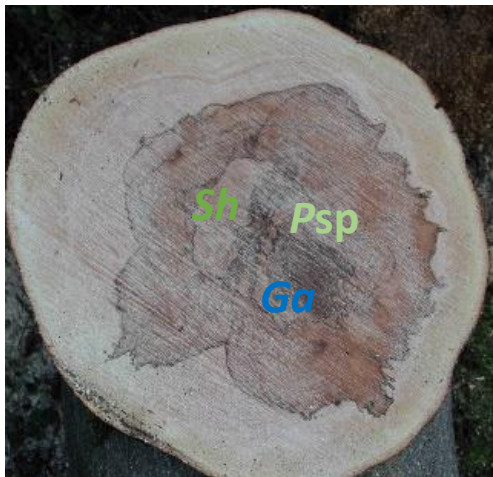
Epping E3: Felled
due to road
proximity



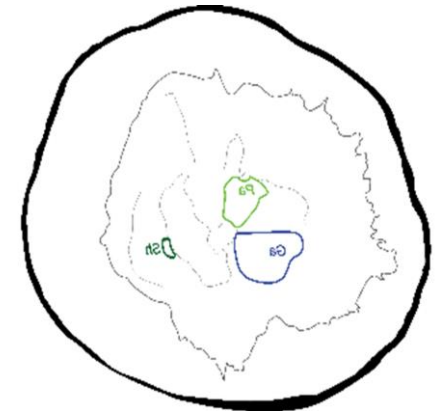
ww wet wood
Kd Kretzschmaria deusta
Psp Pholiota sp.

Photos: © L Boddy

Diagrams: © EC Gilmartin



Epping E2: Spatially distinct decay columns from base, and from broken branch



Ga *Ganoderma adspersum*

Psp *Pholiota* sp.

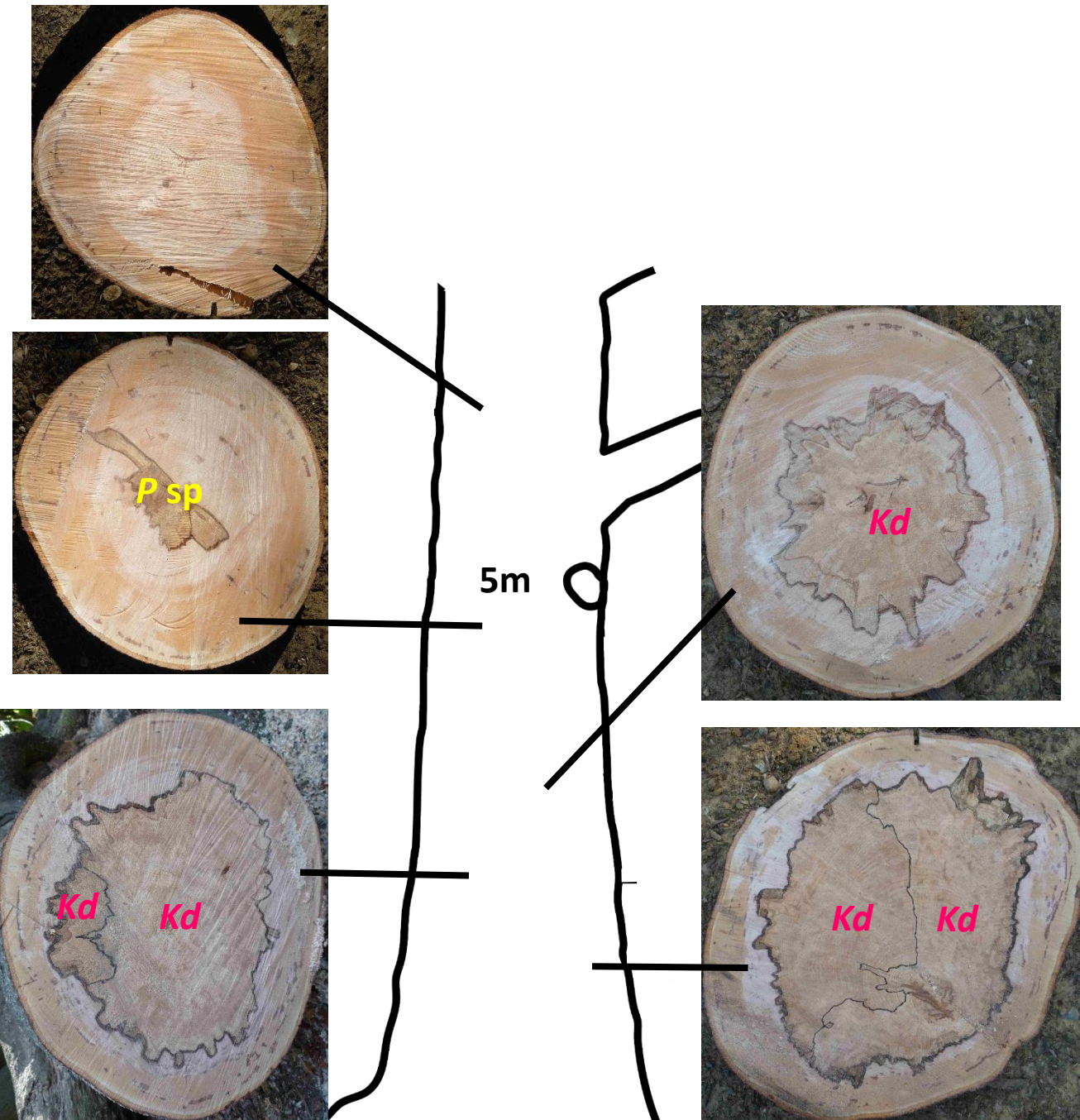
Sh *Stereum hirsutum*

Pc *Pleurotus cornucopiae*

Epping E7: Collapsed due to advanced decay in largest diam. roots

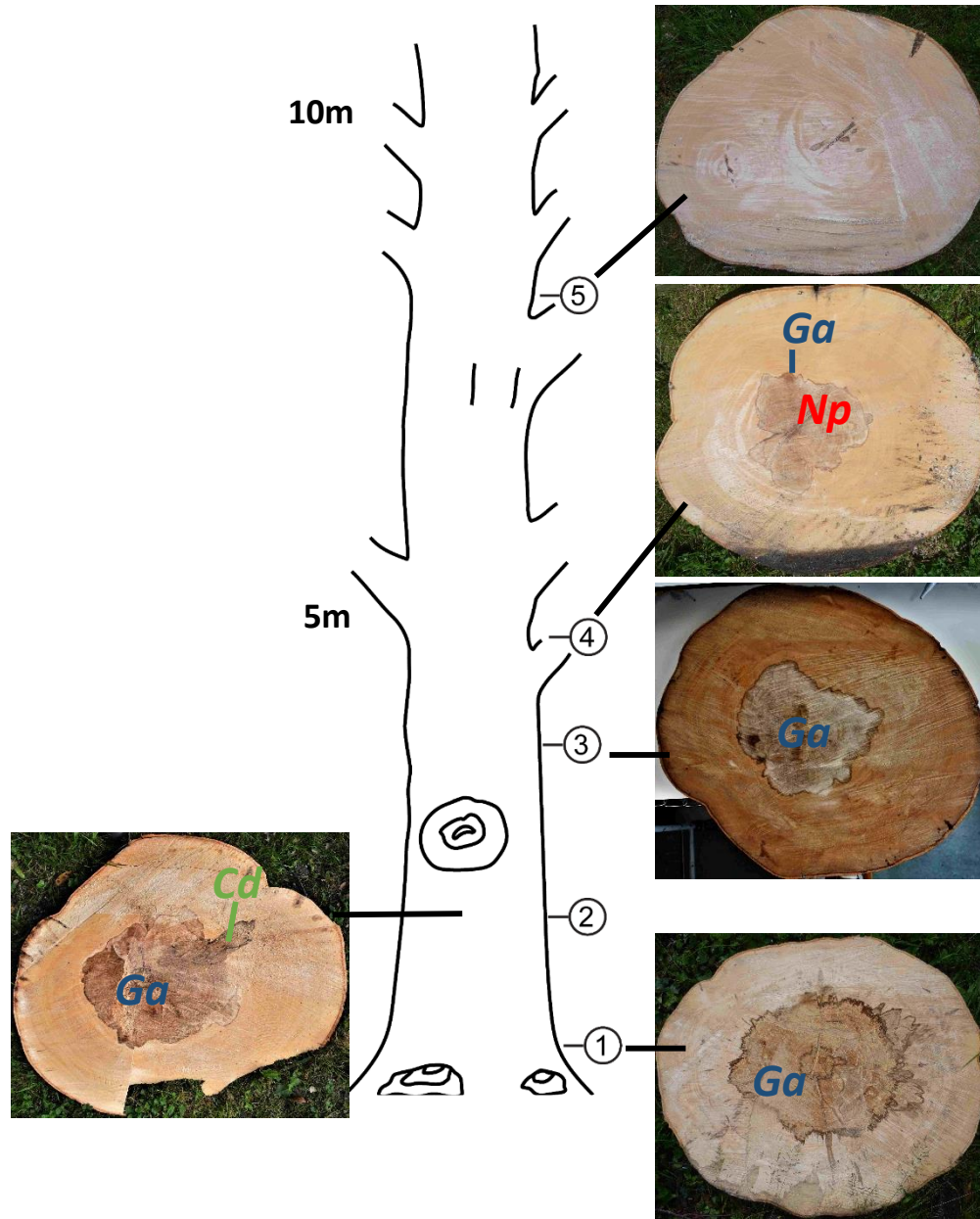
Kd *Kretzschmaria deusta*

P sp *Pholiota* sp.



Photos and diagrams: © EC Gilmartin

Bridgend: Felled, likely because of *G. adspersum*
fruit bodies on 2 sides at base



Ga **Ganoderma adspersum**
Cd **Coprinellus disseminatus**
Np **Neobulgaria pura**

Beech heart-rot fungi detected by different approaches

	coring	sectioning	literature		coring	sectioning	literature
<i>Armillaria gallica</i>		✓	■	<i>Kretzschmaria deusta</i>	✓	✓	■
<i>Armillaria</i> sp.	✓	✓		<i>Laetiporus sulphureus</i>	✓		■
<i>Ascocoryne</i> sp.	✓	✓		<i>Meripilus giganteus</i>			■
<i>Aurantiporus fissilis</i>	✓			<i>Mucidula mucida</i>		✓	■
<i>Biscogniauxia nummularia</i>			■	<i>Neobulgaria</i> sp.	✓	✓	
<i>Bjerkandera adusta</i>		✓	■	<i>Nodulisporium</i> sp.	✓		
<i>Chondrostereum purpureum</i>			■	<i>Oxyporus populinus</i>		✓	
<i>Coprinellus disseminatus</i>	✓	✓		<i>Perenniporia fraxinea</i>		✓	■
<i>Cylindrobasidium evolvens</i>		✓		<i>Pholiota ‘A’</i>	✓	✓	■
<i>Efibula</i> sp.	✓			<i>Pholiota squarrosa</i>		✓	
<i>Eutypa spinosa</i>		✓		<i>Pleurotus cornucopiae</i>		✓	
<i>Fomes fomentarius</i>			■	<i>Pleurotus ostreatus</i>		✓	■
<i>Fomitopsis pinicola</i>			■	<i>Psathyrella cernua</i>	✓		
<i>Ganoderma adspersum</i>	✓	✓	■	<i>Stereum hirsutum</i>		✓	
<i>Ganoderma pfeifferi</i>	✓		■	<i>Trametes versicolor</i>	29✓		■
<i>Hypholoma fasciculare</i>		✓	■				

Notable absentees from UK
Fomitopsis pinicola and
Fomes fomentarius



Interactions between heart rot fungi

Ranking of competitiveness



Fomitopsis pinicola
Hypholoma fasciculare
Trametes versicolor
Bjerkandera adusta
Eutypa spinosa
Pleurotus cornucopiae
Pleurotus ostreatus
Ganoderma pfeifferi
Pholiota adiposa
Kretzschmaria deusta
Chondrostereum purpureum
Ganoderma adspersum
Fomes fomentarius
Perenniporia fraxinea
Meripilus giganteus
Hericium erinaceus
Oudemansiella mucida
Biscogniauxia nummularia
Armillaria mellea
Armillaria gallica



Many thanks!!!

P.S. For more on Fungal Antagonism see You tube –
Lynne Boddy giving Taylor-White lecture Berkeley

Twitter: @FungusProf

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Paul Wald
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John Wells
Nia White
Stephen Woodward

Spore dispersal and hyphal growth movies: Patrick Hickey



**Coming soon –
summer 2020**

Fungi and Trees

Lynne Boddy

Chapter 1 Fungi: What are they? What do they do? Why are they important?

Chapter 2 Trees and woody shrubs: leaves, roots and wood – homes for fungi

Chapter 3 Beneficial relationships between fungi and trees

Chapter 4 Fungi that harm trees

Chapter 5 Interactions among tree-associated fungi and with other organisms

Chapter 6 Wood decay and fungal communities

Chapter 7 Heart-rot and hollowing

Chapter 8 Sapwood decay in living trees

Chapter 9 Environmental change

Chapter 10 Conservation and management