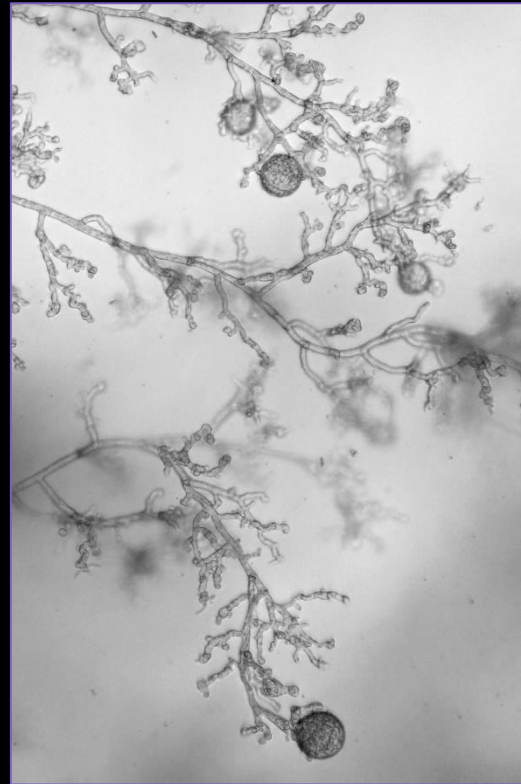


# *Phytophthora* in landscapes: Identifying the major players in natural ecosystems

Laura Sims PhD



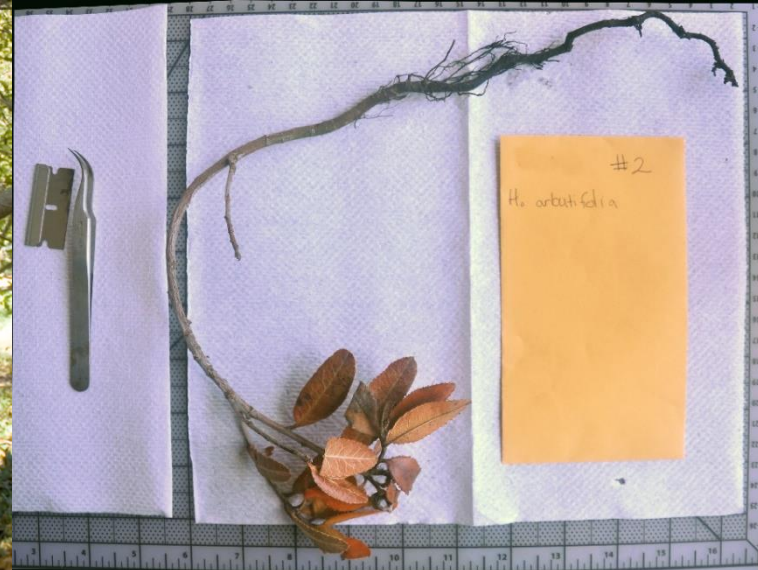
# Steps to identifying the major players in natural ecosystems

- Identify the problem
- Target your population of interest
- Evaluate the level of disease and types of symptoms
- Sample the population of interest and the landscape around it
- Isolate *Phytophthora*
- Identify the species in your system
- Inoculate your test plants with the *Phytophthora* species isolated from the plant host and complete Koch's Postulates
- Use that information to describe the disease cycle

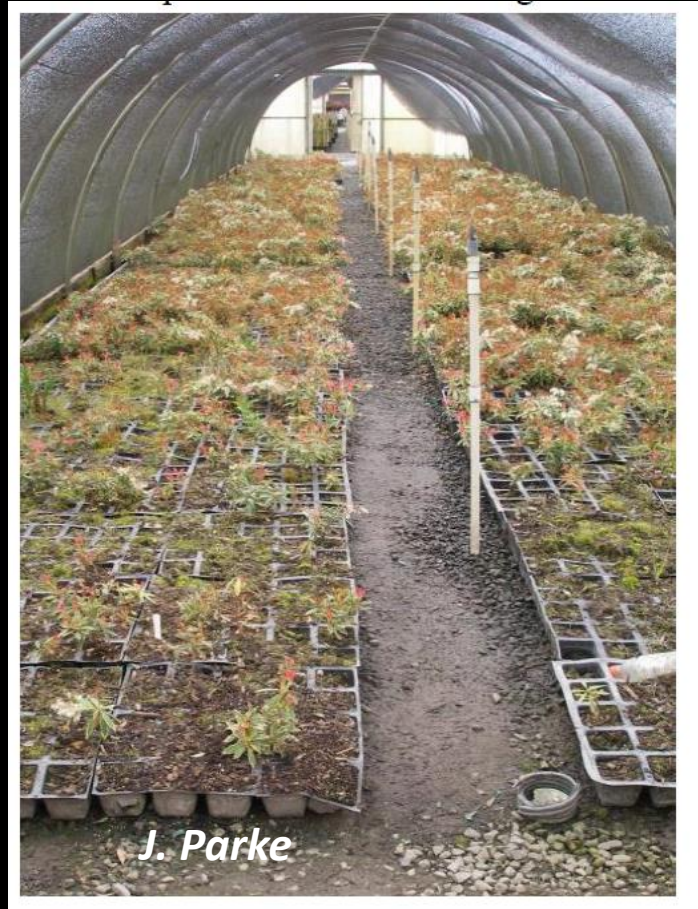
# How do we identify the location of the problem

- If it is a known problem the areas of concern may already be identified
- If it is a new problem , it will probably be necessary to gather background information. Collect information regarding the location of the plant species that have been noted as having problems.

# How to identify the problem



Nursery plant that are grown for natural area may be the source of outplanted epidemics



# Natural areas that are planted



Photo by: Lew Stringer Presidio Trust

## Adjacent to planted areas



Photos by: Lew Stringer dieback of *Ceanothus thrysiflorus*, associated with *Phytophthora multivora* and *Phytophthora cryptogea*

# Further afield



Photos by Alison Forestel of NPS



# Water Management

- *Phytophthora* species thrive in areas with poor water management



Once you have identified the problem

Then, target your population of interest

In addition, evaluate the level of disease and types of symptoms

- SOD in California-California's coastal forests
- SOD in Oregon- Southern Oregon's coastal tanoak forests





Photo: Ellen Goheen



Photo: Ellen Goheen

Evaluate the Level of  
Disease: Aerial  
Surveys and Ground  
Truthing

# Ceanothus root rot





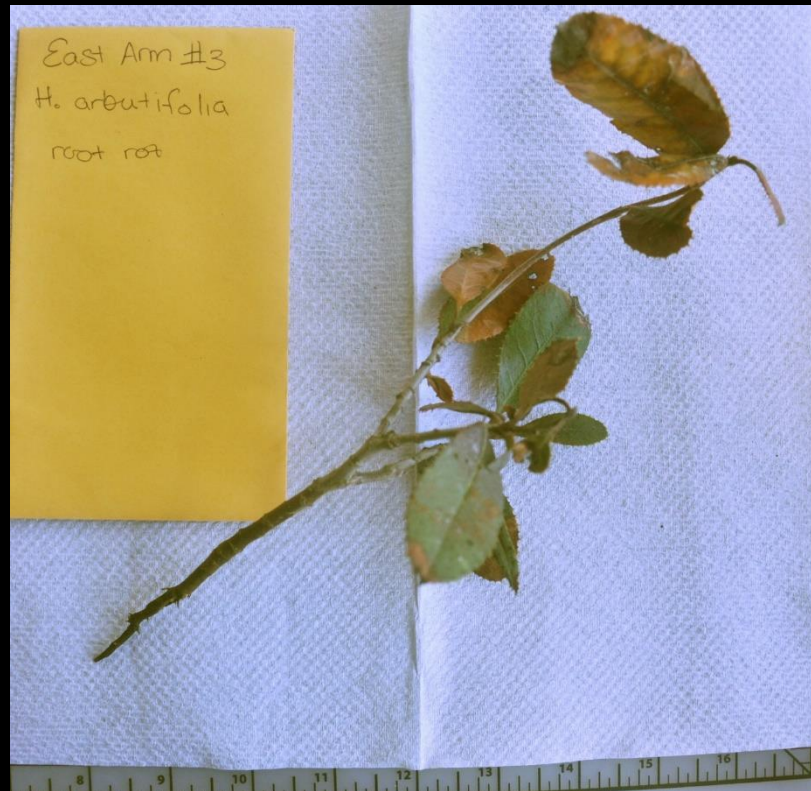
Ceanothous root rot  
Symptoms: Root rot,  
necrotic roots, branch  
dieback and branch necrosis



**Root Rot**

# toyon and sticky monkey flower root rot





Toyon root rot  
Symptoms: Root rot, necrotic roots, leaves turn red  
and plant death





SOD

# Symptoms of Phytophthora canker and root disease of alder



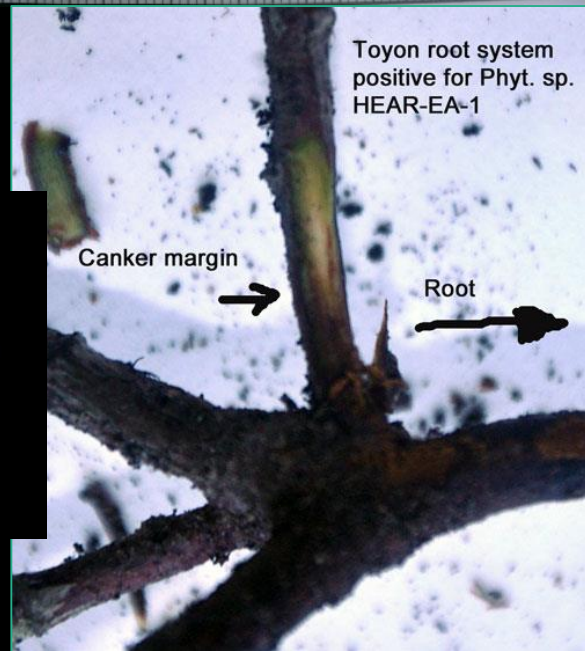
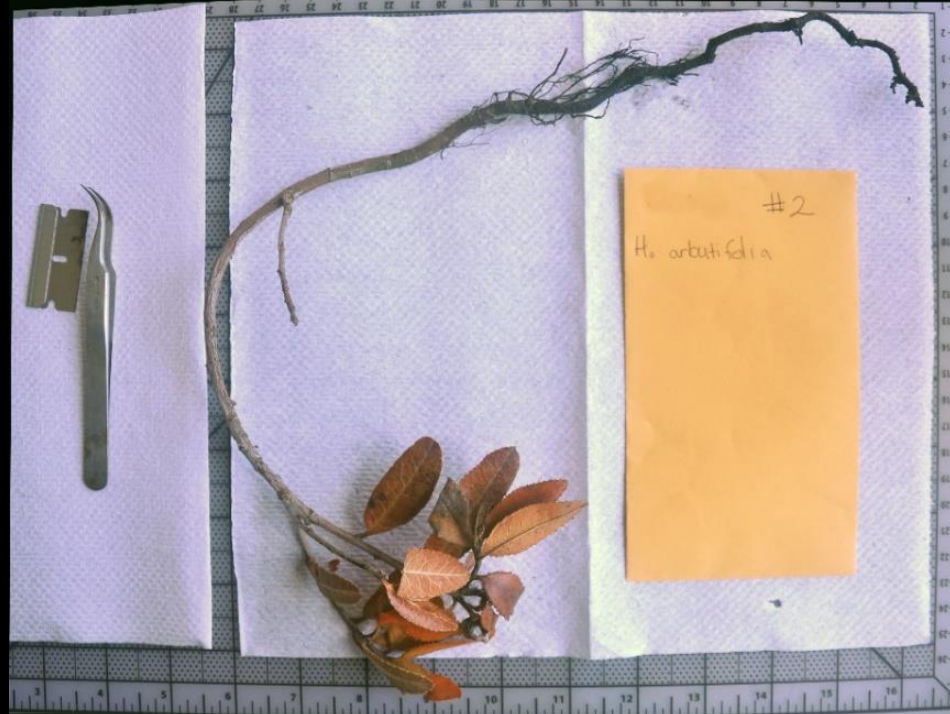
Bleeding lesions, canopy dieback, yellowing foliage, witches brooms on roots.

Once you have evaluated the disease and types of symptoms...

You can sample the population of interest and the landscape around it

Then, isolate the *Phytophthora*

And identify the species in your system

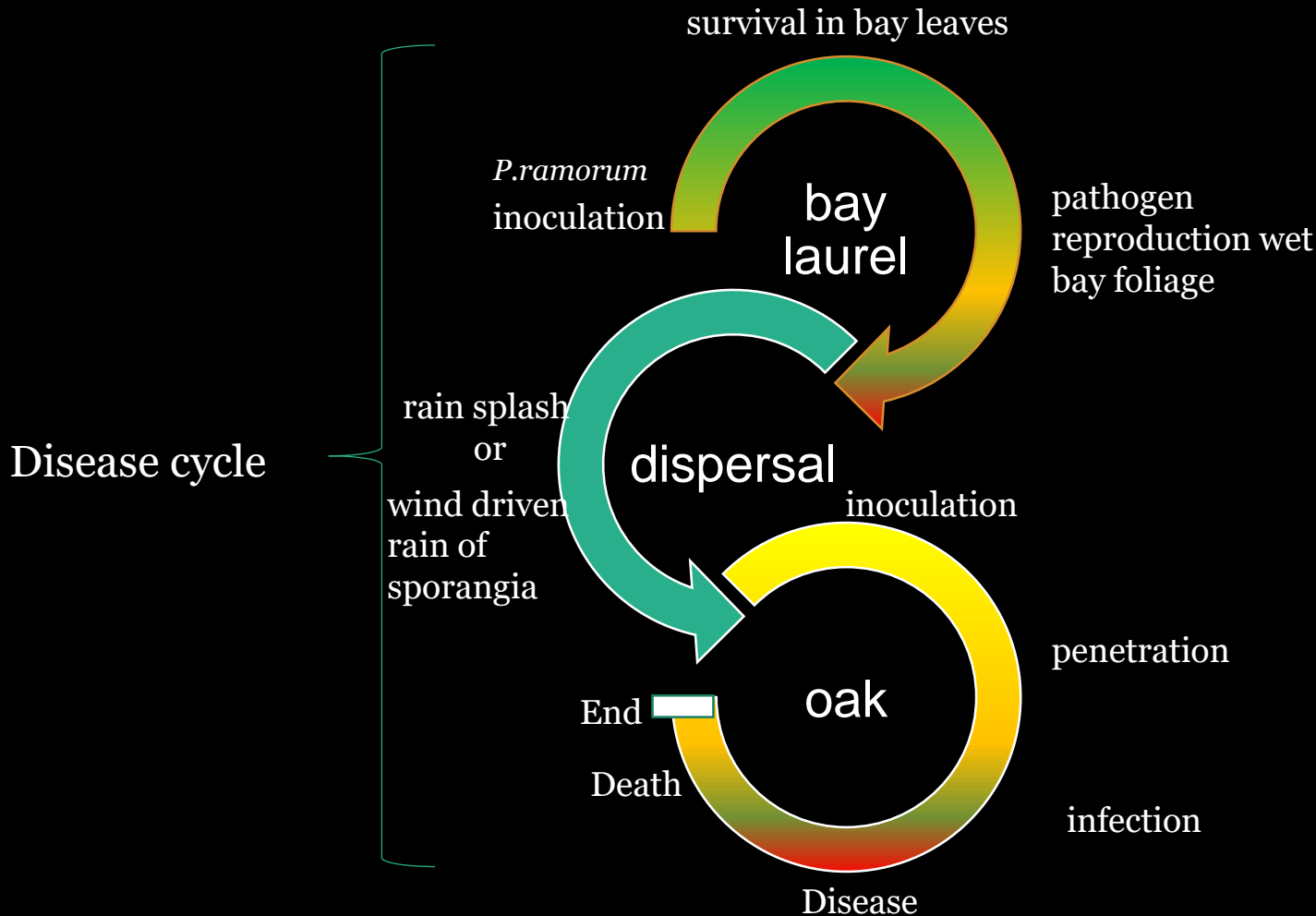


Toyon root system  
positive for Phyt. sp.  
HEAR-EA-1

Canker margin

Root

# Why sample the surrounding landscape? SOD is a good example with its complex Disease cycle in the oak-bay system



# SOD tanoak to tanoak and bay laurel spread

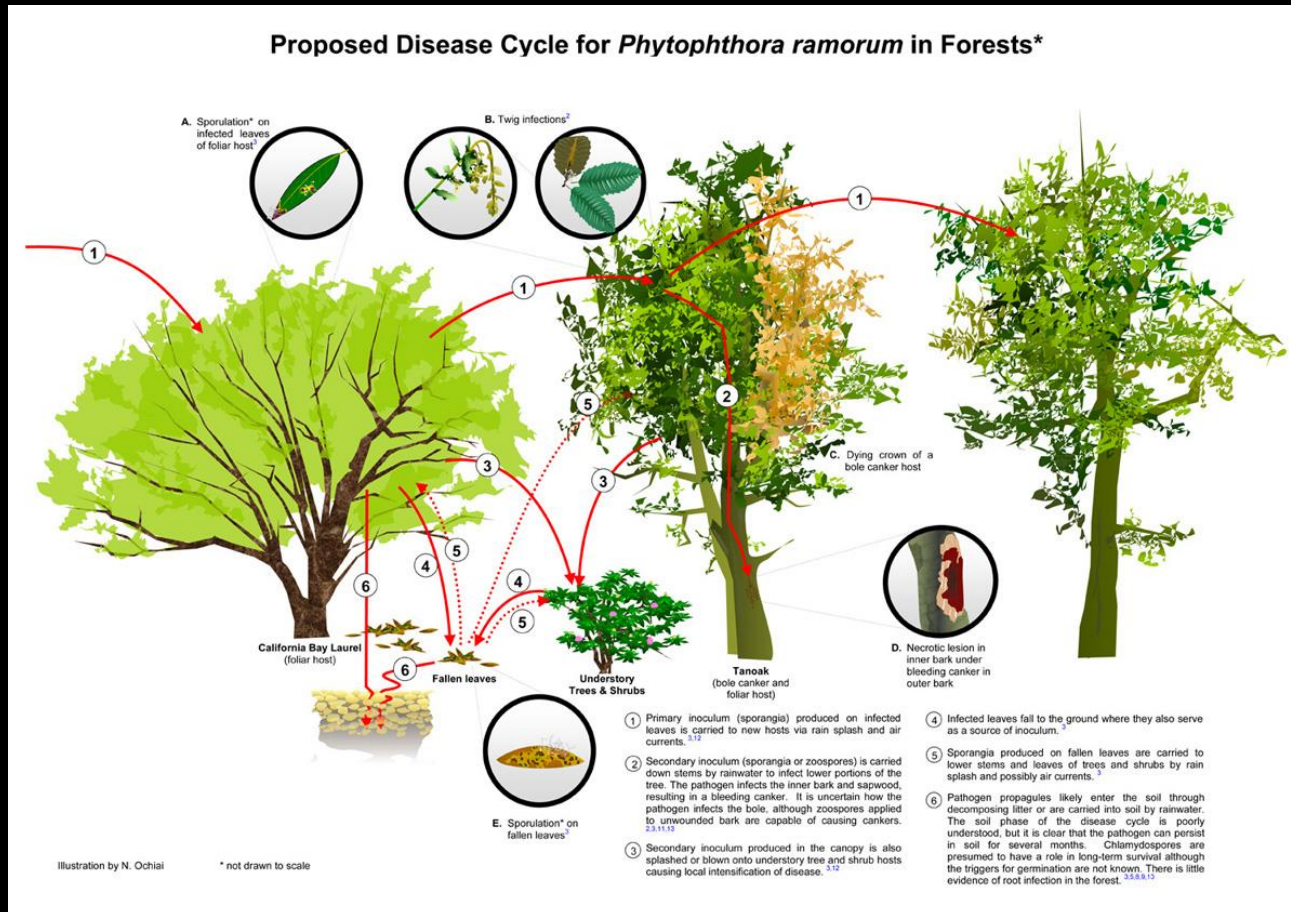
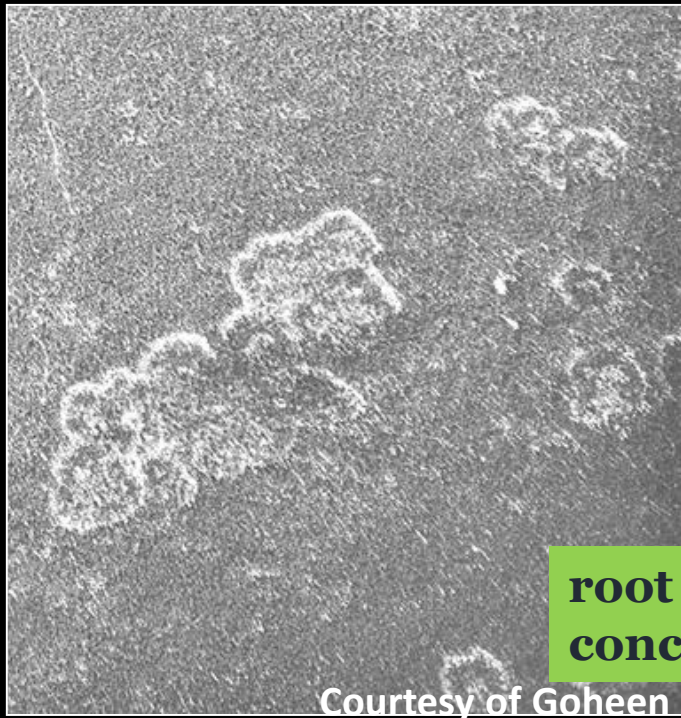


Diagram By: N.Ochiai

# Diversity of life strategies allows for dramatic disease on the landscape for SOD

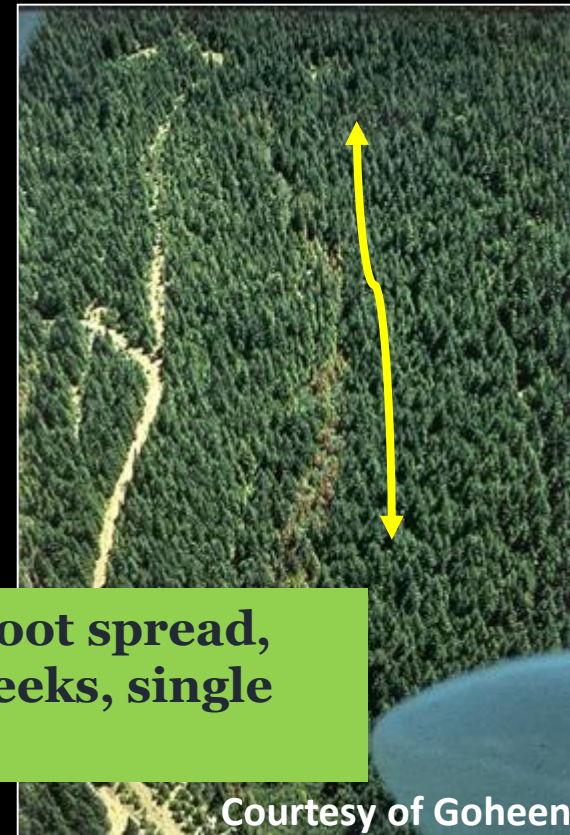


# What does disease look like on the landscape? Depends on the life strategy.



**root to root spread,  
concentric outwards**

Courtesy of Goheen



**root to root spread,  
along creeks, single  
host**

Courtesy of Goheen

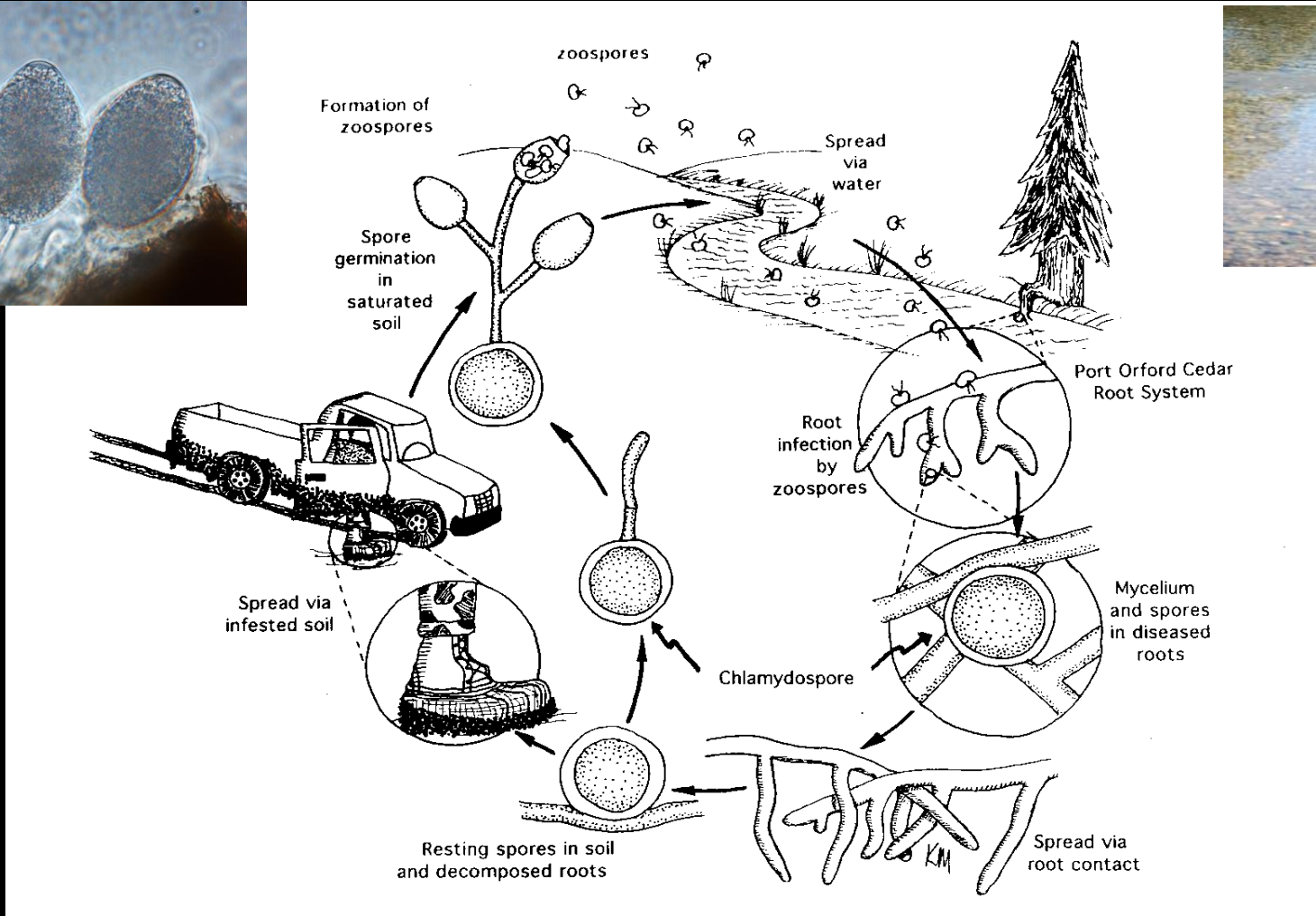


**spread: aerial short  
distance with  
occasional long  
distance jumps from  
wind driven rain more  
than one host spread  
disease**

08/09/2006  
J. Klein MMWD



# Root-rotting watermold lifecycles are also complex and need to evaluate the ecosystem to understand the disease



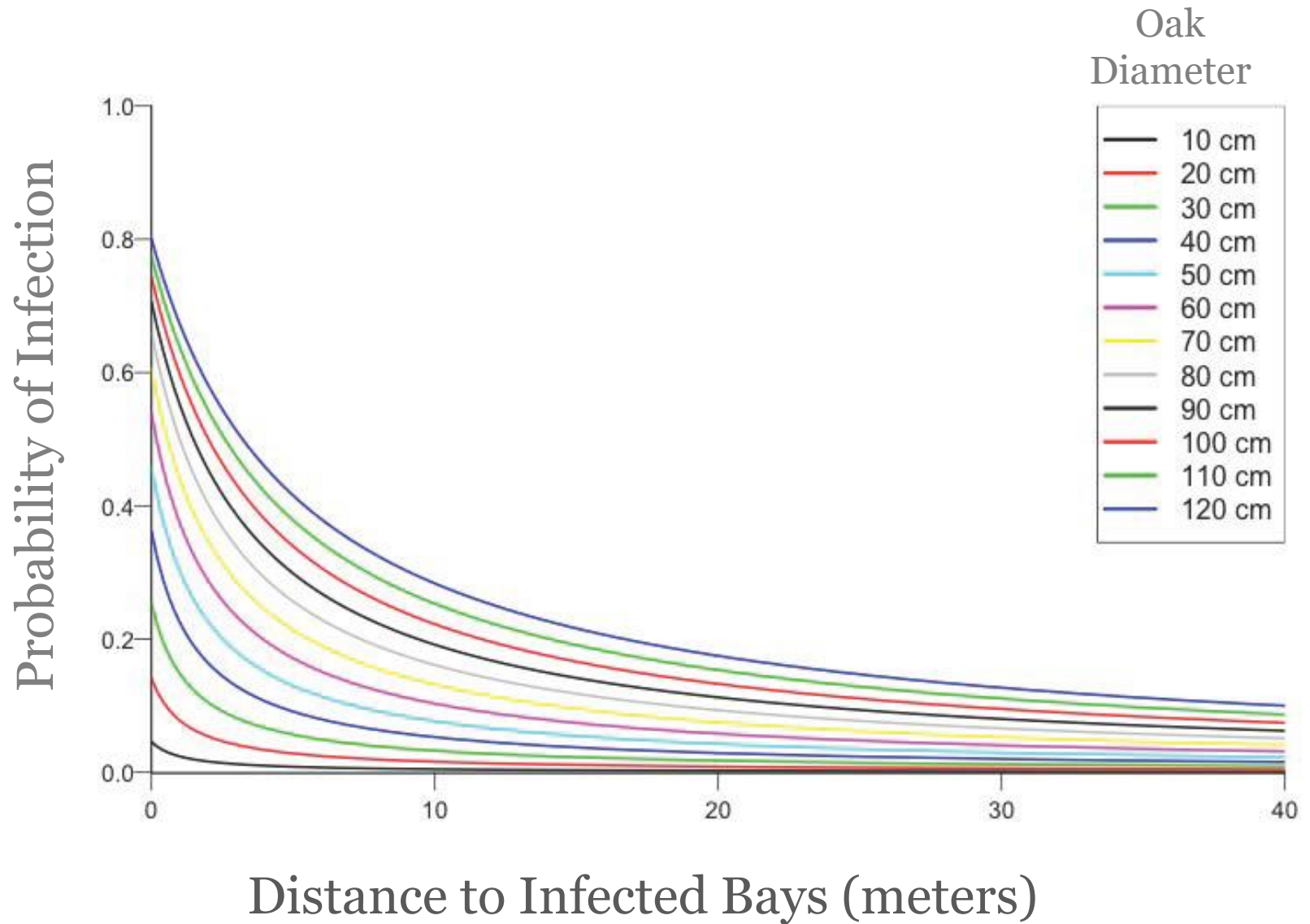
**Lifecycle Diagram from:** Managing Port-Orford-Cedar and the Introduced Pathogen *Phytophthora lateralis*. Everett M. Hansen, Donald J. Goheen, Erik S. Jules, and Barbara Ullian. *Plant Disease* 2000 84:1, 4-1

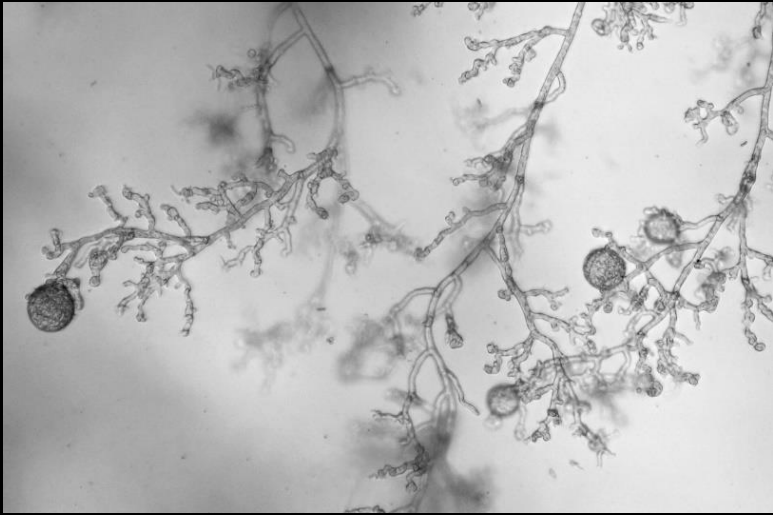


Photo:Chastagner & Benson, The Christmas Tree:  
Traditions, Production, and Diseases

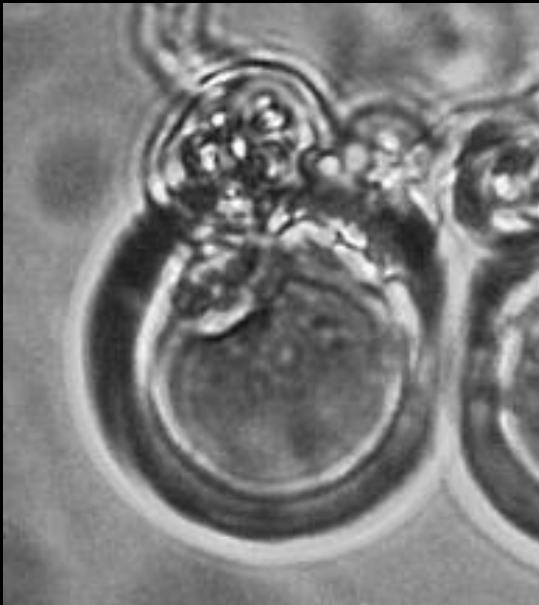
Root infecting  
pathogen moves  
down hill with  
water movement

# Oak Infection vs. Distance to an Infected Bay Laurel





Isolate *Phytophthora*

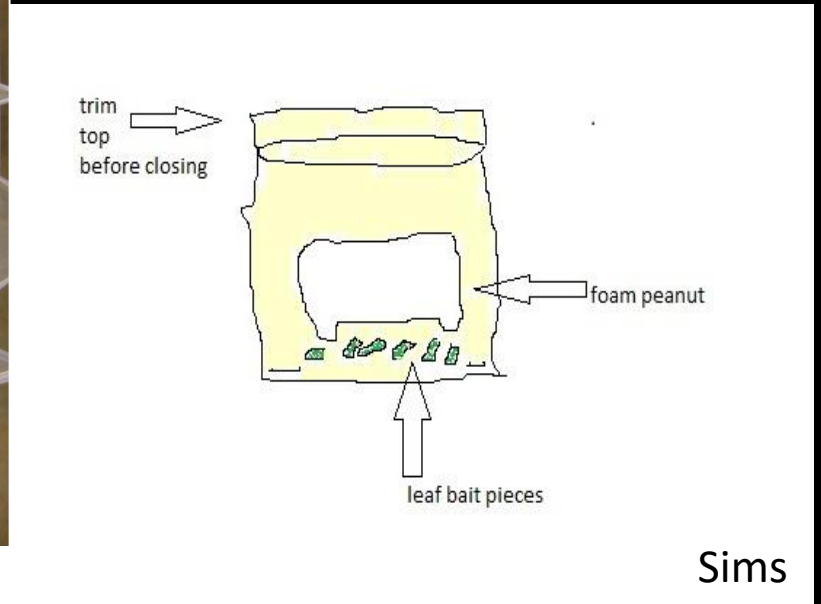
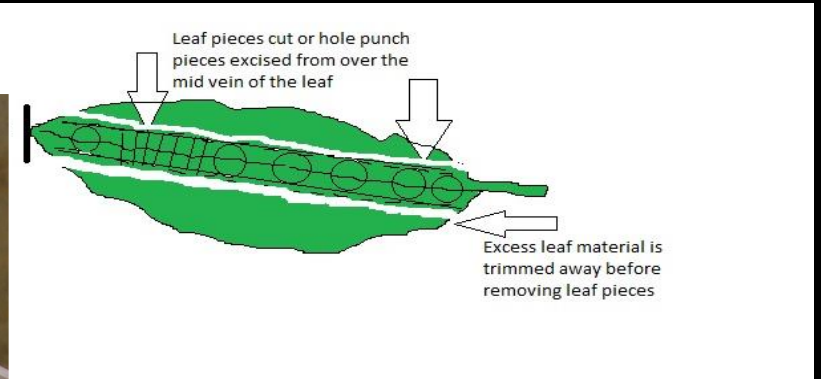


# Isolate *Phytophthora* :Baiting





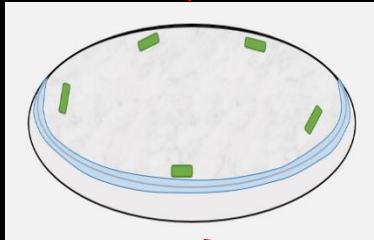
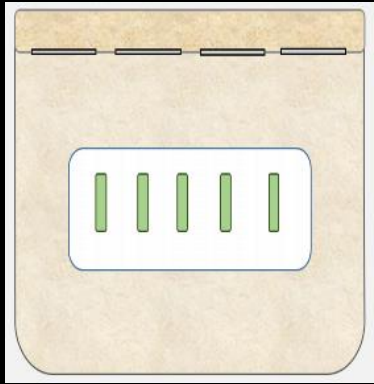
Sutton



Sims

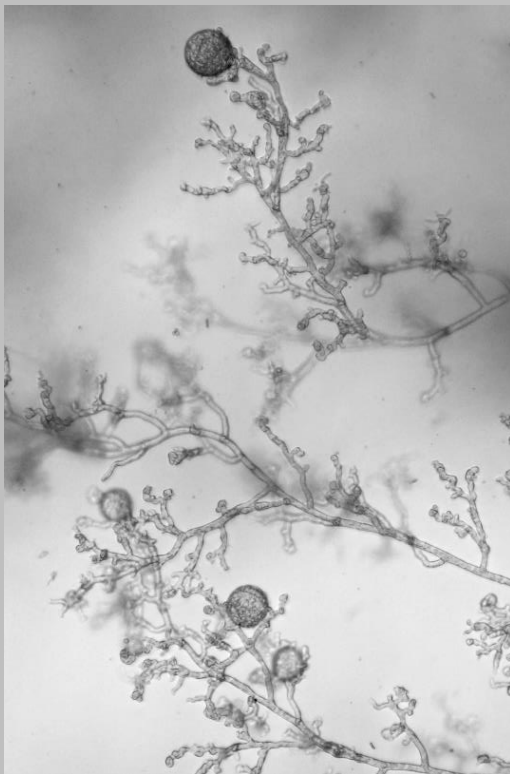
# Bating Technique

# Culturing Technique

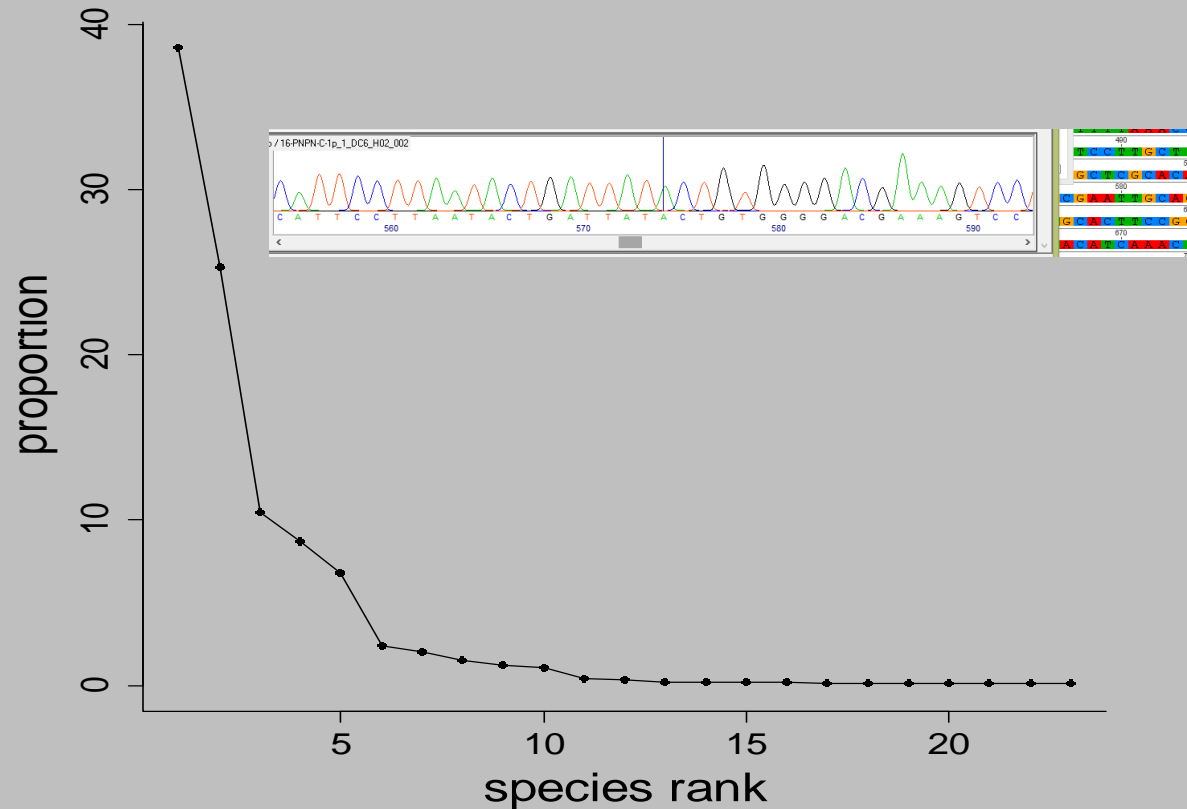


# next step

- Use morphology and sequencing to identify the species in your system

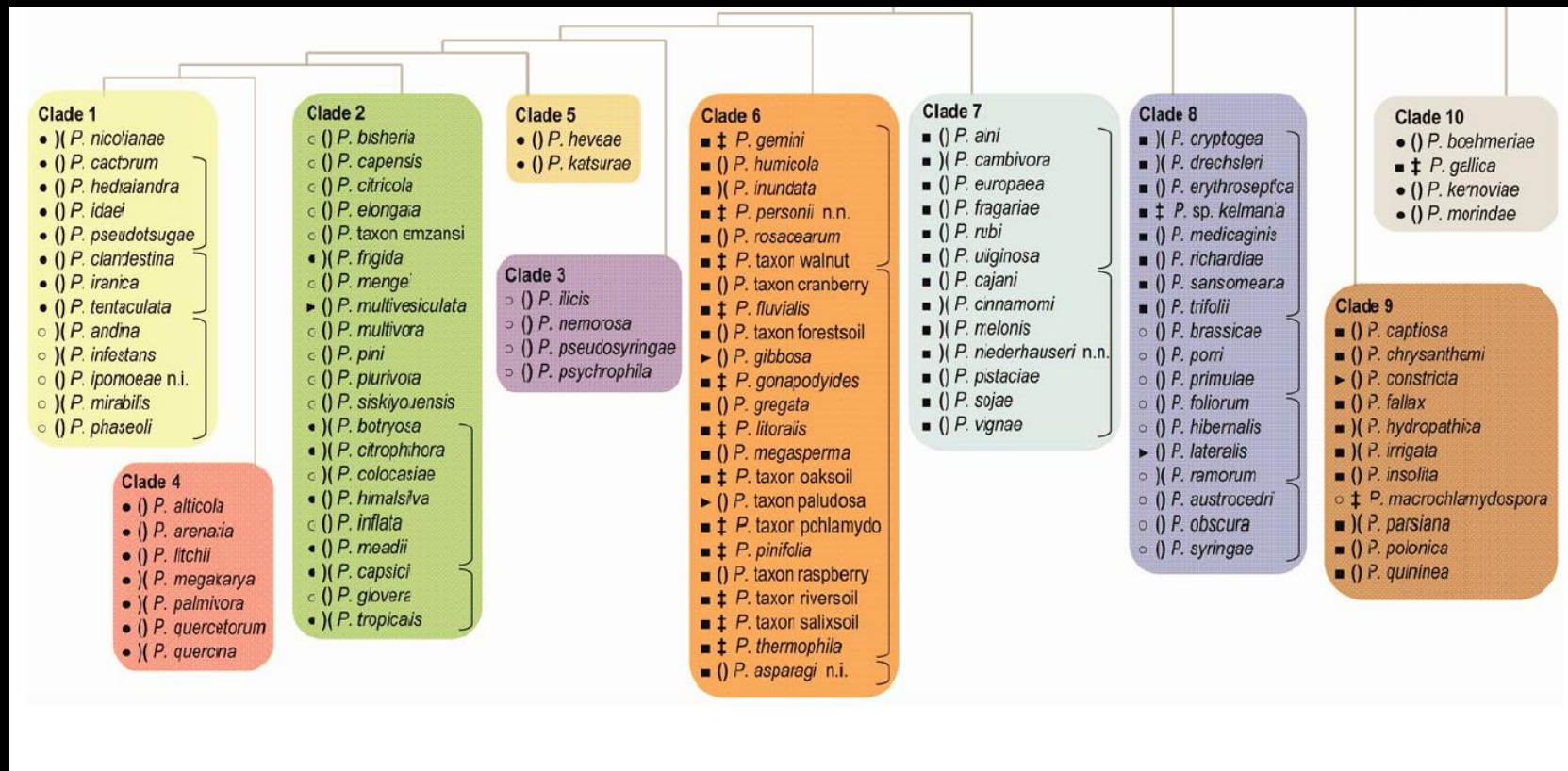


**Figure 2) Species Abundance**





# Around the world ~ 130 *Phytophthora* species described



# Oregon Hansen, E., Reeser, P., Sutton, W., and Sims, L. 2012. *Host and Habitat Index for Phytophthora Species in Oregon*. Forest Phytophthoras 2(1). 32 species in Oregon in 2012

<i>Phytophthora</i> Species	Hosts	Habitats	Plant Parts	Number of Oregon Counties <sup>a</sup>
<i>P. alni uniformis</i>	<i>Alnus rubra</i>	forest	root	1
<i>P. cactorum</i>	<i>Abies procera</i> , <i>Ceanothus integerrimus</i> , <i>Ceanothus velutinus</i> , <i>Notholithocarpus densiflorus</i>	Christmas tree plantation, forest, forest soil, native plant nursery	bole leaf/twig, root, stem	3
<i>P. cambivora</i>	<i>Abies procera</i> , <i>Alnus sp.</i> , <i>Chrysolepis chrysophylla</i> , <i>Fagus grandifolia</i> , <i>Notholithocarpus densiflorus</i>	Christmas tree plantation, forest, forest soil, forest stream, urban	bole	9
<i>P. cinnamomi</i>	<i>Abies procera</i> , <i>Chamaecyparis lawsoniana</i> , <i>Notholithocarpus densiflorus</i> , <i>Pseudotsuga menziesii</i>	Christmas tree plantation, forest, forest soil, forest tree nursery, urban forest soil	bole, root	6
<i>P. cryptogea</i>	<i>Pinus lambertiana</i> , <i>Pseudotsuga menziesii</i>	forest seed orchard, forest soil, forest tree nursery	root	2
<i>P. europaea</i>		forest stream		1
<i>P. gallica</i>	<i>Alnus rubra</i>	forest, forest soil, forest stream	root	2
<i>P. gonapodyides</i>	<i>Alnus rhombifolia</i> , <i>Alnus rubra</i> , <i>Notholithocarpus densiflorus</i> , <i>Pseudotsuga menziesii</i>	forest, forest soil, forest stream, forest tree nursery	bole, leaf/twig, root	13
<i>P. gregata</i>	<i>Alnus rubra</i>	forest, forest soil, forest stream	root	1
<i>P. hydrophatica</i>	<i>Alnus sp.</i>	forest	root	4
<i>P. ilicis</i>	<i>Ilex aquifolium</i>	plantation, landscape	leaf/twig	6
<i>P. lateralis</i>	<i>Chamaecyparis lawsoniana</i> , <i>Taxus brevifolia</i> , <i>Thuja occidentalis</i>	forest, forest research nursery, forest tree nursery, landscape	root	12
<i>P. megasperma</i>	<i>Abies procera</i> , <i>Pseudotsuga menziesii</i>	Christmas tree plantation, forest stream, native tree nursery	bole, root	4
<i>P. multivora</i>		forest soil		1
<i>P. nemorosa</i>	<i>Notholithocarpus densiflorus</i> , <i>Umbellularia californica</i>	forest, forest soil, forest stream, urban forest soil	bole, leaf/twig	1
<i>P. nicotianae</i>		forest stream		1
<i>P. pini</i>	<i>Ceanothus sanguineus</i>	forest stream, native plant nursery	root	3
<i>P. plurivora</i>		forest soil, forest stream		7
<i>P. pseudosyringae</i>	<i>Alnus rubra</i> , <i>Notholithocarpus densiflorus</i>	forest soil, forest stream	bole, leaf /twig, root	5
<i>P. pseudotsugae</i>	<i>Pinus monticola</i> , <i>Pseudotsuga menziesii</i>	Christmas tree plantation, forest soil, forest tree nursery	root	5
<i>P. psychrophyla</i>	<i>Notholithocarpus densiflorus</i> , <i>Notholithocarpus densiflorus</i>	forest	leaf/twig	1

# Twenty species with some intraspecies variation associated with diseased *Alnus* species in Oregon



TABLE II. Phytophthora species, variant sequence types isolated, matching reference isolates and GenBank accessions.

Species	Host	Substrate	Isolate	HPLOSU reference match	GenBank accession			ITS base similarity (Isolate/Alternate reference)
					Cox spacer	ITS	Alternate reference ITS	
<i>P. alni</i> spp. <i>uniformis</i>	<i>Alnus rubra</i>	roots	118-R-1101711.4	—	KJ666717	KJ666754	EU371545	830/831
<i>P. cambivora</i>	<i>A. rubra</i>	roots	112-R-10.2	4048.2	KJ666718	EF486693		
<i>P. cambivora</i>	<i>A. rubra</i>	roots	111-R-40.1	WA18.1-1111003	KJ666719	KJ666756		
<i>P. cambivora</i>	<i>A. rubra</i>	roots	112-R-20.1	—	KJ666719	KJ666755	EF486693	1210/1210
<i>P. cinnamomi</i>	<i>A. rubra</i>	rhizosphere	223-2-R.1	9641.1	KJ666720	KJ666757		
<i>P. citricola</i> sl	stream	water	15-W-1.5	III 5-100B1F	KJ666721	KJ666758		
<i>P. cryptogea</i>	<i>Alnus rhombifolia</i>	rhizosphere	33-2-S.2	MRW2.3.11A	KJ666722	KJ666759		
<i>P. europaea</i>	<i>A. rubra</i>	roots	112-R-10.1	VI 1-2P	KJ666723	HM004226		
<i>P. gallica</i>	<i>A. rhombifolia</i>	rhizosphere	33-14-S.1	—	KJ666725	KJ666761	KF286894	855/855
<i>P. gallica</i>	<i>A. rhombifolia</i>	rhizosphere	33-4-R.1	—	KJ666724	KJ666760	KF286894	855/855
<i>P. gonapodyides</i>	<i>A. rubra</i>	rhizosphere	31-1-S.2	I 2B4L	KJ666726	HM004231		
<i>P. gregata</i>	<i>A. rubra</i>	rhizosphere	11-3-R.1	—	KJ666727	KJ666762	HQ012938	818/819
<i>P. lacustris</i>	stream	water	107-W-2.8	WA21-091603	KJ666730	HM004219		
<i>P. lacustris</i>	<i>A. rhombifolia</i>	rhizosphere	33-2-R.1	—	KJ666728	KJ666763	JF804803	813/817
<i>P. lacustris</i>	<i>A. rhombifolia</i>	rhizosphere	33-2-R.6	—	KJ666729	KJ666734	JF804803	812/817
<i>P. nicotianae</i>	stream	water	207-W-2.4	—	KJ666731	KJ666735	JX978446	849/851
<i>P. parsiana</i>	stream	water	207-W-2.6	RWC2.7.8B	KJ666701	—		
<i>P. parsiana</i>	<i>A. rubra</i>	rhizosphere	111-2-R.1	WA23.3-081803	KJ666702	KJ666742		
<i>P. parsiana</i>	<i>A. rhombifolia</i>	rhizosphere	33-2-R.5	—	KJ666700	KJ666741	AY659736	748/751
<i>P. pini</i>	stream	water	112-W-1.1	V 4-3P	KJ666706	HM004227		
<i>P. plurivora</i>	stream	water	3-W-1.34	151.77	KJ666708	KJ666744		
<i>P. plurivora</i>	stream	water	121-W-1.12	—	KJ666707	KJ666745	HM004223	1136/1138
<i>P. pluvialis</i>	stream	water	19-W-2.3	WA28-022404	KC853447	HM004217		
<i>P. pseudosyringae</i>	stream	water	120-W-1.11	33-2-3.1-1102	KJ666709	KJ666747		
<i>P. pseudosyringae</i>	stream	water	102-W-1.1	WA11-111302	KJ666712	KJ666749		
<i>P. pseudosyringae</i>	stream	water	125-W-2.12	WA64.2-080304	KJ666713	KJ666746		
<i>P. pseudosyringae</i>	stream	water	113-W-1.12	WA1.2-021903	KJ666711	KJ666748		
<i>P. pseudosyringae</i>	stream	water	117-W-2.8	—	KJ666710	KJ666750	HM004228	1165/1166
<i>P. riparia</i>	stream	water	208-W-2.6	208-W-2.6	JQ626581	JQ626594		
<i>P. riparia</i>	stream	water	104-W-1.16	VI_3-100B9	JQ626580	HM004225		
<i>P. riparia</i>	stream	water	33-W-2.1	—	KJ666714	KJ666751	JQ626594	1191/1193
<i>P. siskiyouensis</i>	<i>A. rubra</i>	canker	222-29-B.1	33-2-3.2-1102	KJ666716	KJ666752		
<i>P. siskiyouensis</i>	<i>A. rubra</i>	roots	118-R-1081011.5	—	KJ666715	KJ666753	EF490682	1131/1131
" <i>P. taxon Oaksoil</i> "	stream	water	101-W-1.3	WA46.3-101804	KJ666697	HM004234		
" <i>P. taxon Oaksoil</i> "	stream	water	101-W-1.1	VI 5-100B1F	KJ666732	KJ666736		
" <i>P. taxon Oaksoil</i> "	stream	water	108-W-2.3	—	KJ666733	KJ666737	HM004233	1193/1193
" <i>P. taxon Oaksoil</i> "	stream	water	219-W-1.1	VI 5-100B1F	KJ666732	KJ666740		
" <i>P. taxon Oaksoil</i> "	stream	water	123-W-2.13	—	KJ666696	KJ666738	HM004233	1191/1193
" <i>P. taxon Oaksoil</i> "	stream	water	122-W-1.2	—	KJ666699	KJ666739	HM004234	1191/1193
" <i>P. taxon Pgchlamydo</i> "	stream	water	104-W-1.14	133	KJ666703	AF541902		
" <i>P. taxon Pgchlamydo</i> "	stream	water	113-W-1.16	WA5.1-072003	KJ666704	HM004224		
" <i>P. taxon Pgchlamydo</i> "	<i>A. rubra</i>	rhizosphere	102-2-R.1	WA46.3-100404	KJ666705	KJ666743		

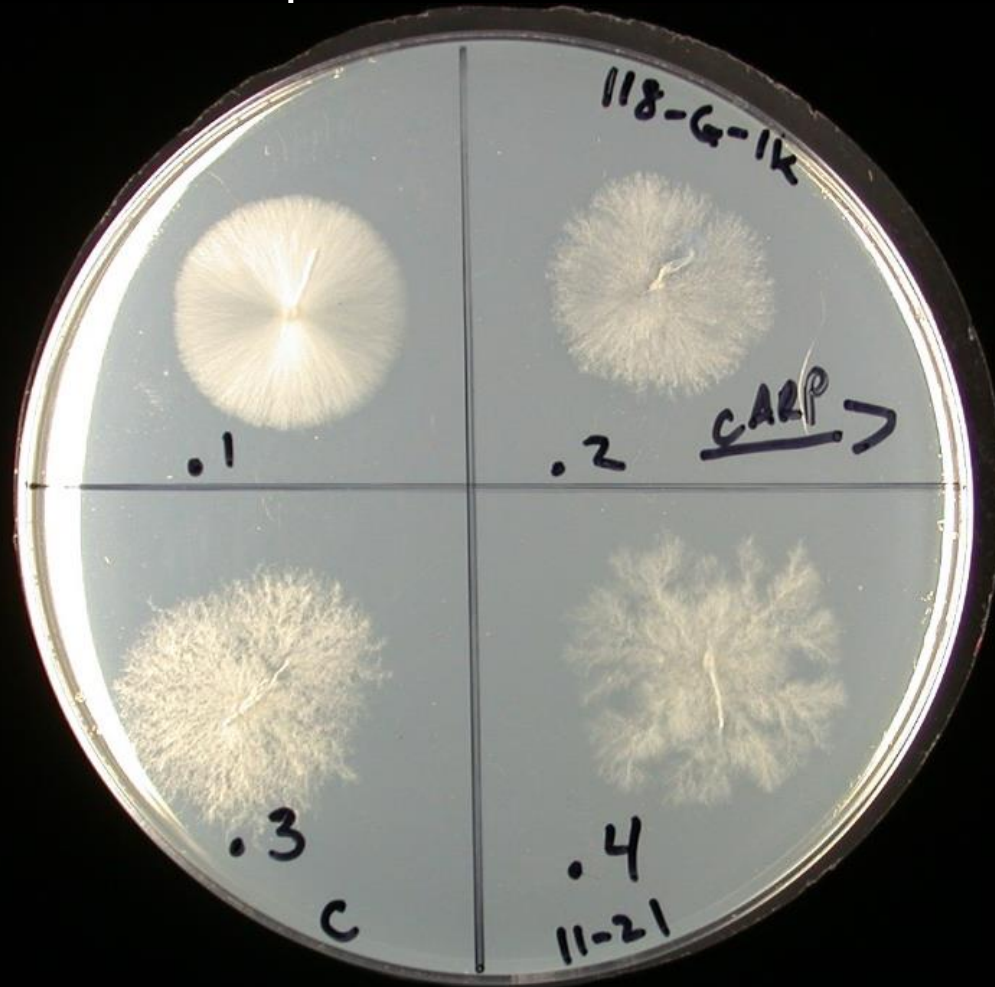
# California CDFA species list of *Phytophthora* from nurseries and restoration sites. *In Progress.*

<b><i>Aesculus californica</i></b>	<b><i>Arbutus menziesii</i></b>	<b><i>Arctostaphylos</i> sp.</b>
<i>P. lacustris/inundata</i> group	<i>P. cactorum</i>	<i>P. cactorum</i>
<i>P. multivora</i>	<b><i>Carex barbarae</i></b>	<i>P. cambivora</i>
<i>Phytophthora</i> sp. (clade 6)	<i>P. plurivora</i>	<i>P. hedraiandra</i>
<b><i>Baccharis</i> sp.</b>	<b><i>Eriophyllum staechadifolium</i></b>	<i>P. multivora</i>
<i>P. multivora</i>	<i>P. crytozea</i>	<b><i>Ceanothus</i> sp.</b>
<i>P. megasperma</i>	<b><i>Juncus patnes</i></b>	<i>P. cactorum</i>
<b><i>Cornus cornuta</i></b>	<i>P. megasperma</i>	<b><i>Frangula californica</i></b>
<i>P. plurivora</i> group	<b><i>Mimulus</i> sp.</b>	<i>P. cactorum</i>
<b><i>Heteromeles arbutifolia</i></b>	<i>P. cactorum</i>	<i>P. hedraiandra</i>
<i>P. cactorum</i>	<i>P. crytozea</i>	<i>P. multivora</i>
<i>P. hedraiandra</i>	<i>P. dreschleri</i>	<i>P. tentaculata</i>
<i>P. inundata</i>	<i>P. megasperma</i>	<b><i>Lessingia</i> sp.</b>
<i>P. tentaculata</i>	<i>P. multivora</i>	<i>Phytophthora</i> sp. (clade 6)
<b><i>Lonicera hispidula</i></b>	<i>P. nicotianae</i>	<b><i>Myrica californica</i></b>
<i>P. cactorum</i>	<i>P. niederhauserii</i>	close to <i>P. megasperma</i>
<b><i>Quercus agrifolia</i></b>	<i>P. pini</i>	<b><i>Salvia</i> sp:</b>
<i>P. cactorum</i>	<i>P. tentaculata</i>	<i>P. niederhauserii</i>
<i>P. megasperma</i>	<b><i>Rhododendron occidentale</i></b>	<i>P. tentaculata</i>
<i>P. quercitorum</i>	<i>P. plurivora</i> group	
<i>P. undulatum</i>		
<i>P. chlamydospora</i>		

# California Phytosphere plant species X *Phytophthora* species list. *In Progress.*

Plant Species	Confirmed <i>Phytophthora</i> species detected
<i>Anaphalis margaritacea</i>	<i>Phytophthora cryptogea</i>
<i>Baccharis douglasii</i>	<i>Phytophthora megasperma</i>
<i>Carex barbara</i>	<i>Phytophthora plurivora</i>
<i>Ceanothus ferrisiae</i>	<i>Phytophthora cactorum</i>
<i>Euthamia occidentalis</i>	<i>Phytophthora inundata</i>
<i>Euthamia occidentalis</i>	<i>Phytophthora megasperma</i>
<i>Frangula californica</i>	<i>Phytophthora cactorum</i>
<i>Frangula californica</i>	<i>Phytophthora tentaculata</i>
<i>Heteromeles arbutifolia</i>	<i>Phytophthora cactorum</i>
<i>Heteromeles arbutifolia</i>	<i>Phytophthora cambivora</i>
<i>Heteromeles arbutifolia</i>	<i>Phytophthora tentaculata</i>
<i>Hordeum brachyantherum</i>	<i>Phytophthora gonapodyides</i>
<i>Juncus effusus</i>	<i>Phytophthora inundata</i>
<i>Juncus</i> species	<i>Phytophthora megasperma</i>
<i>Lyonothamnus floribundus</i>	<i>Phytophthora</i> species.
<i>Mimulus (Diplacus) aurianticus</i>	<i>Phytophthora cactorum</i>
<i>Mimulus (Diplacus) aurianticus</i>	<i>Phytophthora cryptogea</i>
<i>Mimulus (Diplacus) aurianticus</i>	<i>Phytophthora megasperma</i>
<i>Mimulus (Diplacus) aurianticus</i>	<i>Phytophthora nicotianae</i>
<i>Mimulus (Diplacus) aurianticus</i>	<i>Phytophthora niederhauserii</i>
<i>Mimulus (Diplacus) aurianticus</i>	<i>Phytophthora pini</i>
<i>Mimulus (Diplacus) aurianticus</i>	<i>Phytophthora tentaculata</i>
<i>Platanus racemosa</i>	<i>Phytophthora megasperma</i>
<i>Quercus agrifolia</i>	<i>Phytophthora cambivora</i> , <i>Phytophthora quercetorum</i>
<i>Quercus agrifolia</i>	<i>Phytophthora quercetorum</i>

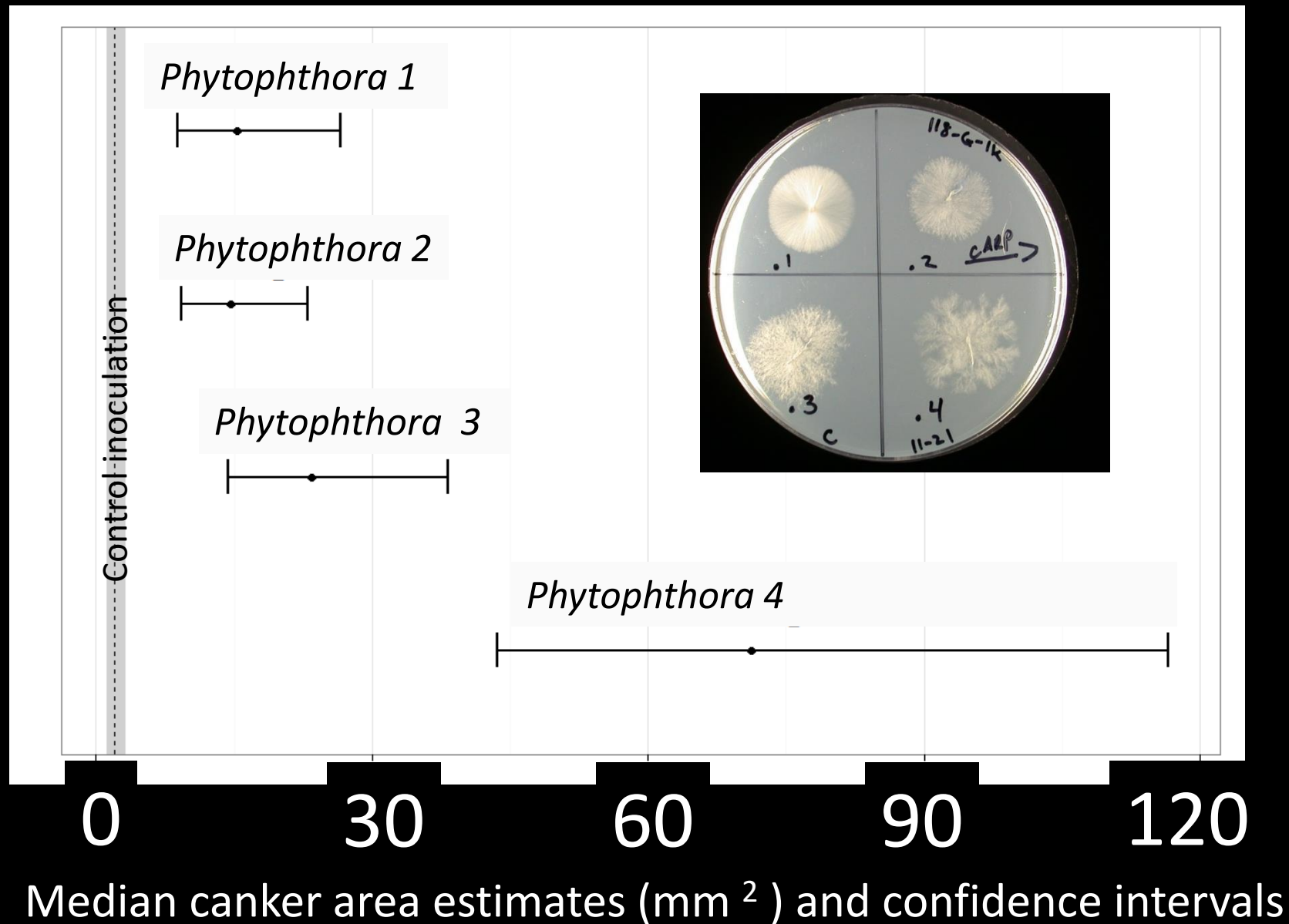
There is a diversity of species in a single rhizosphere sample from one plant root –still this number is much smaller than the total number of species around the world



# Next steps

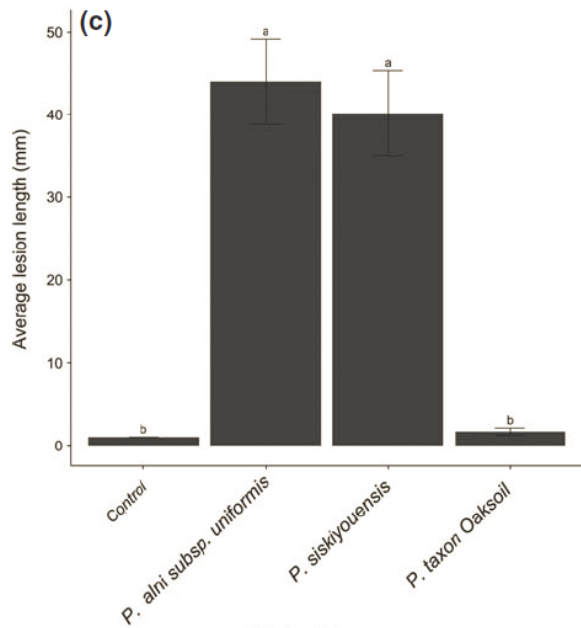
- Inoculate your test plants with the different species and compare their pathogenicity
- Perform Koch's Postulates

# Pathogenicity Test. Results





With diversity in species comes differing levels of pathogenicity



Phytophthora spp.

Navarro, Sims, and Hansen. 2015

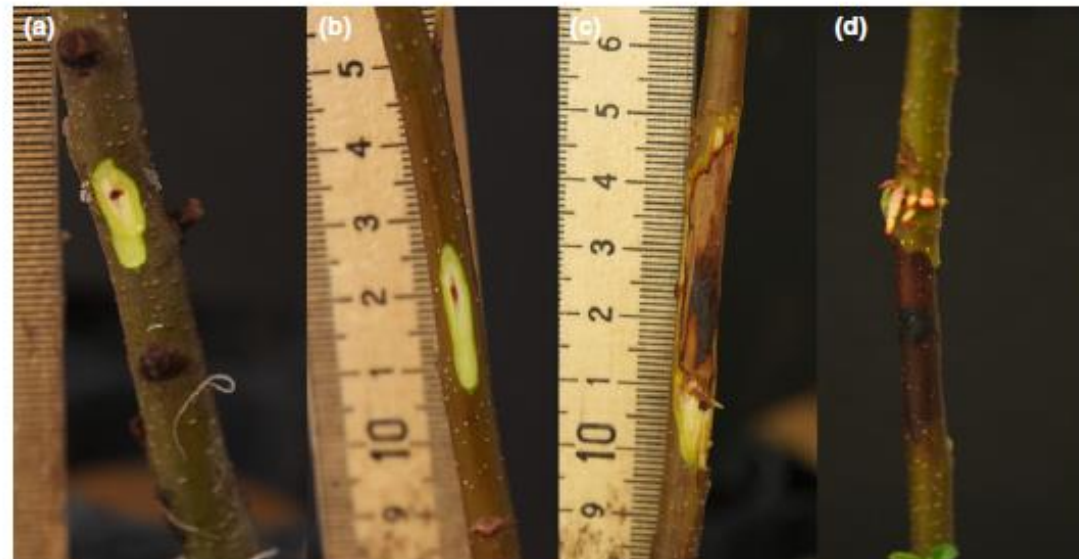
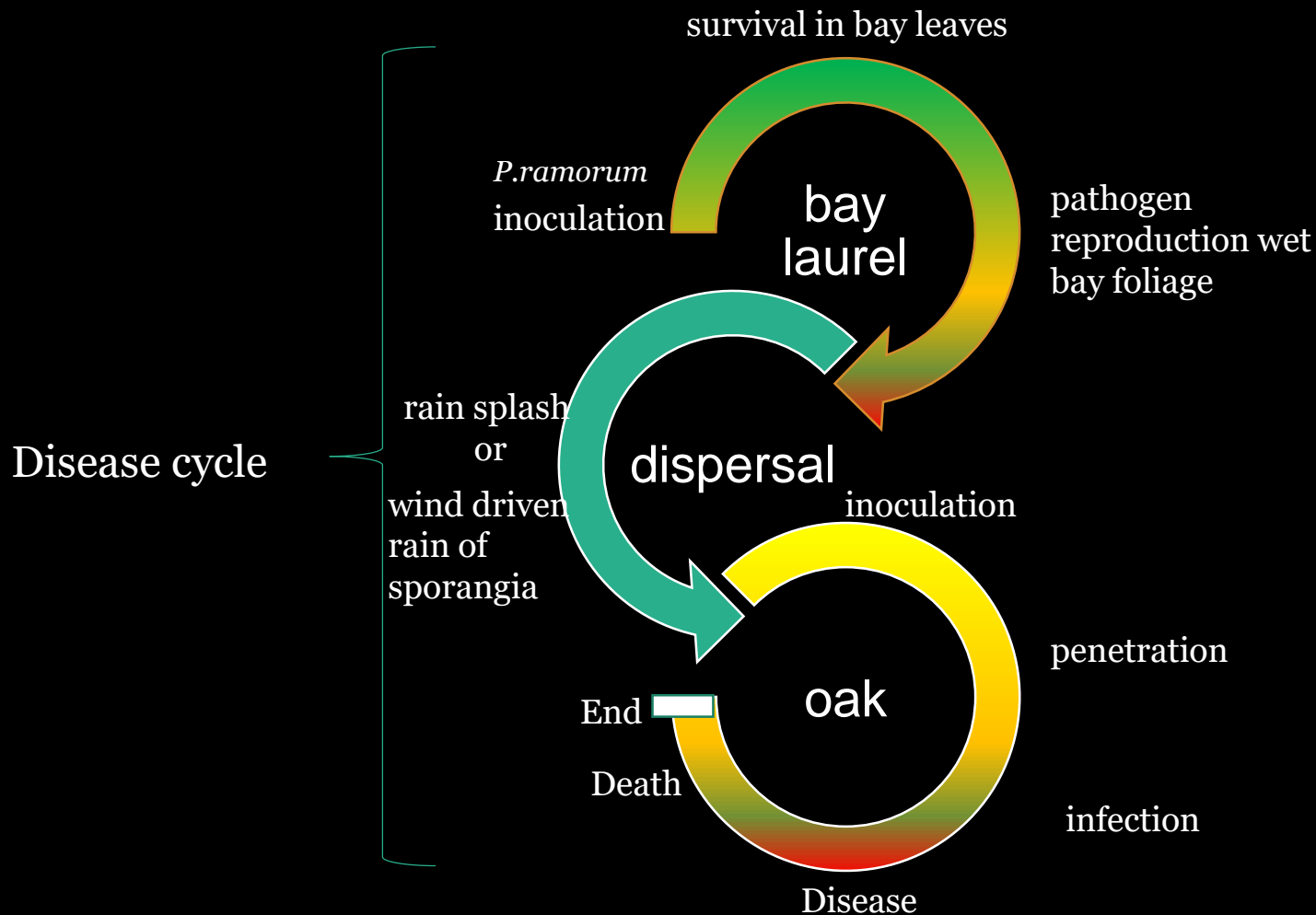


Fig. 2. Cankers resulting from inoculation with (a) carrot agar plug, (b) *P. taxon* Oaksoil, (c) *P. siskiyouensis* and (d) *P. alni* subsp. *uniformis*. Each alder tree unit pictured was stem wound inoculated over a pinprick wound. Trees were incubated in the greenhouse for 15 days prior to examining cankers.

# Koch's Postulates

1. The pathogen must be present on the diseased host
2. The pathogen must be isolated from the diseased host and grown in pure culture
3. The pathogen from the pure culture must cause the disease when inoculated into a healthy, susceptible host
4. The pathogen must be reisolated from the new host and shown to be the same as the originally inoculated pathogen

# Use that information to describe the Disease cycle



# How to id the major players

- Identify the problem
- Target your population of interest
- Evaluate the level of disease and types of symptoms
- Sample the population of interest and the landscape around it
- Isolate *Phytophthora*
- Identify the species in your system
- Inoculate your test plants with the species from the plant host and from the surrounding environment and compare their pathogenicity
- Perform Koch's Postulates
- Use that information to describe the disease cycle

Thank you! Questions?

