There's a fungus among us….

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Disease

- Anything abnormal
- A change in the form, functions or physiology of the plant that results in the expression of **symptoms**.

Disease

- Biotic
  - Infectious
  - Pathogen
  - Epidemics (epiphytotics)
- Abiotic

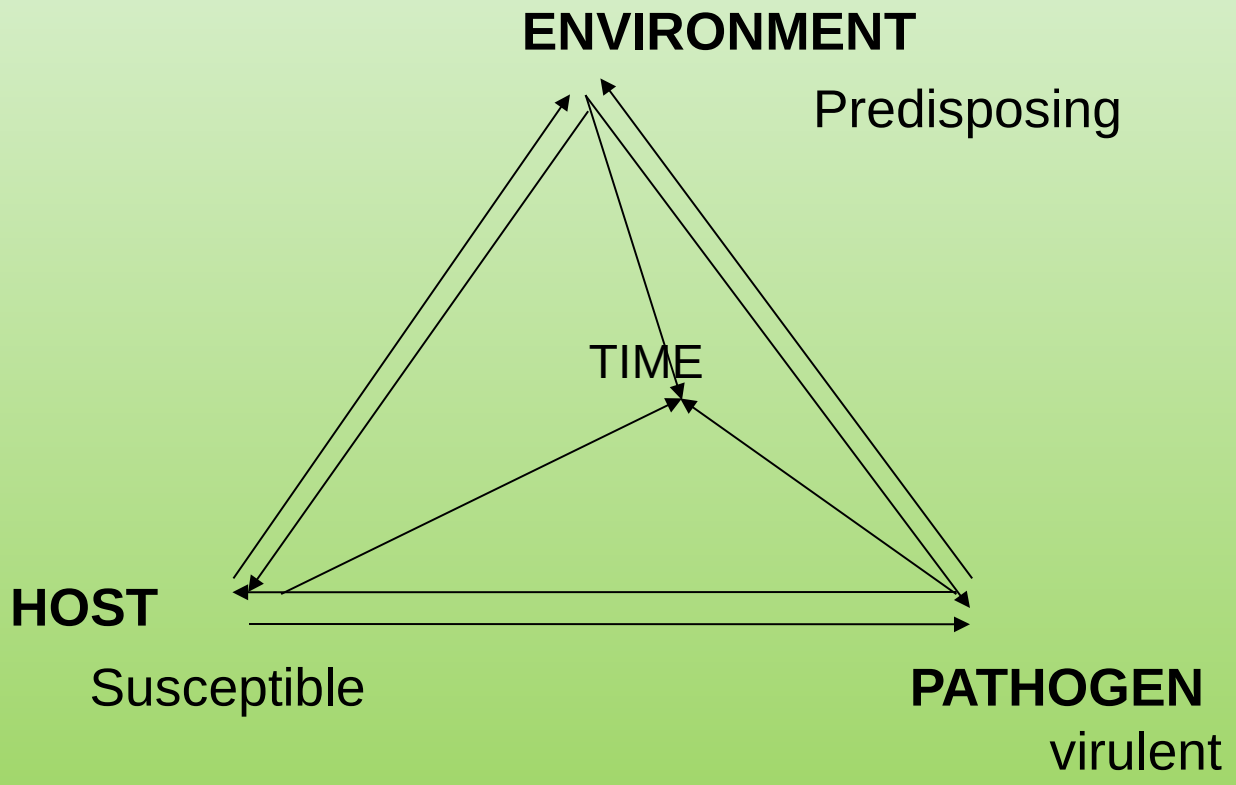
Disease results from an interaction of the virulence of the pathogen, susceptibility of the host and conduciveness of the environment.

Disease Detection/Diagnosis

- Disease results in the formation of ***SYMPTOMS*** which are plant responses to a disease agent
- Diseases may also show ***SIGNS*** which are actual observable pathogens or their fruiting bodies

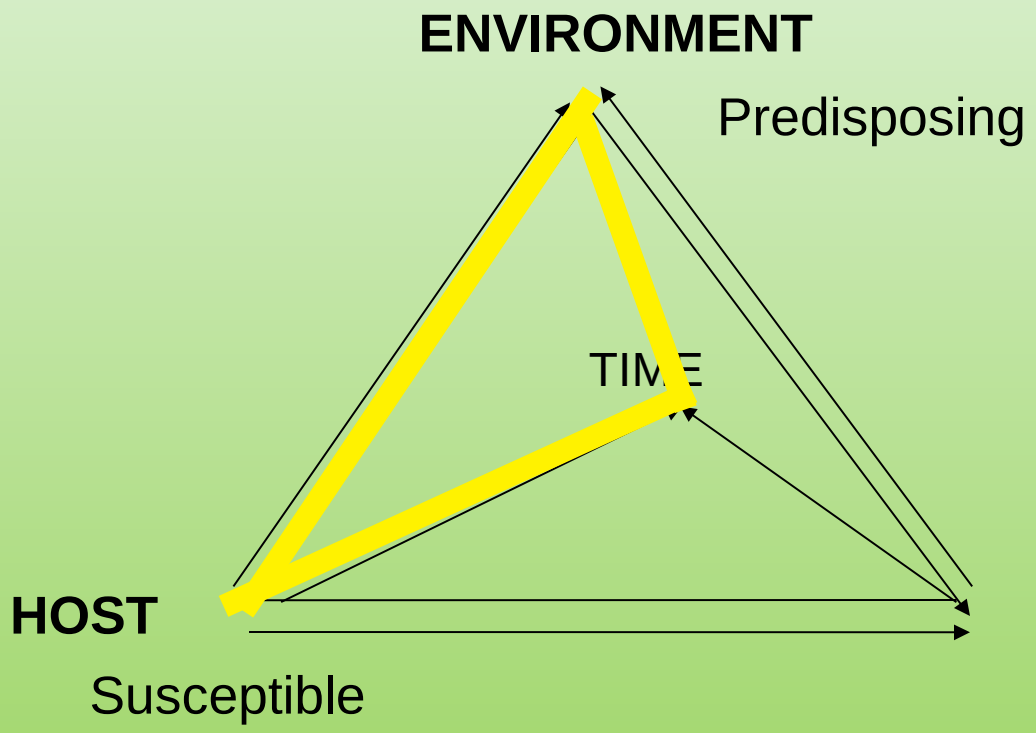
Disease

- Biotic



Disease

- Abiotic



Why do plants become Diseased?

- A pathogen is introduced that is “compatible” with the host and infects it.
- Host resistance is reduced by Stress
- The plant is not adapted to its growing location
- The Environment favors disease agents but not the host

- ***Predisposition*** is the environmental modification of host plant resistance making the plant more susceptible to disease.

Pathogenesis

Pathogen arrival

Host Recognition

Germination

Orientation

Prepenetration events

Penetration

Ramification

Reproduction

Dispersal

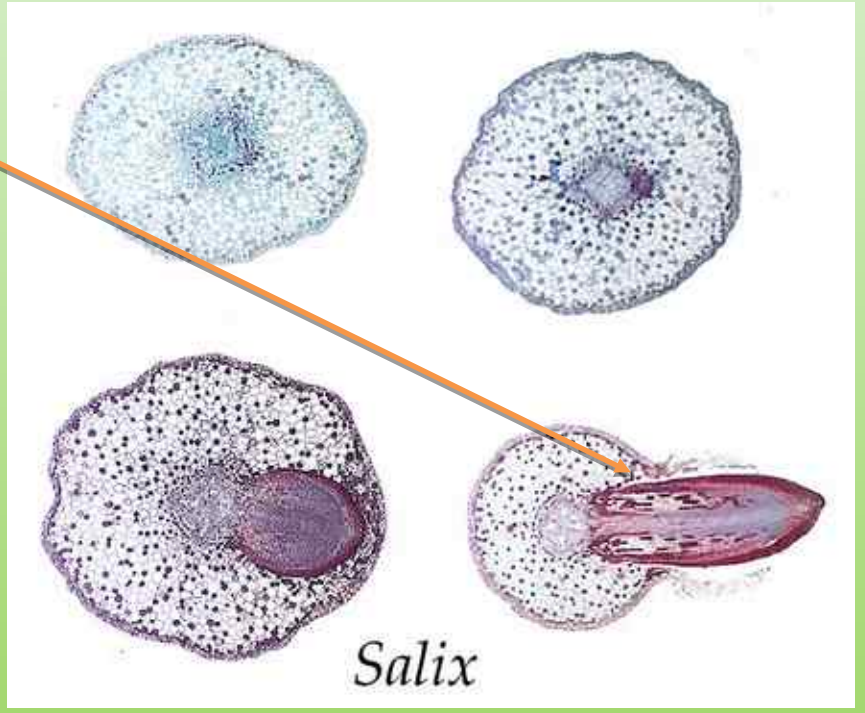
Infection Courts

the places where pathogens enter a tree

- Indirect penetration
  - Wounds or stomata
    - biotrophs
- Direct Penetration
  - Pathogens Create their own entry point
    - necrotrophs

A developing root is a natural infection court for soil-borne fungal pathogens

- As a new branch root emerges from the cortex it has to erupt or break out of its parent root.
- Branch root formation can not occur without leaving a wound and a chemical scent that is “noticed” by fungi.



Infection Courts

- Floral nectaries are the main infection court for the fireblight bacterium *Erwinia amylovora*.

Infection Courts

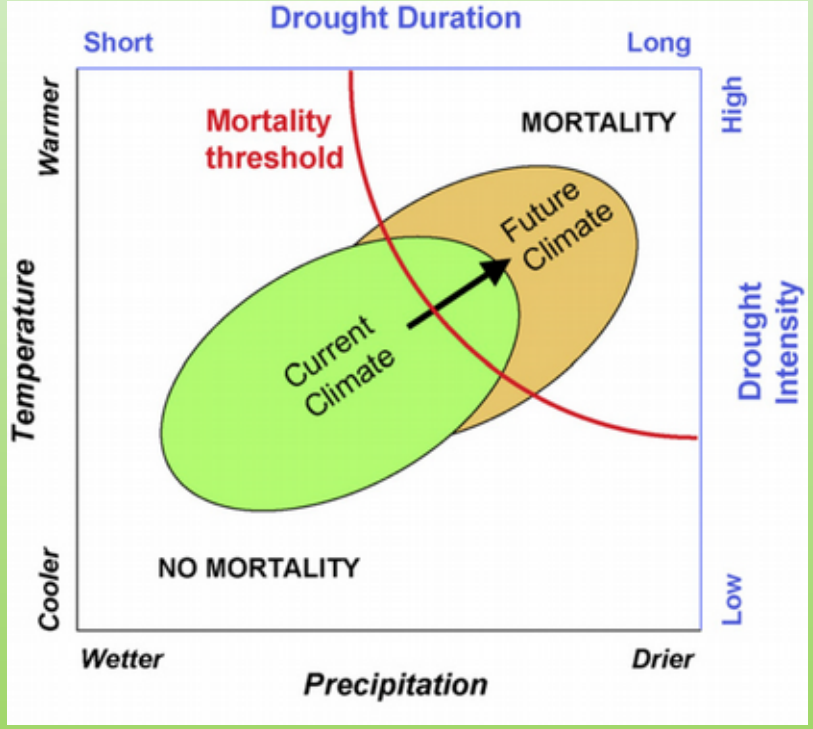
The Root Collar

Branches

- But sometimes, conditions which favor plant growth and health can also favor disease!!

Epidemics of introduced (invasive) species are more severe than epidemics of endemic species

- Introduction of plant pathogens is at an all time high in the recorded history of the United States



Diagnosis

- The discovery of the cause of disease
- Must be familiar with “normal” plant growth and development
- Must have some concept of the plant’s “history”
- Look for Symptoms and Signs
- Labwork may be necessary for confirmation

Phenology is an indicator of disease

Root Collar inspections are necessary for trees (always)

Buried Trunks often show Symptoms or signs under or in Bark

Signs of mycelium

Symptom of oxidation of tissues

Canopy Density, Leaf Retention, Deadwood content

Symptoms in foliage

May indicate problems with root function or stem functions

Escalonia X *fraseri* with (right) and without (left) shearing.

Bleeding

Symptom: Bleeding

Cracks

Growth cracks

Disease cracks

Plant disease is best managed through an integrated management strategy that includes:

- 1. cultural practices
- 2. epidemiology
- 3. host resistance
- 4. pesticides
- 5. biological controls

New street tree planting in Kiev, Ukraine

Water Placement

- Don’t do silly things with water
- Irrigate through the root ball—always
- Don’t place water under the rootball!

A major approach to disease control is inoculum reduction.

- Clipping off and disposing of diseased parts, plants or other debris
- Stopping movement of inoculum
  - Sterilizing clippers, water, soil etc.
- Stopping vectors of inoculum
- Inhibiting the pathogen from inoculum production

Quarantine is often the best method of combating exotic diseases

- And sometimes the least effective as quarantines are ignored by many including the regulators who institute them.

Do No Harm!

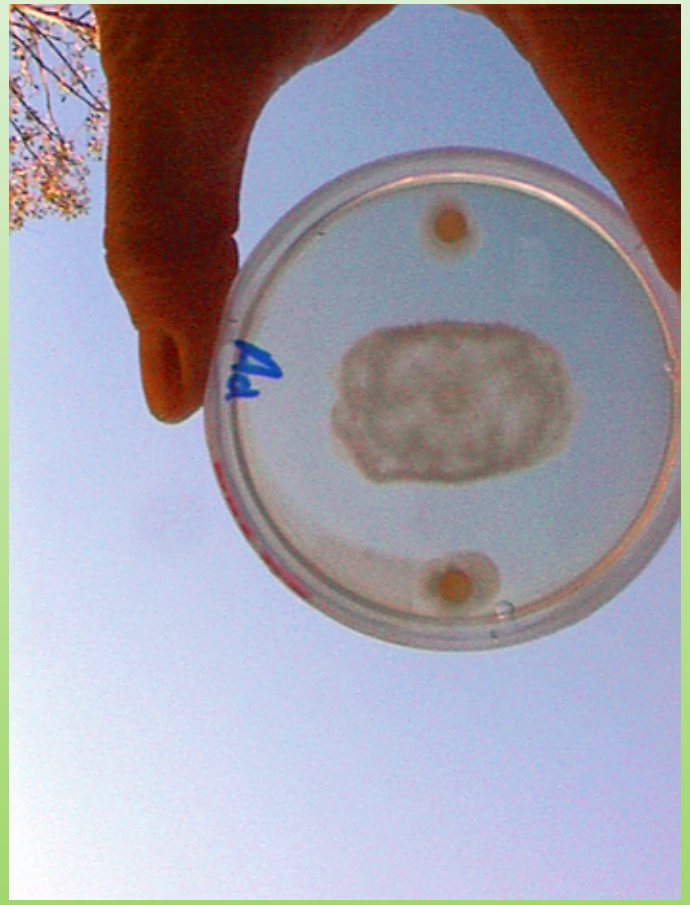
- An understanding of why diseases form and develop gives us a new responsibility to prevent disease through proper horticulture.

Kinds of diseases: Disease Categories

- Anthracnose/blights
- Cankers
- Rots
  - Root, stem, flower, fruit, wood
- Wilts
- Damping off
- Leaf spots
- Declines

Kinds of pathogens: Etiology of Plant Disease

- Fungi
- Bacteria
- Nematodes
- Virus/viroids
- Parasitic seed plants
- Algae

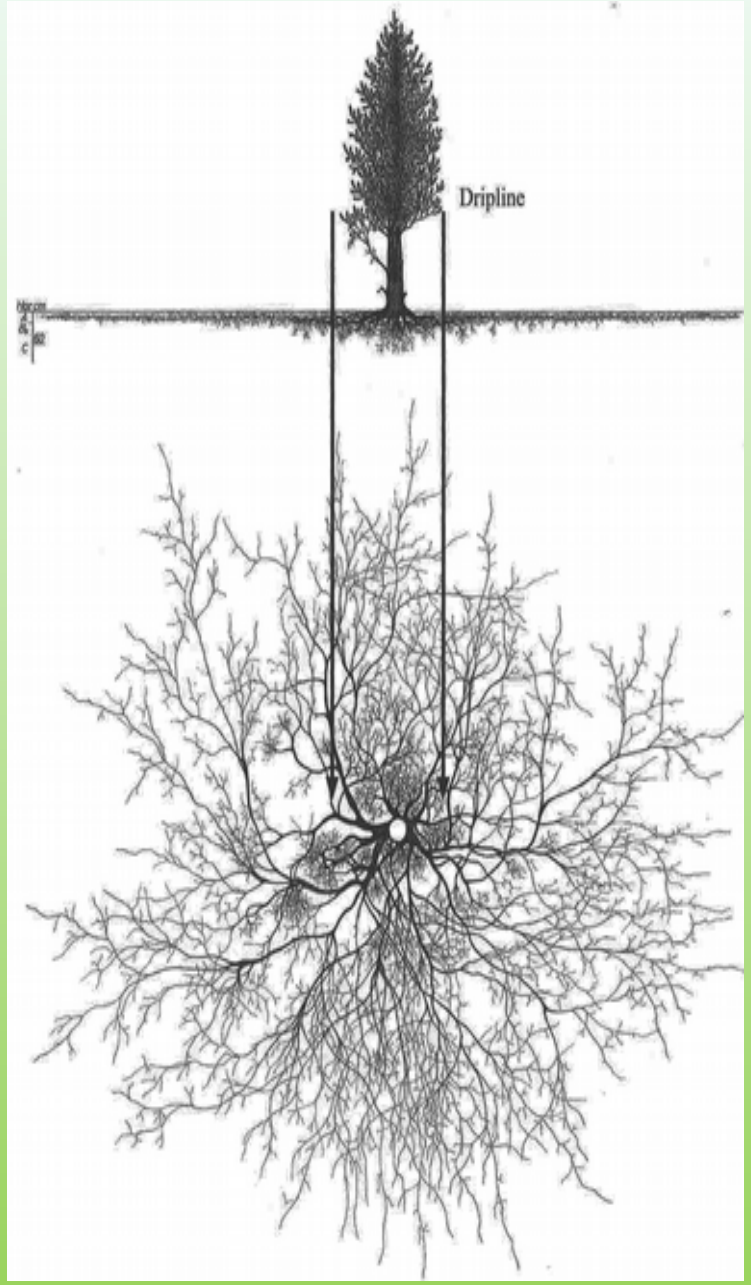


Root Rots

- *Armillaria mellea*: Oak Root Fungus
- *Phytophthora* spp. Various root rots
- Anoxic conditions
  - Flooding
  - Natural Gas Leakage

Root systems

- Are Extensive
- Are not always where you think they are
- Are diverse (different kinds of roots in differing places)
- Are Fragile
- Need protection and sometimes enhancement



From R. Kourik, 2015

Roots are constrained or enhanced by the soil/water/oxygen environment in which they reside

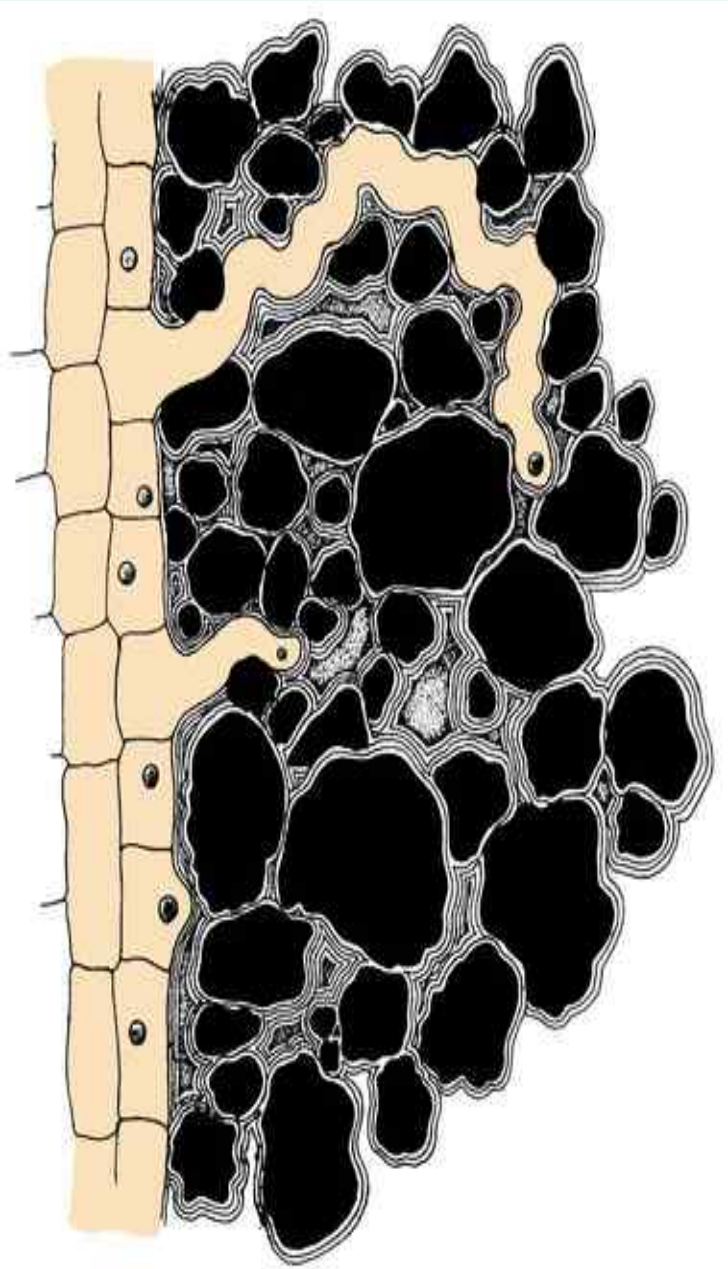
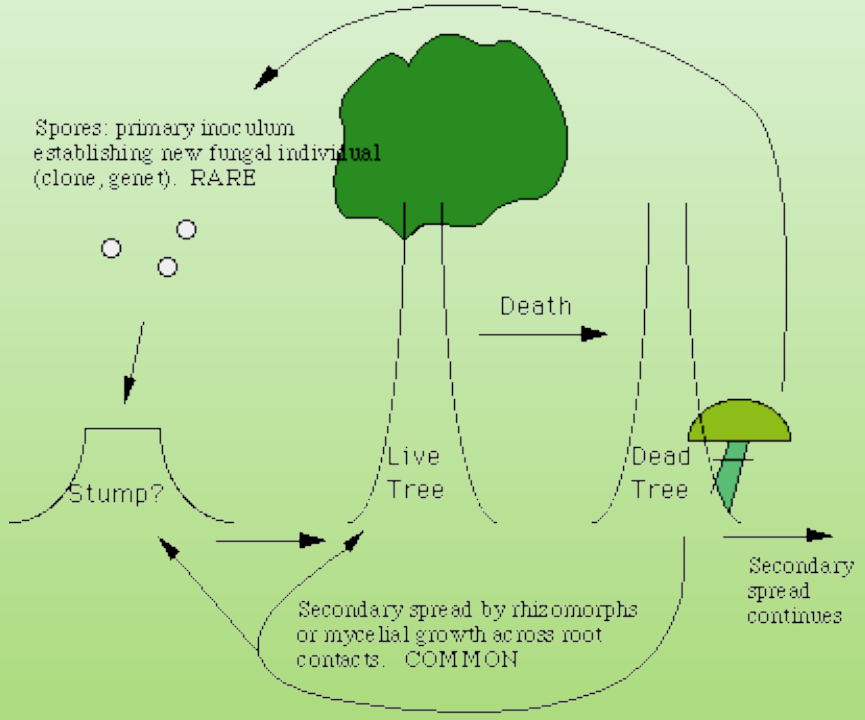
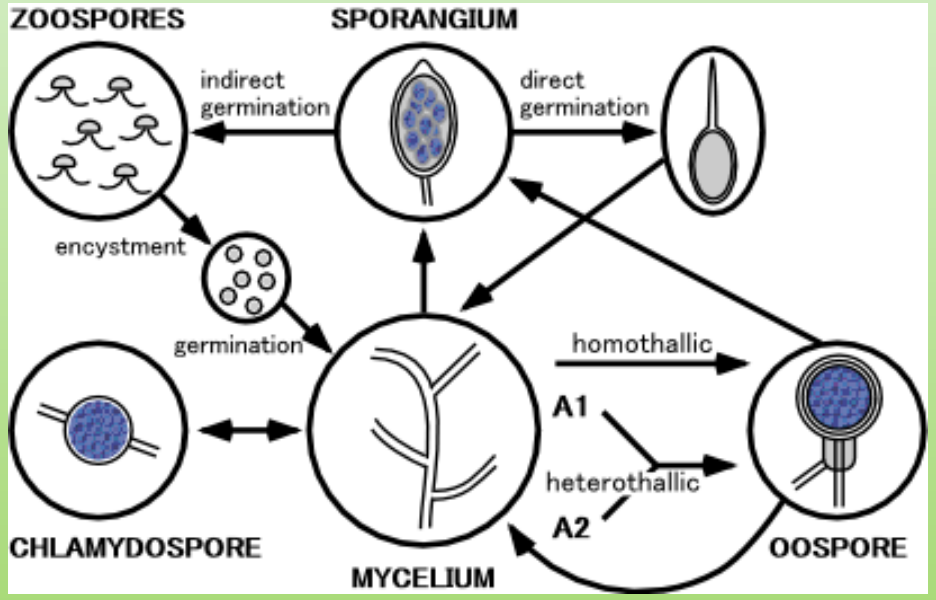


Figure 30-13b
Biology of Plants, Seventh Edition

Root Rot Life Histories



Armillaria root rot



Phytophthora root rot

Root rot is expressed in two ways

canker

rotting roots

Roots

Roots are often dark or melanized. Melanin is a protective chemical that reduces microbial attack

Annual emergence of young roots indicates their health

"Skinning" the root with a pocket knife will assure you that they are not decayed.

Roots of Prunus spp.

Some roots are so black they look decayed

Most Roots are mycorrhizal

Mycorrhizal roots are stubby and are often prolific

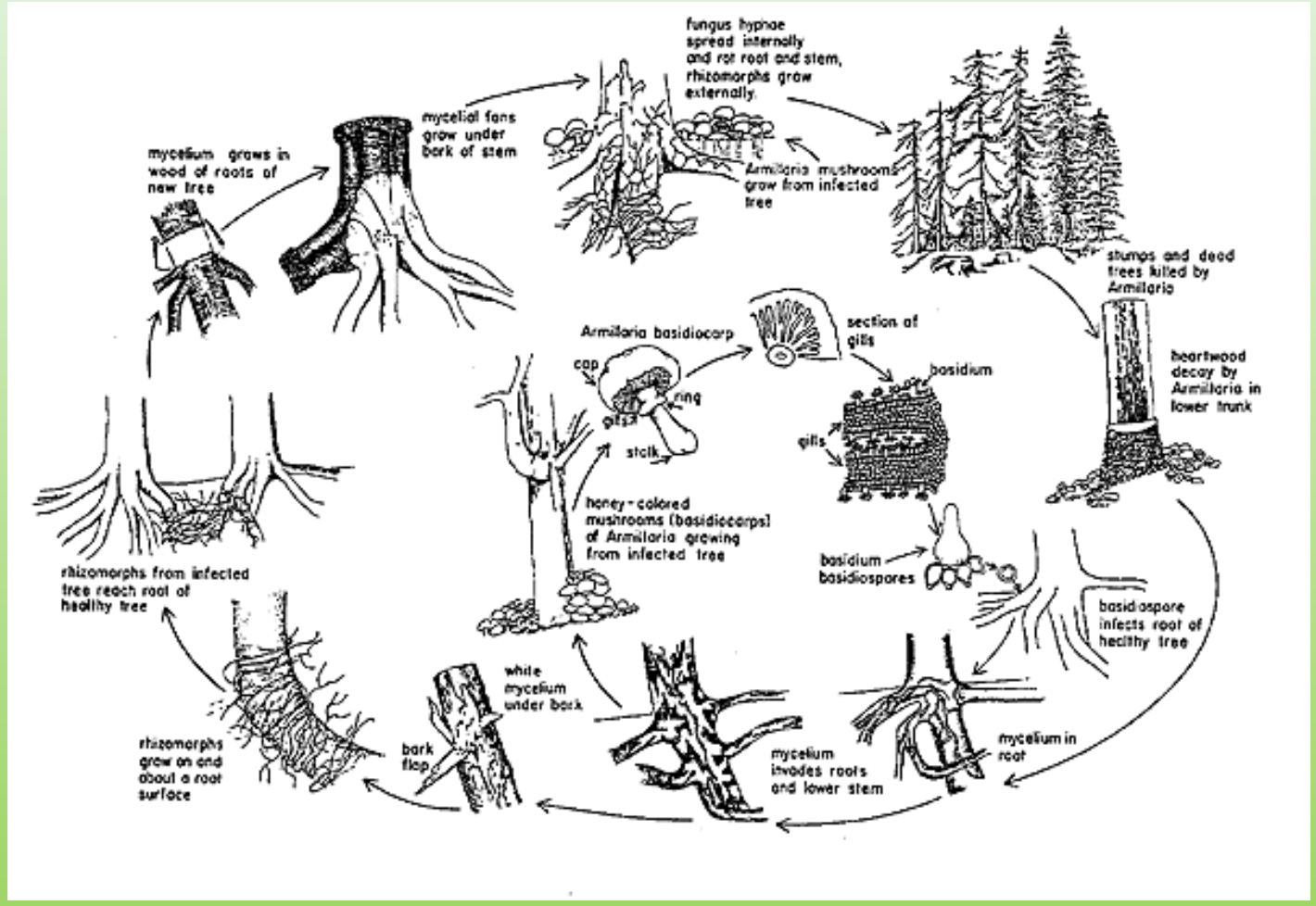
Some mycorrhizal roots may be swollen or appear to be covered in fungal mycelium.

Gingko biloba

Healthy vs. Not

Armillaria mellea

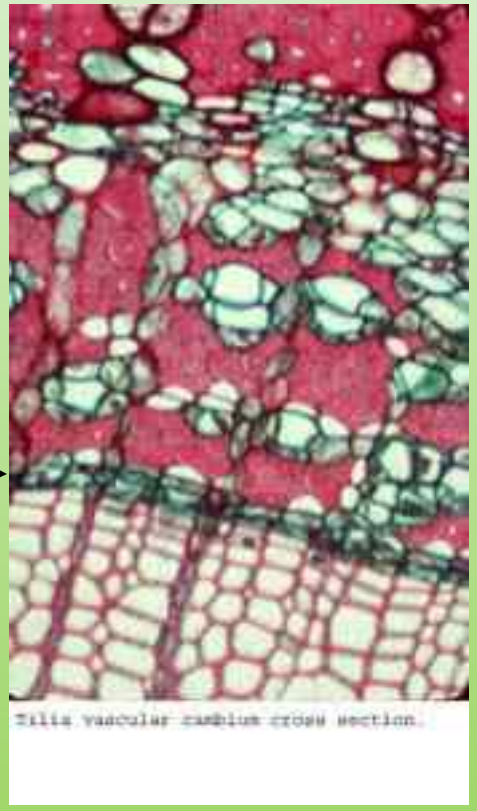
- Signs: Mushroom, Mycelial Fans
- Symptoms: Decline, leaf loss, dieback, basal cankers, bleeding, trunk flat sides and death of the tree


fungus hyphae spread internally and rot root and stem, rhizomorphs grow externally
mycelial fans grow under bark of stem
mycelium grows in wood of roots of new tree
Armillaria mushrooms grow from infected tree
stumps and dead trees killed by Armillaria
heartwood decay by Armillaria in lower trunk
Armillaria basidiocarp
cap
ring
gills
stalk
section of gills
basidium
honey-colored mushrooms (basidiocarps) of Armillaria growing from infected tree
basidium basidiospores
basidiospore infects root of healthy tree
rhizomorphs from infected tree reach root of healthy tree
white mycelium under bark
bark flap
rhizomorphs grow on and about a root surface
mycelium invades roots and lower stem
mycelium in root

The vascular cambium

- A meristematic tissue
- Subject to pathogenic attack
- One cell layer thick

Vascular cambium



Stem/Root intersection

- Crown of the tree
- A metabolic region
- Physiologically sensitive to the environment
- Deep planting violates this part of a plant's physiology

Rapid Death

Slow Death

Armillaria mellea

Signs of infection

Root Collar Examinations are a must with *Armillaria* infections

Armillaria mellea
identification

- Mushrooms with an annulus
- Gills not running down stipe
- Gregarious
- Color is variable
- Size is variable

Rhizomorphs

Rhizomorphs are rare
In Southern California soils

They can spread the fungus
From tree to tree

They form readily in culture

Root Rots Caused by “water molds”

- These are actually highly evolved algae
- They no longer photosynthesize but now parasitize plants.
- They are common in the horticultural industries and landscapes
- They are microscopic
- You can not see the pathogen only the symptoms

Phytophthora: symptoms

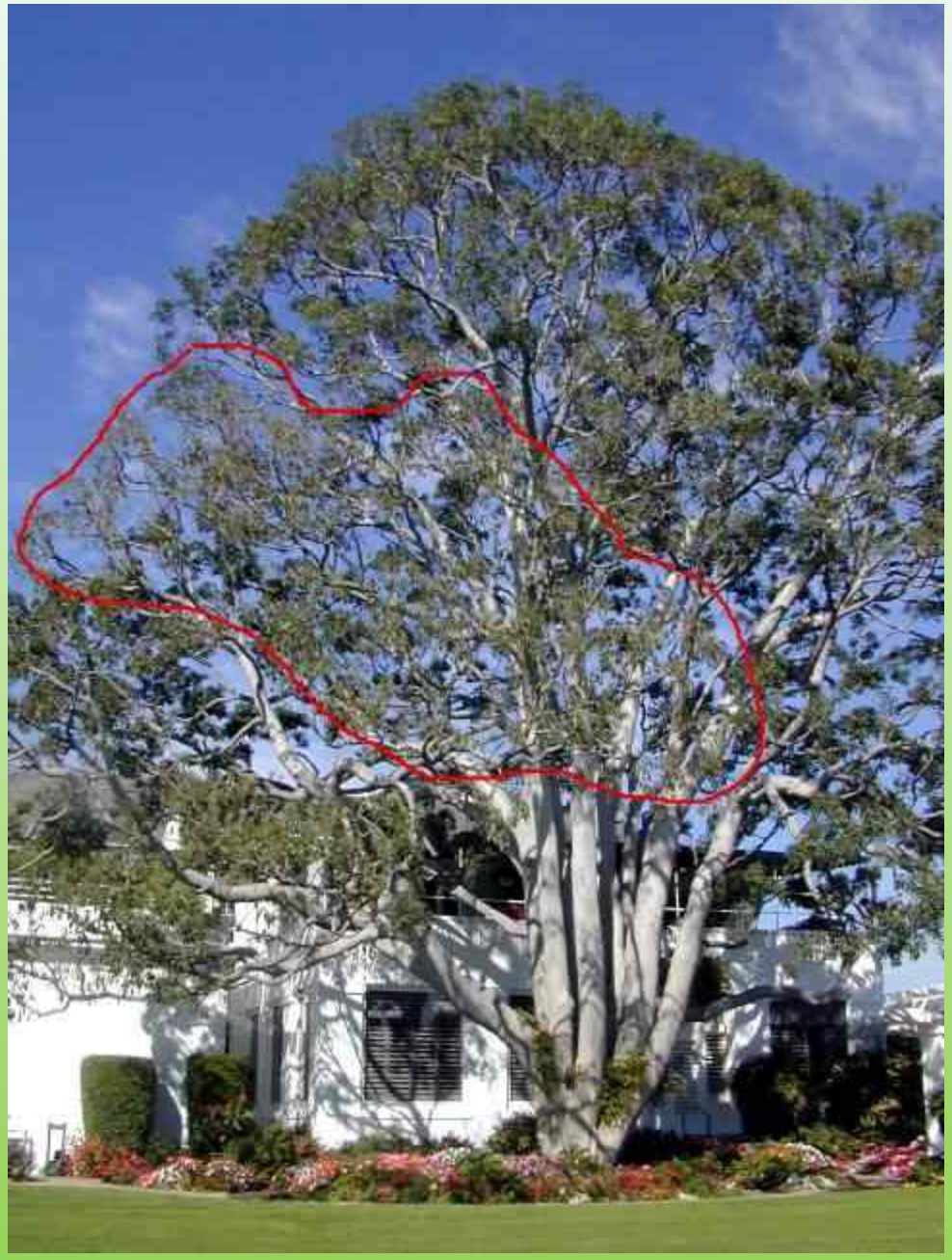
Phytophthora:symptoms

Root Rot: color changes

Boxwood knot garden, Kiev, Ukraine, 2015

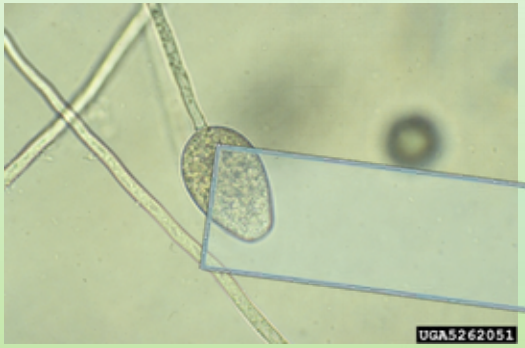
Ficus Symptoms

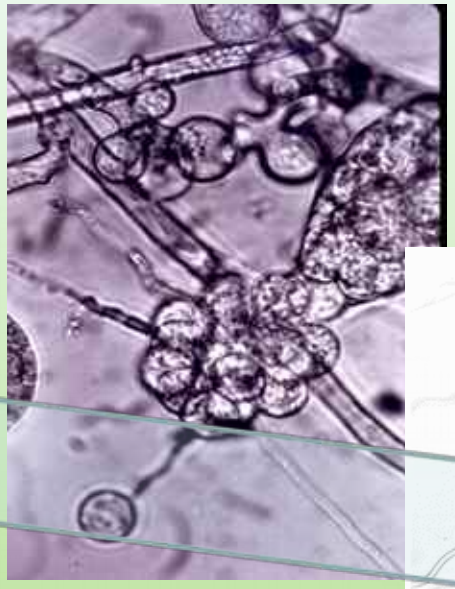
- Thinning of foliage is really lack of regrowth. Canopy vigor is severely compromised.

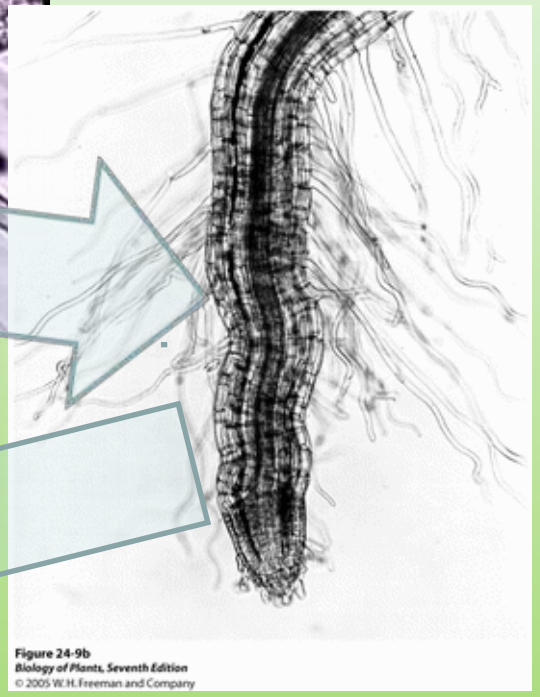


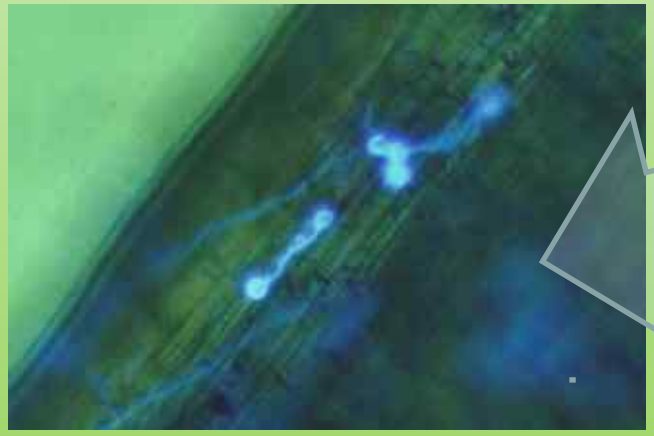
Palm Root Rot
Phytophthora nicotianeae

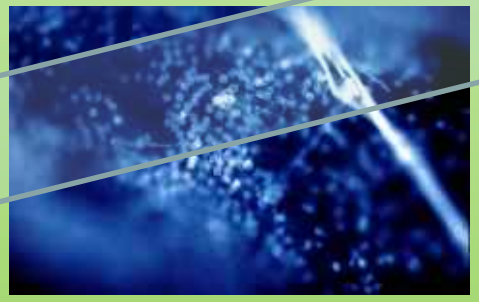
Damages many ornamental trees







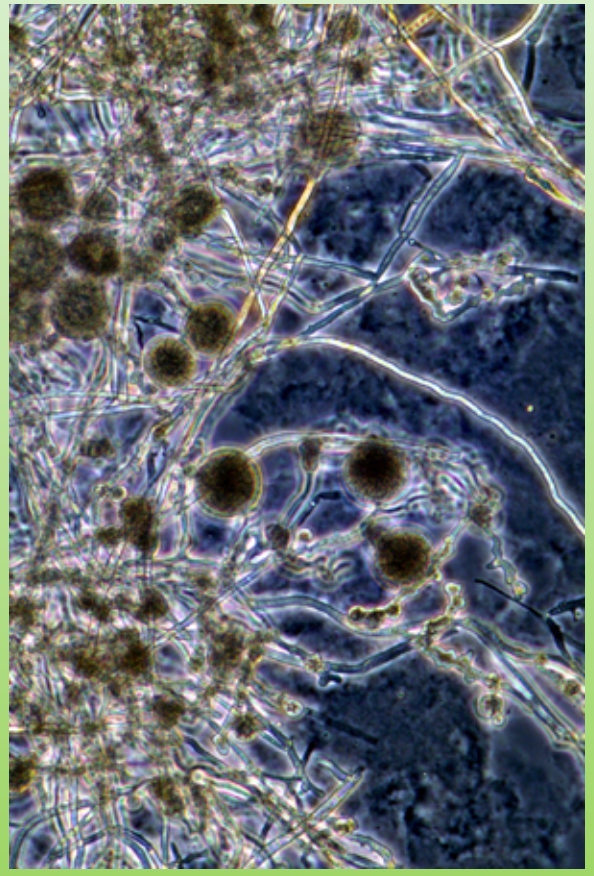




Downer ASCA Conference 2015,
Tucson, AZ

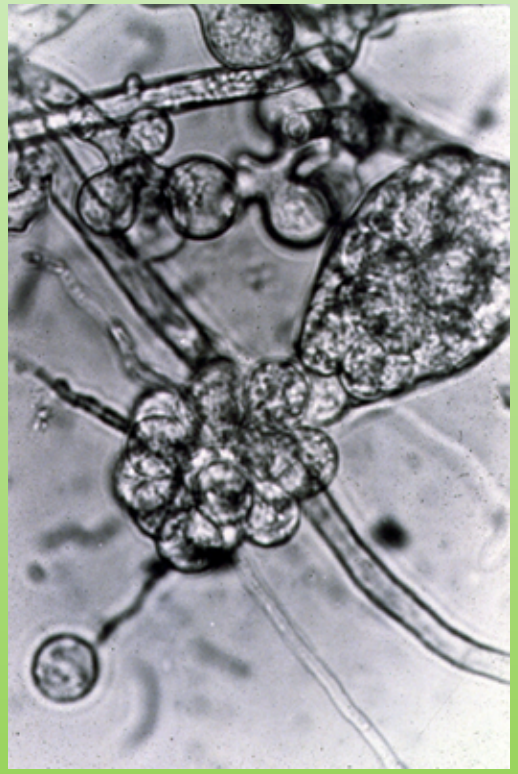
Chlamydospores

- Long-term survival in soil as chlamydospores or oospores in old root pieces.



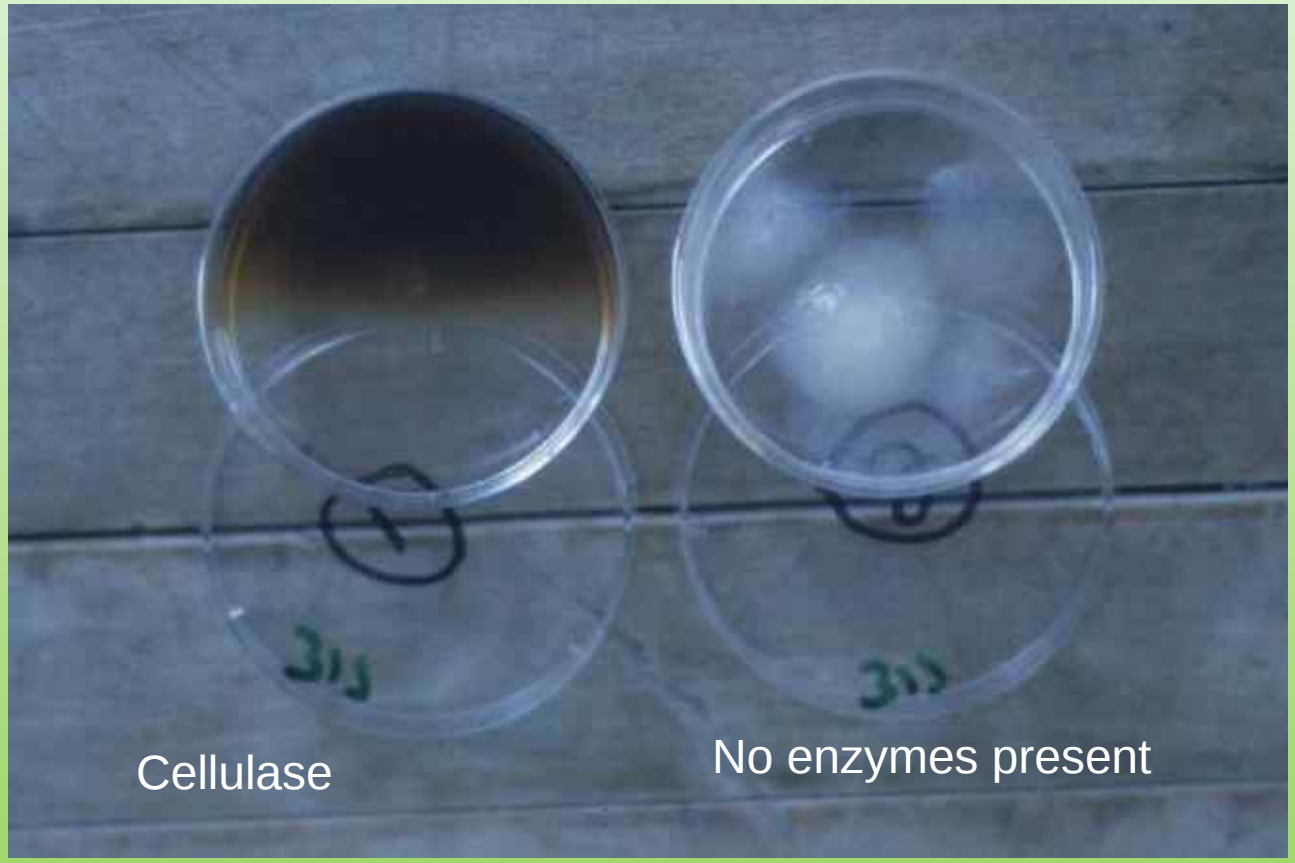
Zoospores become Cysts

- Zoospores will encyst on roots in the zone of elongation “en masse”



Mulch full of fungi

Enzyme meltdown



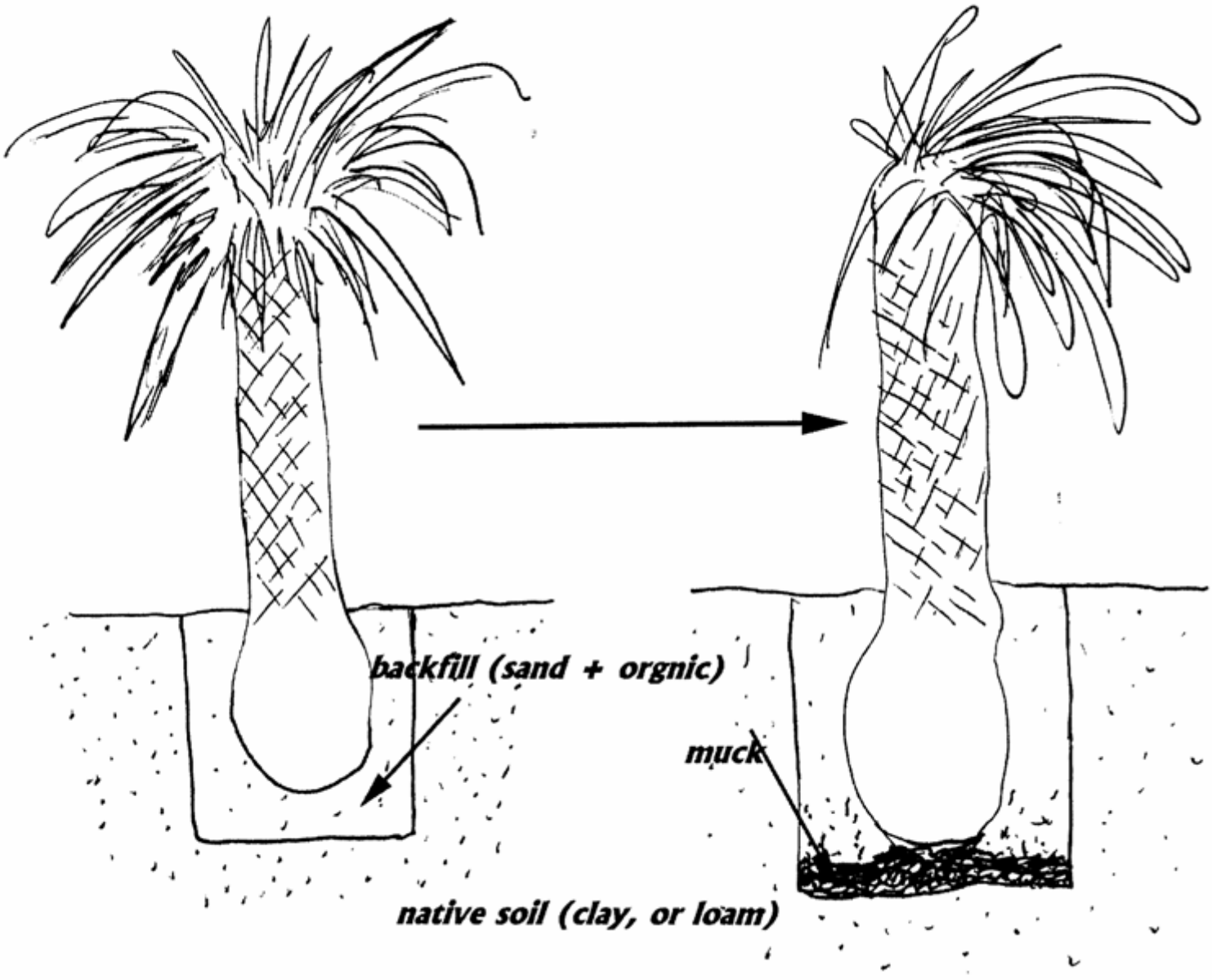
Anoxic root rots

- Due to root suffocation
  - Excess water
  - Natural gas suffocatio
  - Compacted soils

Planting Too Deep

- Almost always leads to problems/death of the plant
- Associated with *Phytophthora* collar rots
- “Kiss of death” for native plants

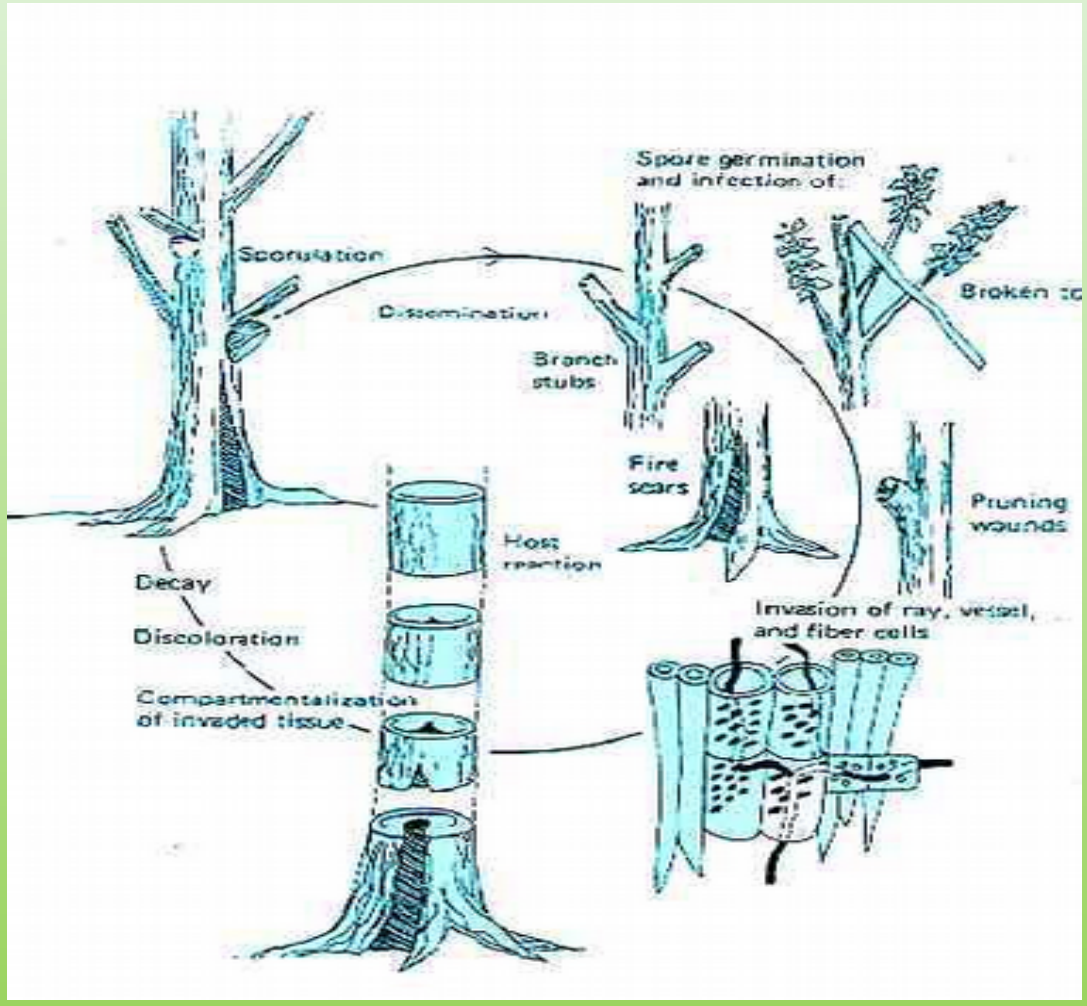
Figure 2



Heart Rot of Trees

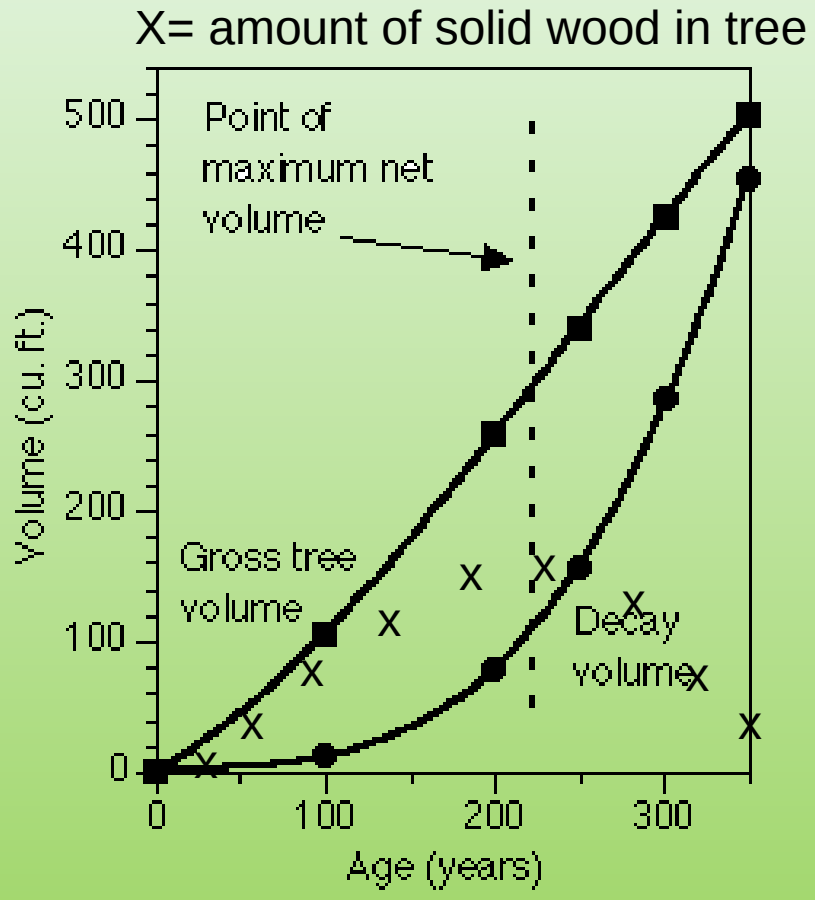
- *Ganoderma*
- *Laetiporus*
- Often associated with a decline in vigor.
- Associated with wounds to roots or the main stem
- Wood decay organisms result in wind damage and breakage in trees.

Heart Rot: a monocyclic disease



Old Trees Rot!

- Old trees have more decay.
- It is impossible to limit the progress of decay in trees once they have been infected!!
- Decay is best limited by proper management over the course of a tree's lifetime.



From forest pathology.org
Jim Worrall

Conks

- White Rots
  - *Armillaria*
  - *Oxyporus*
  - *Ganoderma*
- Brown Rots
  - *Laetiporus*

Heart Rot

Ganoderma lucidum

Anullohypoxylon spp.

Biscogniauxia atropunctata confirmed in Santa Clarita

Biscogniauxia is a sap rotting fungus

Oxyporus

Oxyporus latemarginatus

Resupinate often ground dwelling fruiting bodies

Wood Decay Fungi

- *Laetiporus sulfureus*

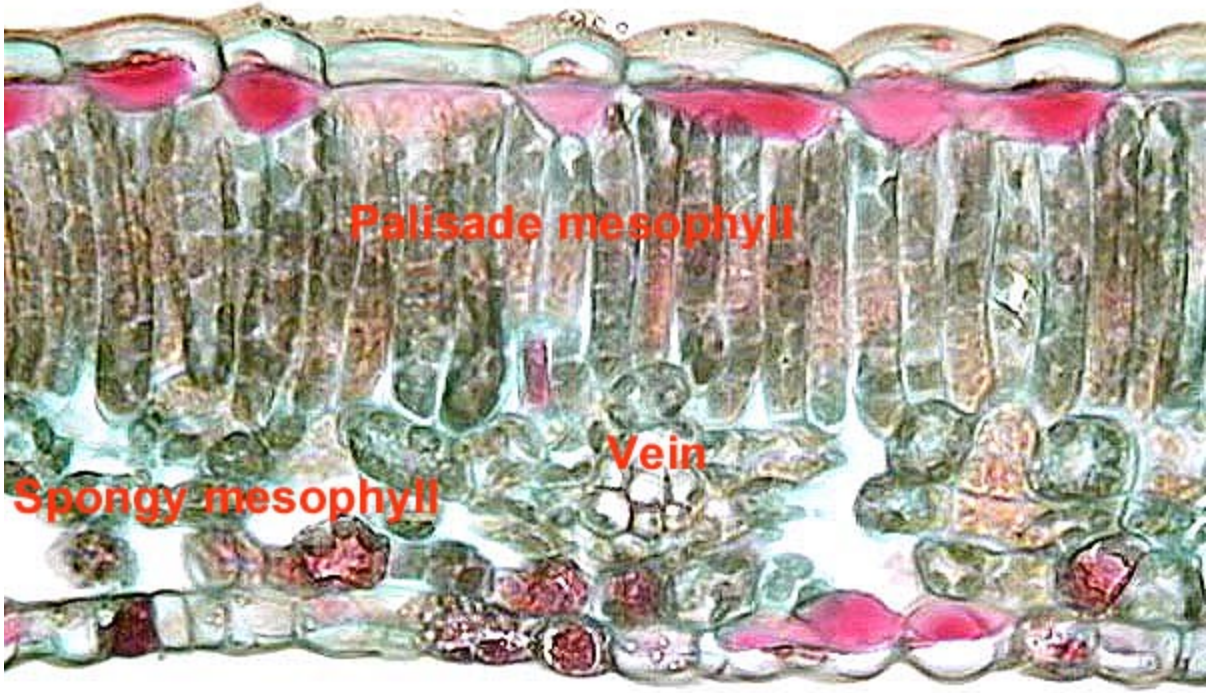
  a brown rot fungus
- *Oxyporus latemarginatus* a white rot fungus

Pruning

- Removing stems removes stored energy
- Pruning is wounding
  - Wounds are infection courts
- Pruning redirects the allocation of energy and tree hormones.

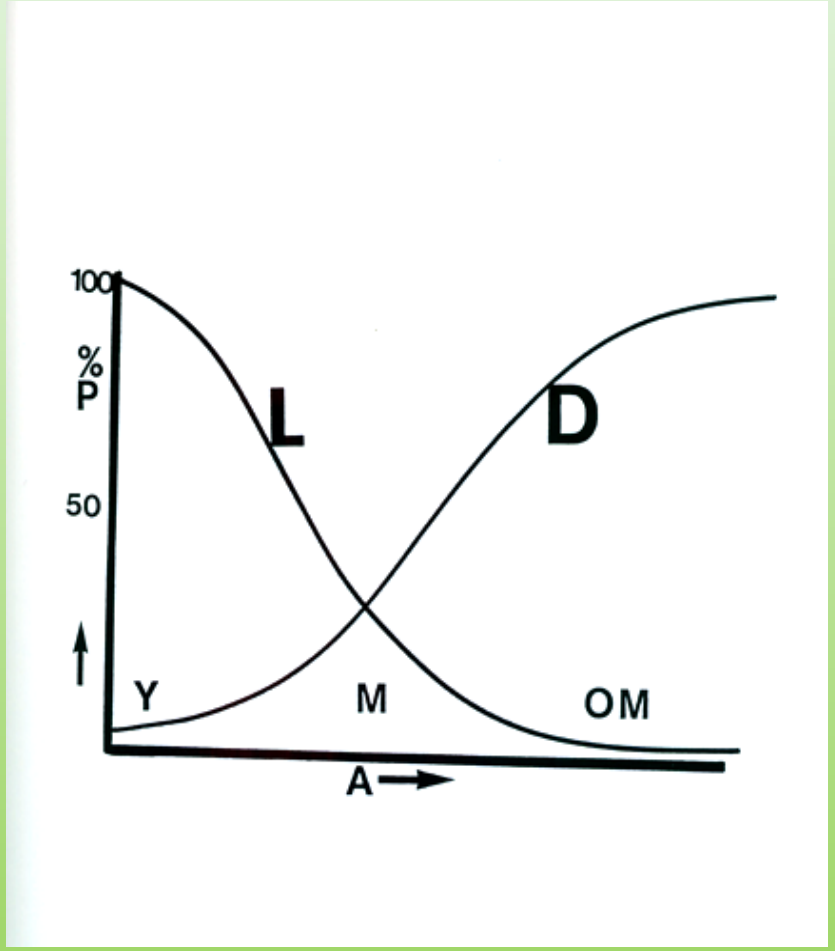
Pruning

- Removing leaves removes energy producing cells



How much to prune?

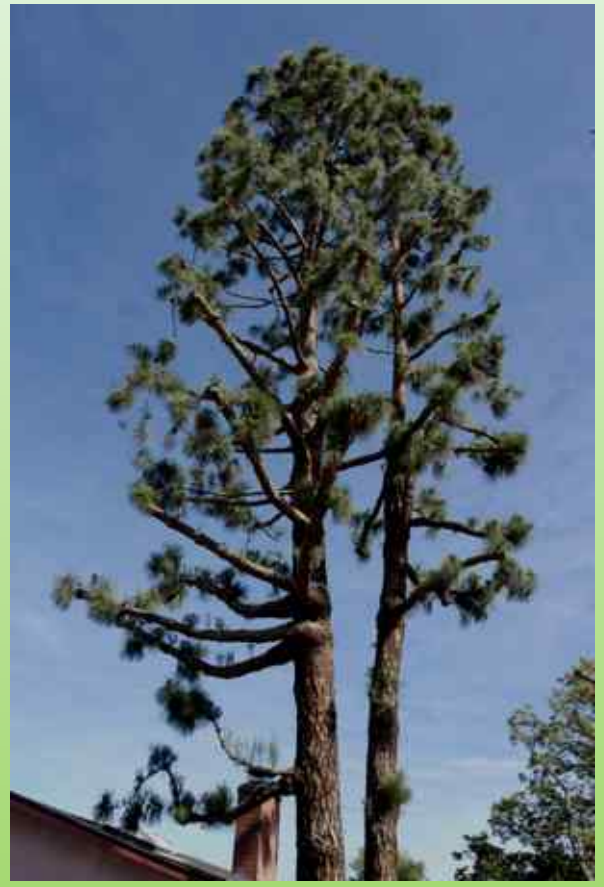
- Pruning removes photosynthetic machinery necessary for carbohydrate production
- X axis = increasing Age
- Y axis % wood removed
- L =living wood removed
- D = Dead Wood removed
- Y = young tree
- M = mature tree
- OM = Over mature tree



From A. Shigo, Modern Arboriculture, 1991

Pruning

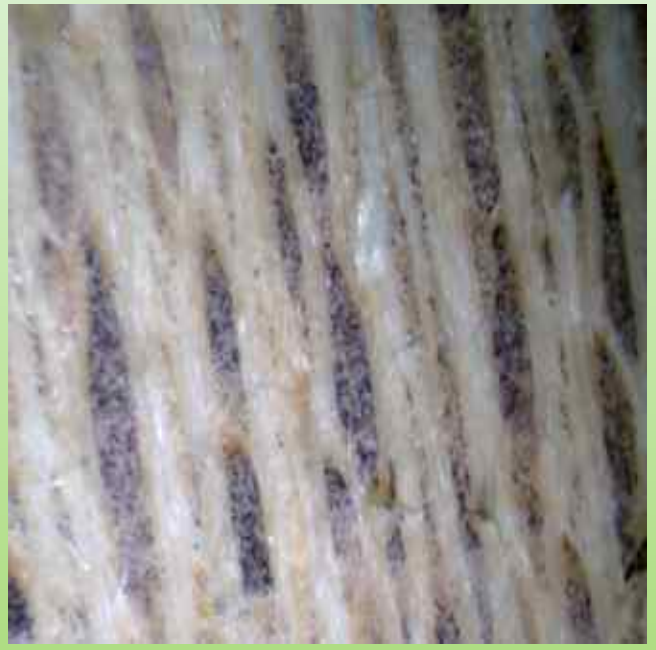
- Thinning vs Overthinning
- Crown Cleaning?
- Removing green canopy from the tree can be detrimental.
- Green canopy removal is always growth preventing
- Green canopy removal depletes stored carbohydrates and draws on reserves in this way roots are compromised and predisposed to infection by root rots.



Wounds and the potential for their infection in the deeper layers of the tree's xylem.

Heart Rot of Trees

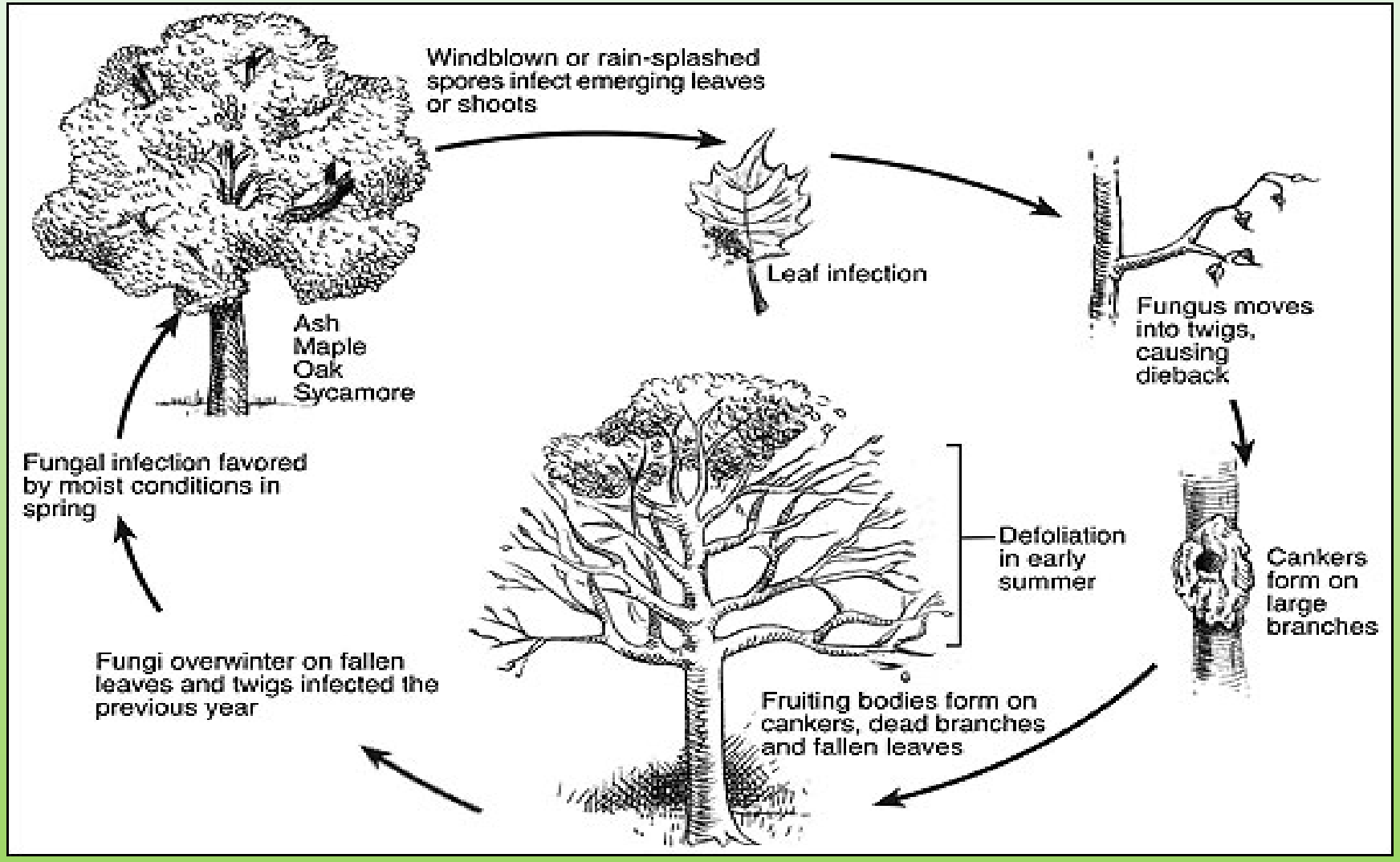
- Ganoderma
- Laetiporus
- Often associated with a decline in vigor.
- Associated with wounds to roots or the main stem
- Wood decay fungi feed on stored sugars in wood and



Multiseriate rays stained with Potassium iodide to show starch storage in wood (Kevin Smith Seminar, 2015 San Marino, CA,)

Anthracnose Diseases

- Diseases of leaves and twigs
- Produce conidia (spores) in acervuli.
- Symptoms: leaf spots, blights, cankers and twig dieback.
  - Vein Associated Symptoms
  - Irregular spreading necrotic blotches
  - Blight
- Fungi over-summer in dead twigs on the tree.


Windblown or rain-splashed spores infect emerging leaves or shoots
Leaf infection
Fungus moves into twigs, causing dieback
Cankers form on large branches
Defoliation in early summer
Fruiting bodies form on cankers, dead branches and fallen leaves
Fungi overwinter on fallen leaves and twigs infected the previous year
Fungal infection favored by moist conditions in spring
Ash
Maple
Oak
Sycamore

Sycamore Anthracnose

Anthracnose: oak

Symptoms on leaves

Stegophora ulmea on Chinese elm

Apiognomonia veneta on California Sycamore

Anthracnose: Ash

Canopy Symptoms

Anthracnose diseases defoliate the tree from the ground moving upward in the canopy

Rarely causing a complete defoliation

Anthracnose diseases are defined as those with spores in an acervulus.

Anthracnose:Chinese Elm

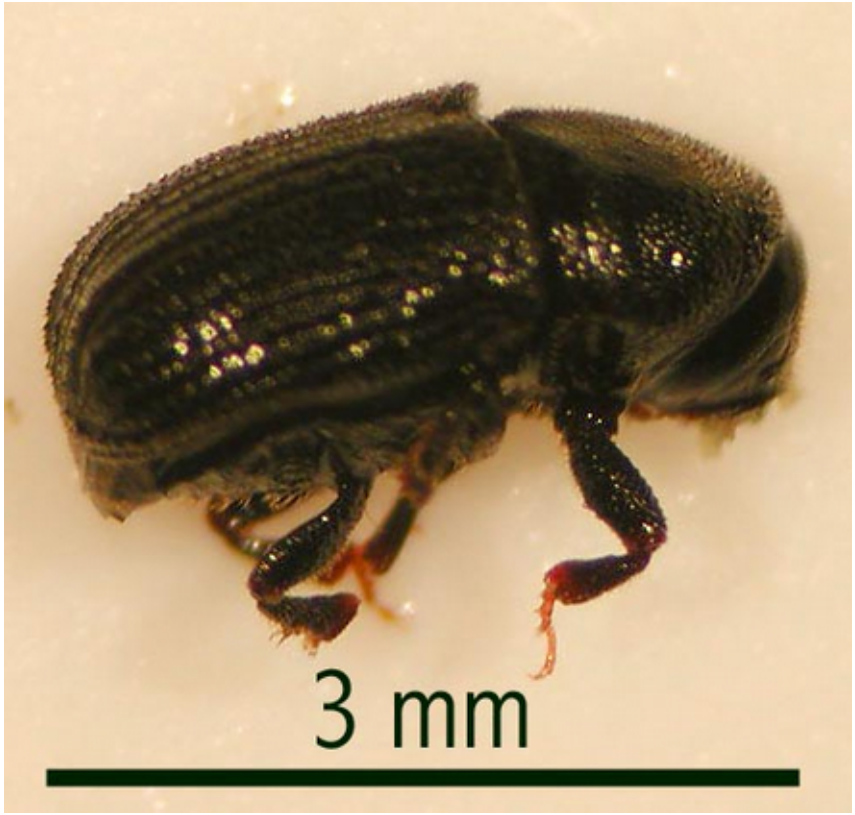
Canker Diseases

- Cypress Canker
- Dothiorella Canker
- Ficus Canker
- Pitch Canker
- Willow (Cytospora) canker
- Madrone Canker

Cypress Canker
Seiridium cardinale

Cypress Canker Acervuli

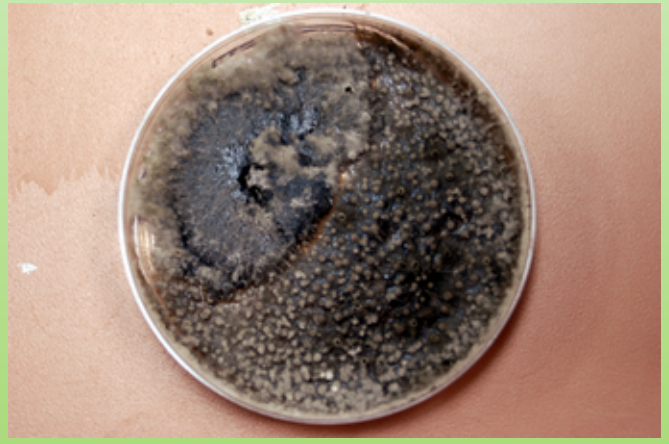
Vectors of cypress canker



Madrone Canker
Fusicoccum arbuti
(*Natrassia mangiferae)*

Redwood Canker

- Trees with disease caused by *Botryosphaeria* are predisposed by drought in previous years.



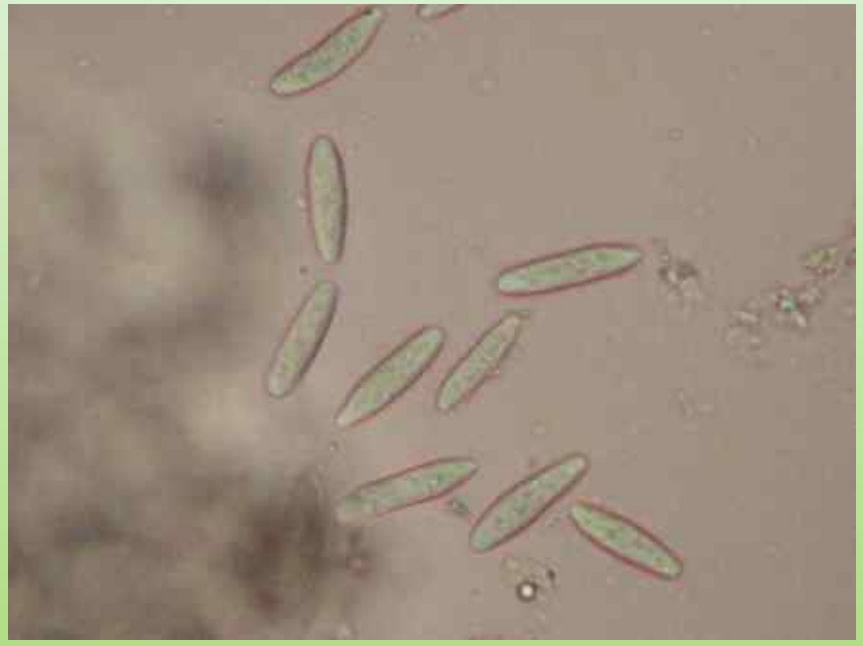
Pitch Canker
Gibberella (*Fusarium*) *circinatum*

- Located along the coastal strip of California
- Monterey Pine mostly
- Now spreading in VC

Ficus Canker
Neoscytalidium dimidatum

Cankers are deep, easily invading the wood.

Ficus Canker



Anamorph

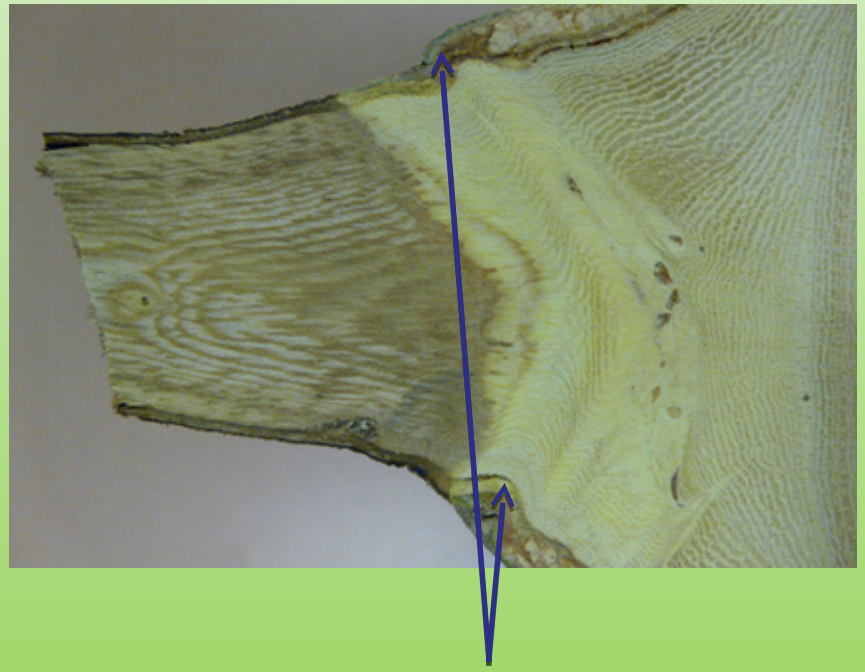
Teleomorph

Fruiting bodies are very difficult to see because they are covered in dirt

- There are both pycnidia and perithecia of this fungus present on cankered branches
- DNA sequencing is underway at UCR as well as pathogenicity testing.

Symptoms in stems

- Cankers are held back at the branch collar
- Eventually the pathogen can penetrate this defense zone.



The branch collar.

Vascular Wilt diseases

- Symptoms of browning of vascular tissue (xylem).
- May or may not be present
- One branch death is common

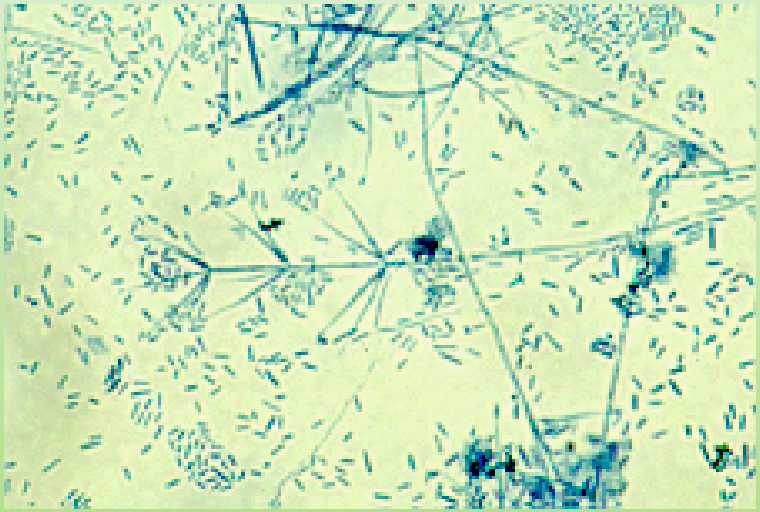
Symptoms in stems

Fusarium Wilt

Verticillium Wilt

Verticillium

http://www.umassvegetable.org/soil_crop_pest_mgt/disease_mgt/tomato_verticillum_wilt.html



http://www.mycology.adelaide.edu.au/Fungal_Descriptions/Hyphomycetes_(hyaline)/Verticilliu m/

Verticillium wilt in Olive

Palm Wilt

- *Fusarium oxysporum* f.sp. *canariensis*
- Soil borne but also spread by pruning tools

Fusarium Wilt of palms

- One-sided wilt of the leaves and discoloration of the rachis are common symptoms of the disease.
- There are no fungicidal controls

Sanitizing hand saws

Flaming

Really Flaming

Fungi isolated from a flamed saw

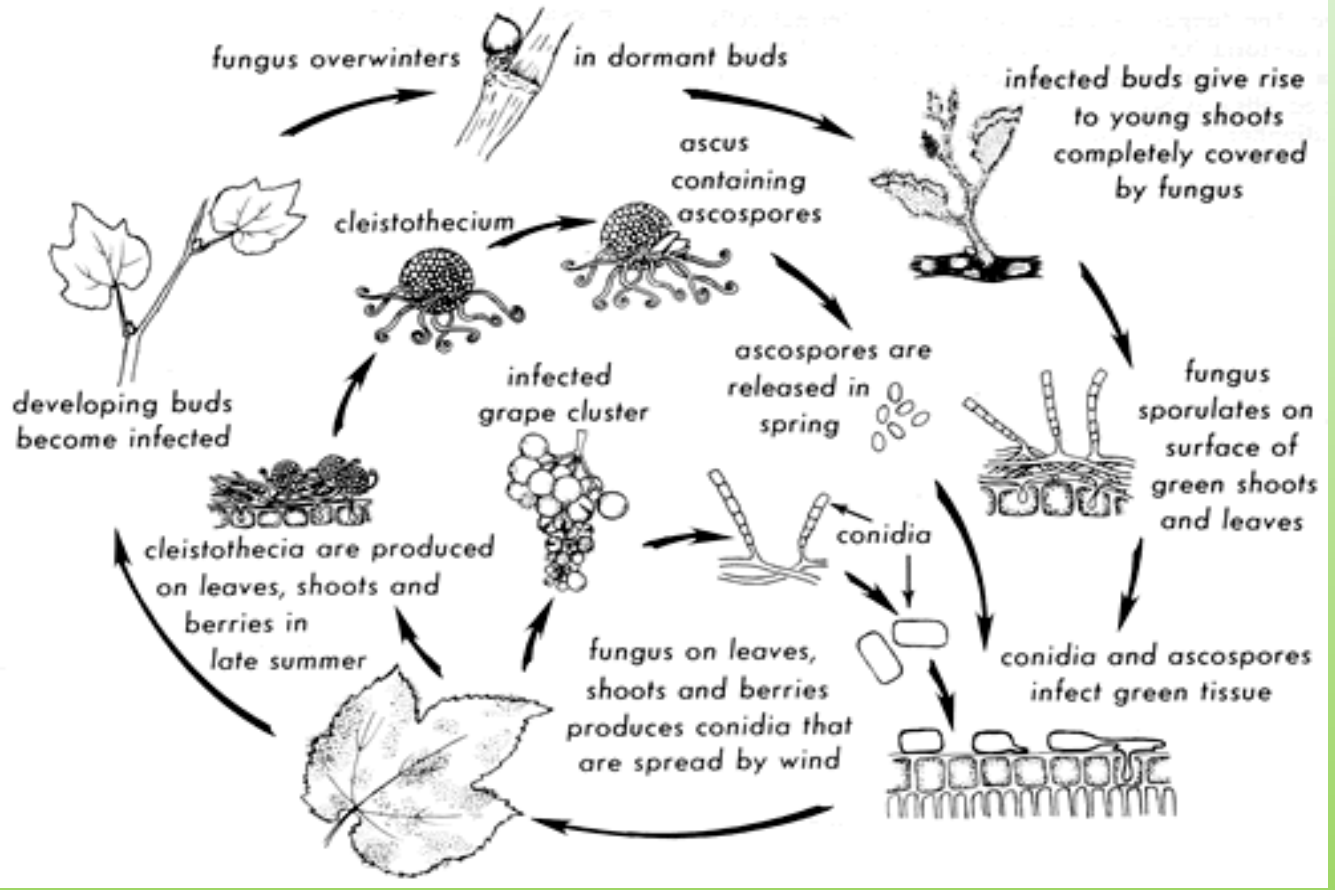
Isolations of fungi (CFU)		
Flame time	Total CFU	Total Pathogens
0 (no flame)	42a	17a
10s	2b	1b
20s	0.4b	0.1b
40s	0.3b	0b
P value	<0.0001	<0.0001

From: Downer, Hodel and Mochizuki, 2007, HortTechnology 19:695-699.

Powdery Mildews

- Ascomycete fungi
- A compound interest disease
- Obligate Biotrophs
- Overwinter in leaf litter
- Asexual conidial stage is Oidium

A polycyclic plant disease

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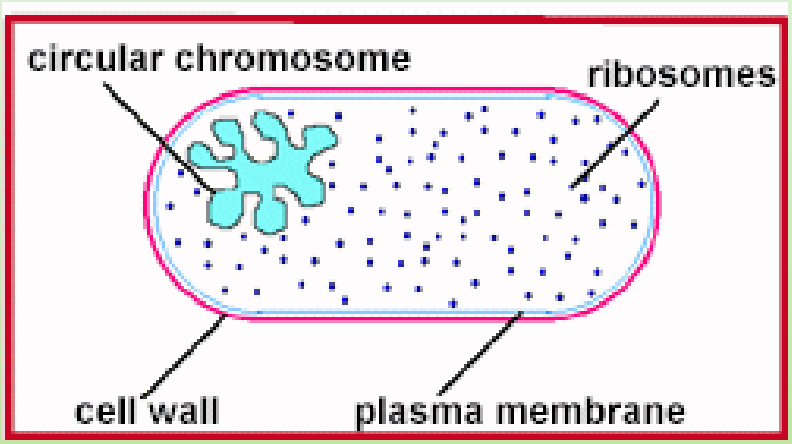
Bacterial Diseases

- Crown Gall
- Fireblight
- Bacterial Canker
- Xylem (Scorch) Diseases
- Slime Flux

Bacteria



Bacterial cells are small (5 or 10 micrometers) rods or spheres (cocci), just visible under the light microscope. In their active state they have a thin peptidoglycan cell wall and a lipid membrane enclosing all of their genetic material, enzymes and metabolic intermediates.

Crown Gall
Agrobacterium tumefasciens

Crown Gall
Agrobacterium tumefasciens

- Soil-borne bacteria
- Infects through wounds
- Graft unions
- Can occur on above ground parts

http://www.ces.ncsu.edu/depts/pp/notes/Ornamental/odin003/peachcg.htm

BACTERIAL CANKER
Pathogen: *Pseudomonas syringae*

- Major canker disease of all stone fruits

Pseudomonas syringae
Bacterial canker

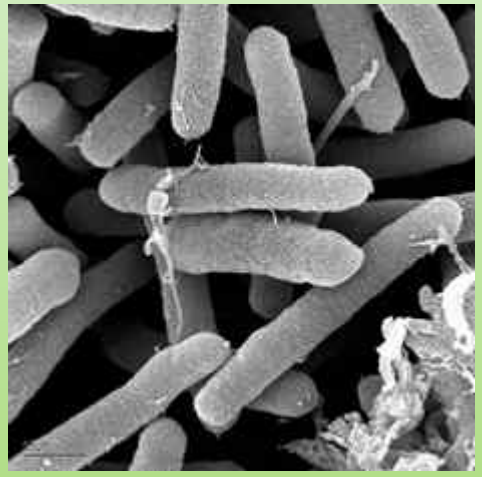


Photo: Gordon Vrdoljak

http://www.agf.gov.bc.ca/cropprot/tfipm/bacterialcanker.htm

Bacterial Canker Symptoms

- Bleeding

Bacterial Canker

- Death of fruit spurs

Olive Knot Disease
Pseudomonas savastanoi

Fireblight

- *Erwinia amylovora*
- Warm and Wet
- Infects flowers

Flowers and Fruit are infected by honeybees

Fireblight

- Erwinia amylovora
- Spread by bees
- Infection Court:
  - Floral nectaries
- Prune it OUT!

http://www.extension.iastate.edu/NR/rdonlyres/97F06C66-385D-40CD-90AF-3666EC98B741/13896/FireBlight.jpg

Fireblight

- Cankers can move into the woody part of the plant leading to extensive dieback after girdling

Bacterial Leaf Scorch Diseases

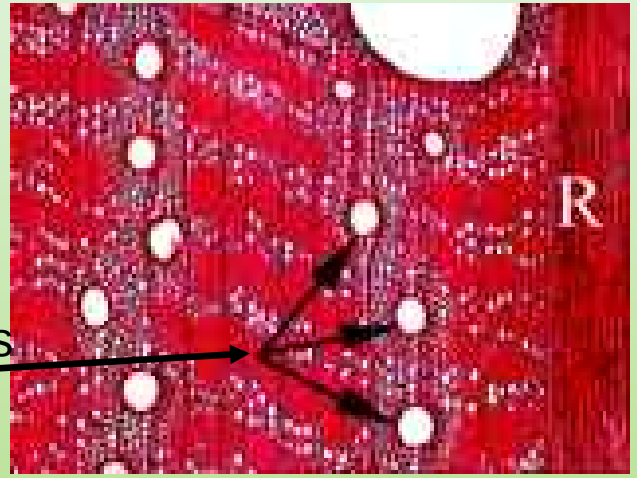
- Caused by strains of *Xylella fastidiosa*

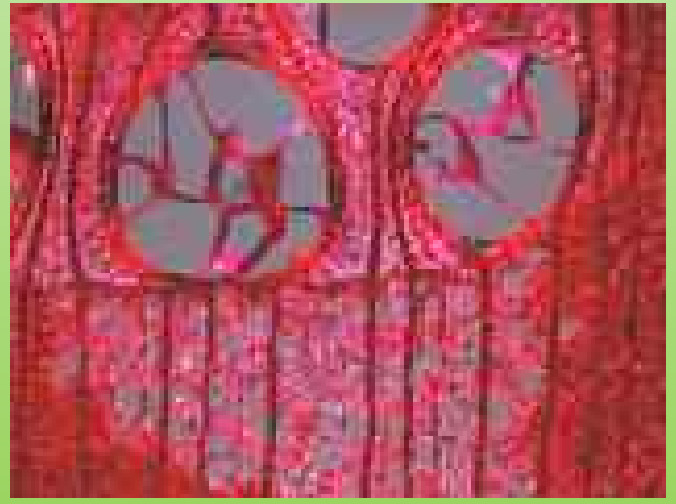
Almond Leaf Scorch

White Oak

Xylem:Wood = the tree water delivery system

- Bacteria plug the xylem of woody plants
- Wilt, scorch and death of the tree result



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Leaf Scorch

- Vectored by the glassy winged sharpshooter.

Leaf Scorch Symptoms

- Yellowing
- Necrosis
- Total death

Scorch Diseases

(continued)

- *Xyllella fastidiosa* is fast becoming a very important pathogen in Southern California landscapes.
- This is largely due to host range expansion enabled by the Glassy Winged Sharpshooter

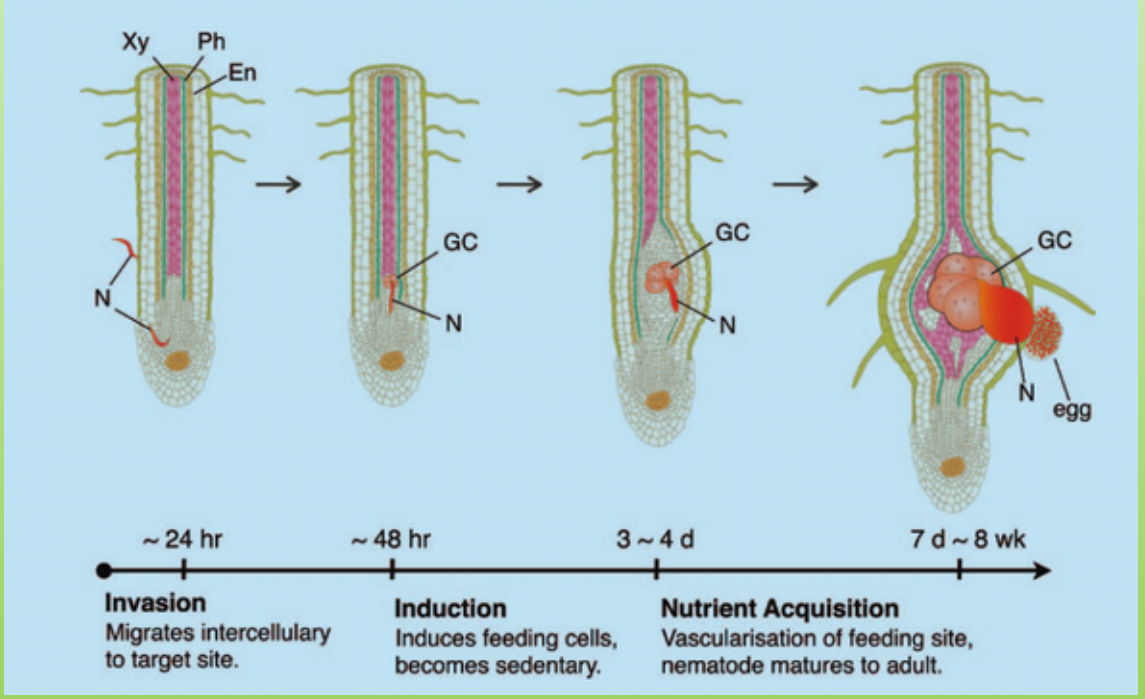
Historic Olive Tree at Rancho Camulos in Ventura County

Wetwood in Elm
Although it seems bad it rarely is!

1986 2001 2011

Nematodes

- Reduce yield
- Stunting, loss of vigor
- Wilting
- Necrosis
- Death
- Endoparasitic
- Ectoparasitic



Nematode Diseases

- Root Knot Nematode

Photo: Michael McClure: sugar beet cyst nematode

An Ectoparasitic nematode

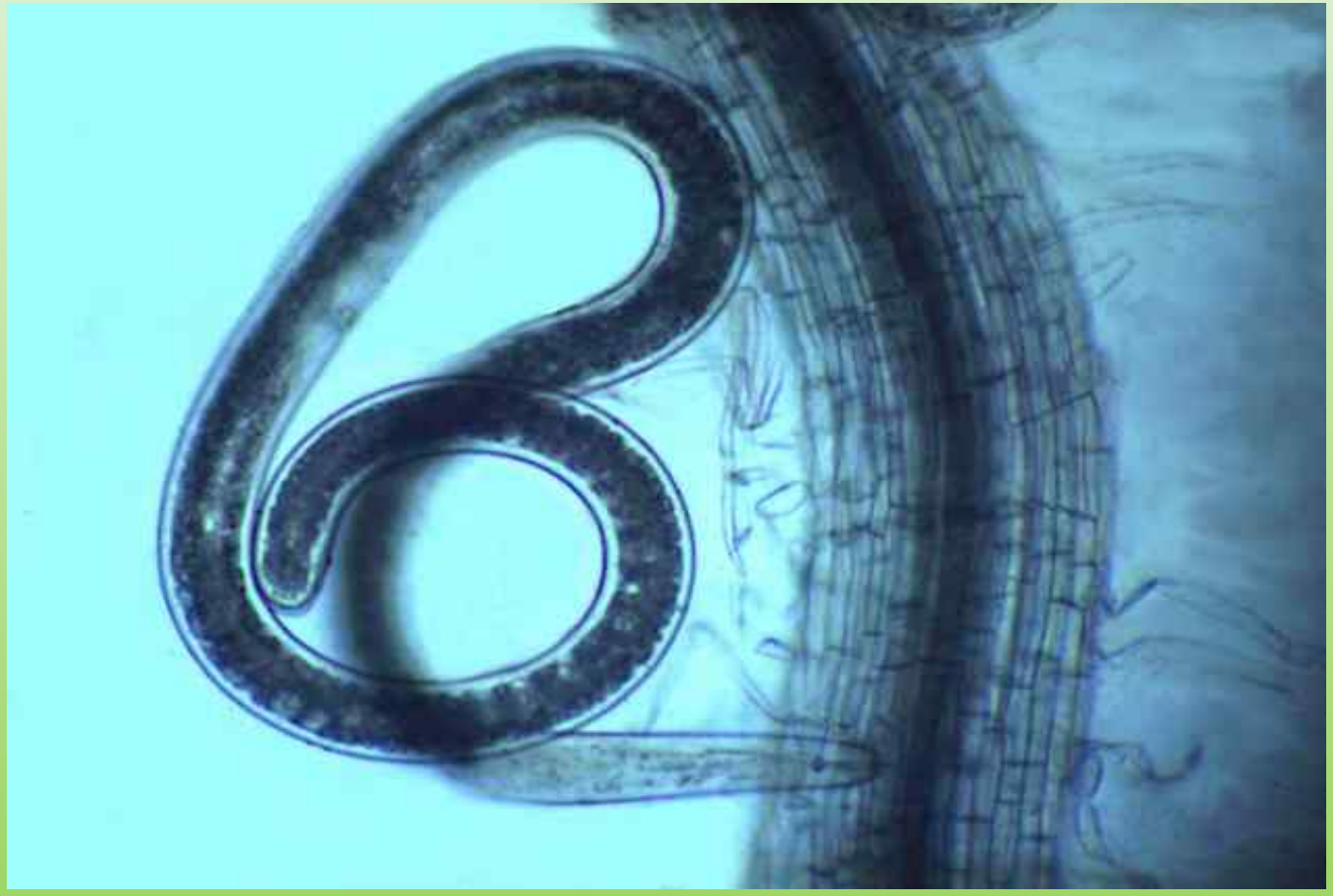


Photo: Ulrich Zunke: *Rotylenchus robusta*

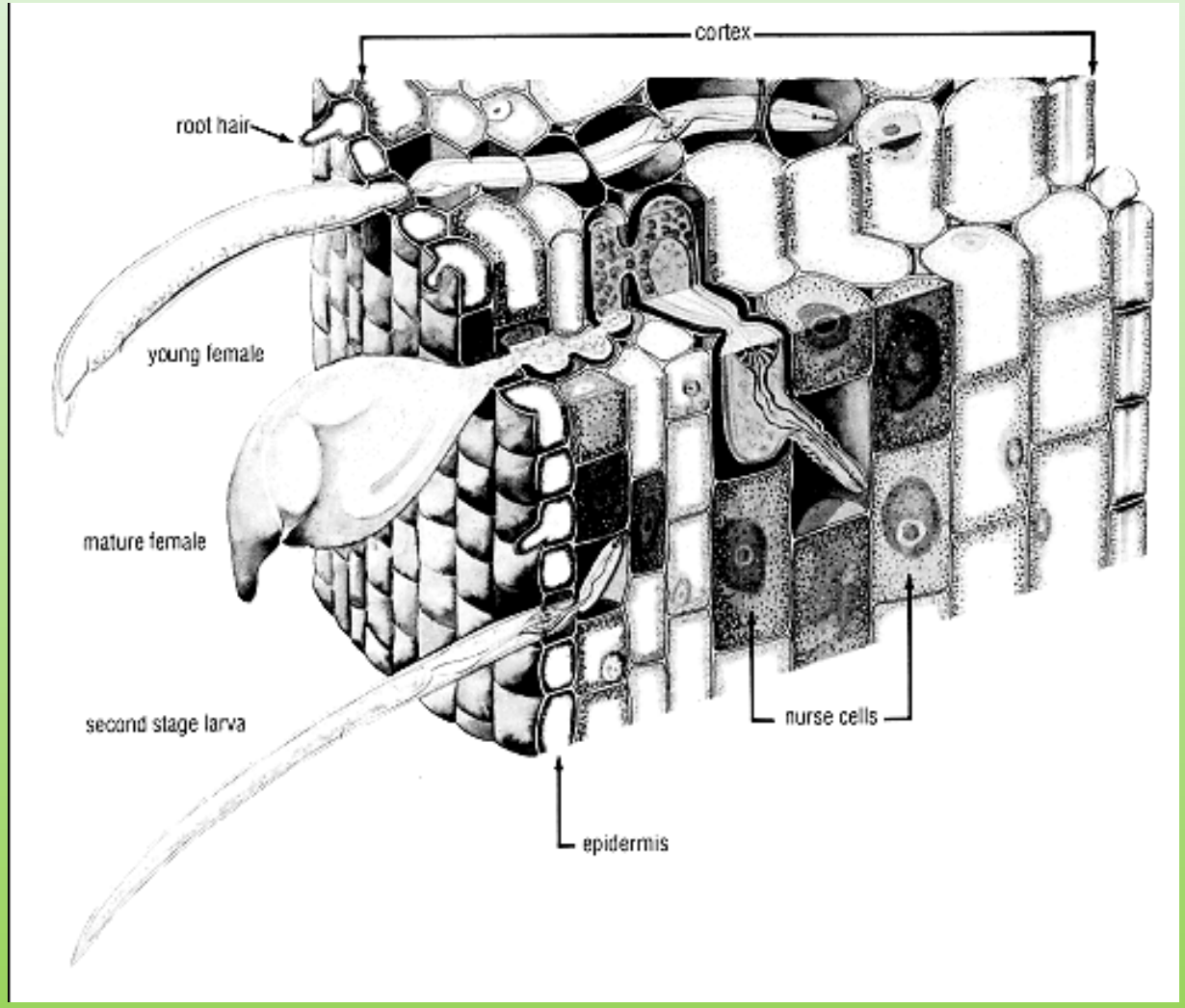
Giant cells and RKN a sedentary endoparasitic nematode

Photo: Victor Dropkin

Root Knot Nematode
Meloidogyne incognita

Lesion Nematode Stunting

Citrus nematode: *Tylenchulus semipenetrans*



Nematodes

- Root Knot Nematode and swollen root

Parasitic Seed Plants

- Leafy Mistletoe
  - *Phoradendron tomentosum*
- Dwarf Mistletoe
  - *Arceuthobium*
- Dodder
- Broomrapes and other orobanchaceae

http://www.sbs.utexas.edu/mbierner/bio406d/images/pics/vis/phoradendron_tomentosum.htm

Dwarf Mistletoe

http://www.parasiticplants.siu.edu/Viscaceae/

Parasitic plant pathogens are a part of California's Flora

Dodder
Cuscuta spp.

Virus

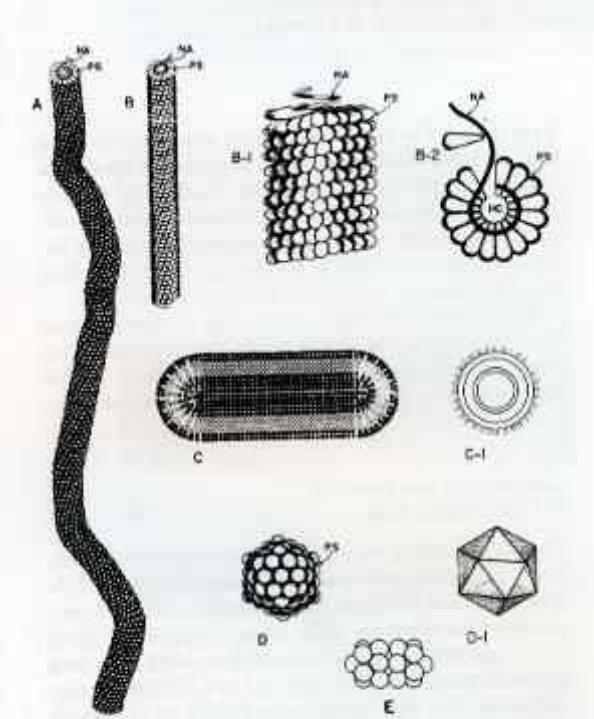


FIGURE 14-5 Relative shapes, sizes, and structures of some representative plant viruses. (A) Flexous threadlike virus. (B) Rigid rod-shaped virus. (B-1) Side arrangement of protein subunits (PS) and nucleic acid (NA) in viruses A and B. (B-2) Cross-section view of the same viruses. HC, Hollow core. (C) Short, bacilluslike virus. (C-1) Cross-section view of such a virus. (D) Polyhedral virus. (D-1) Icosahedron, representing the 20-sided symmetry of the protein subunits of the polyhedral virus. (E) Geminivirus, consisting of twin particles.

Viral Diseases

- Symptoms
  - Vein Clearing
  - Mosaics
  - Ringspots
  - Necrosis
  - Stunting
  - No symptoms

Virus Diseases/Symptoms

- Tomato spotted wilt virus
- Vectored by aphids

Citrus Tristeza Virus

Big Vein of Lettuce

Soil-borne fungus *Olpidium* is the vector

Vein clearing in rose

Watermellon Mosaic Virus

Weeds are common viral hosts

- Malva as a weed host of Lettuce infectious yellows virus

Rose mosaic virus

- Graft transmissible
- Can spread by root to root contact.

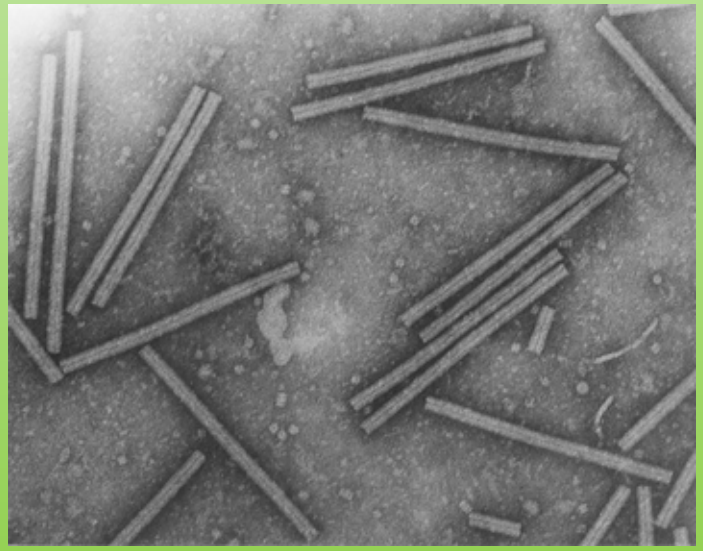
Image form APS.net

Hydrangea Ringspot Virus

Impatiens Necrotic Spot Virus

Tobaco Mosaic Virus
tobamovirus

- Wide host range
- Transmitted mechanically
- Very infectious
- Survives very high heat




© NSW Department of Primary Industries
Margaret Senior

Viroid
Sun Blotch

Sequence Sun blotch of single stranded circular RNA

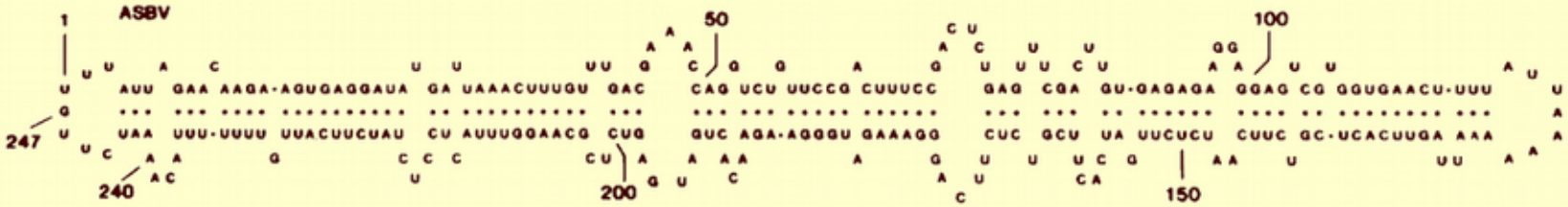
```
UUUAUUAGAACAAGAAGUGAGGAUAUGAUUAAACUUUGUUUGACGAAACCAGGUCUGUUC
1          10          20          30          40          50          60

CGACUUUCCGACUCUGAGUUUCGACUUGUGAGAGAAGGAGGAGUCGUGGUGAACUUUUAU
           70          80          90          100         110         120

UAAAAAAAUUAGUUCACUCGUCUUCAAUCUCUUGAUCACUUCGUCUCUUCAGGGAAAGAU
           130         140         150         160         170         180

GGGAAGAACACUGAUGAGUCUCGCAAGGUUUACUCCUCUAUCUUCAUUGUUUUUUUACAA
           190         200         210         220         230         240

AAUCUUG
      247
```



Abiotic Diseases

No Pathogen, No epidemics, No signs (usually)

Sunburn on the foliage of Citrus

Symptoms on Leaves

Classic symptoms of sunburn. Bleaching and necrosis confined to the center of leaves exposed to too much sunlight or sunlight/drought combinations.

Abiotic Diseases

- Environmental often man-induced diseases.
- Light, Air, Water, Soil, and Temperature all play critical roles in creating these disorders
- Plant adaptations or lack thereof predispose to abiotic disorders

Chlorotic Camphor (*Cinnamomum camphora*)

Escalonia x exoniensis ‘Pink Princess’

Not Sheared

Regular shearing

Symptoms on/in stems

- Wilt symptoms include vascular staining
- Canker diseases exhibit the canker itself as well as foliage effects when it girdles the stem
- Sometimes the bark masks the symptoms and signs but not the loss in growth…so look for flat sides!

Chitalpa Blow out disorder

Tree Declines

- Result from not one, but many causes
- May involve abiotic and biotic diseases
- Often involves the injurious practices of people
- Reduced growth
- Chronic Symptoms
- Death

The Mortality Spiral

Trees in decline undergo a spiraling loss of vigor.

There are 3 factors:

inciting,

sustaining

contributing

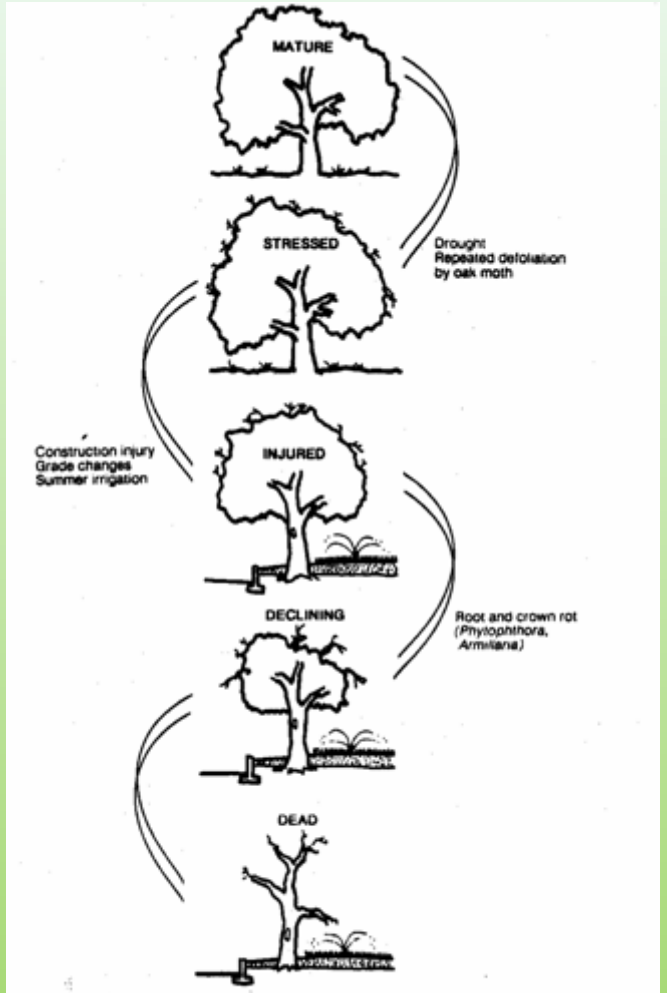


Figure 1. Proposed mortality spiral for California live oak (*Quercus agrifolia*).

With permission from Clark and Matheny, 1991

Maintaining Tree Health

- For disease to occur: some trees need to be predisposed

Ficus

- Thinning of foliage is really lack of regrowth. Canopy vigor is severely compromised.

Vigor Assessments

- Shoot Length
- Leaf Size
- Canopy Density
  - Ratings
  - Light transmittance
  - Photographic records
- Increment borings
- Epicormic branching
- Loss of “Robustness”
- Extent of Decay

Stored Starch in *Acacia melanoxylon*

From a healthy branch

From a declining branch

Predisposing Factor

- Soil moisture status is the most common predisposing factor to tree declines and disease that I encounter.
- Drought or Overwatering can contribute
- Some fungi (Sooty Canker) are encouraged by drought

Be aware of predisposing issues

- Many of these have to do with water and overwatering.
- Improper placement of organic mulches can predispose to disease
- Pruning
- Plant Selection/Adaptation

An “Inciting Factor”

Backfill
(sustaining or inciting factor)

- Backfill surrounding a tree can have disastrous or no effects at all!

Contributing (killing) Factors
Insect damage and fungal pathogens

Control possibilities with various diseases

Disease type	preventable	Therapy	Eradicate	Cultural controls	fungicides
Virus	Yes	No	No	Yes	no
Root rots	Yes/no	Yes	No	Yes	Yes/no
Wood rots	Yes	No	No	Yes	no
Wilts	Yes	?	No	No	no
Rusts	Yes	No	No	No	yes
Leaf fungi	Yes	no	No	+/-	Yes
Abiotics	+/-	Yes	Yes/no	Yes	no

Pruning

- Removing leaves removes energy producing cells