Two finals

- about two hours each

-each is different

- all questions are multiple choice and one essay question

(essay will only improve grade!)

No need for sample questions, you get two chances

- you can take both exams or only one, **only best one will count**

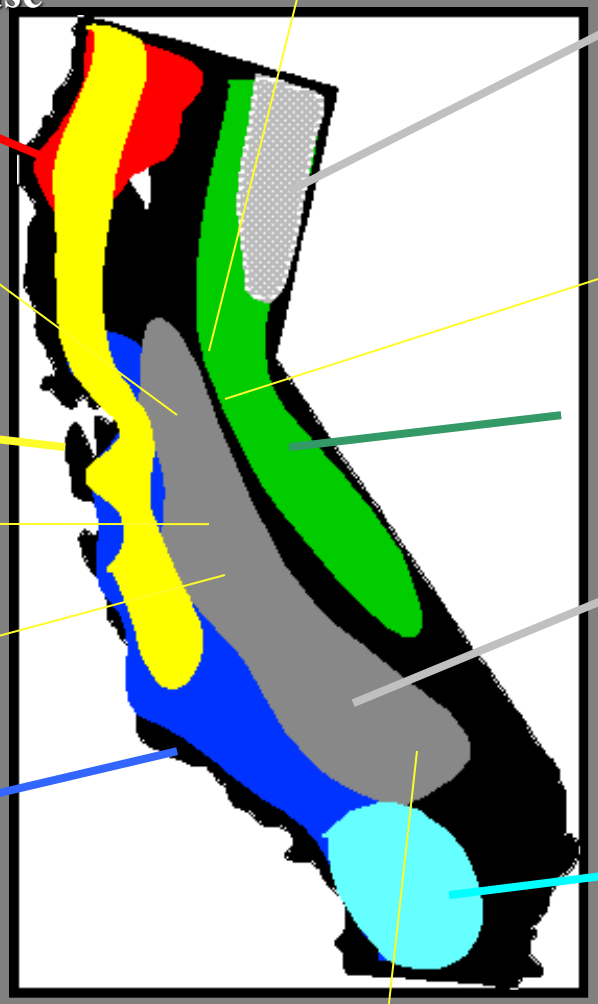
December 10th : **need to start between 7 and 8 pm!**

December 17th: **need to start between 7 and 8 pm!**

-I will be online **Wednesday December 8th 9 to 10 am (will send link)** for questions

-You can write a paper to improve grade: topics and details are posted on website.
Must send by email to matteog@berkeley.edu by 11:59 pm of December 20th

California invaded: 1849 A.D.



Xylella scorch of maples 2000s

Port Orford Cedar Root Disease 1950s

Expansion of root pathogens Post 1880s

Root canker of Pacific Madrone and Bay laurel (70s)

Manzanita die-back 2004

Sudden Oak Death 1990s

White pine blister rust 1930s

Cypress canker 20s

Dutch Elm Disease 1960s

Colored canker of sycamore 70s

Pitch canker disease 1980s

Oak root canker 2000

1000 canker disease of walnuts 2001

- Port Orford Cedar root disease; exotic agent= *Phytophthora lateralis* (East Asia); first found in a nursery in Oregon
- Sudden Oak Death; exotic agent *Phytophthora ramorum* (origin unknown) introduced late ‘80s multiple times by infected ornamental plants
- Colored canker of sycamore, exotic agent *Ceratocystsis platani* from East coast, introduced through wood packaging or untreated wood
- Pine pitch canker, exotic agent *Fusarium circinatum* introduced in the 80s on pine seed and pine seedlings, origin: Mexico
- Oak root canker caused by exotic *Phytophthora cinnamomi* introduced from Papua New Guinea via orchard stock prbably after World War II. Same pathogen causes manzanita die-offs (Sierra Nevada Foothills) and decline of Bay Laurel and Pacific Madrone (greater bay area)
- Cypress canker outbreaks caused by native *Seiridium cardinale* on trees planted off site or on artificial crosses
- Dutch Elm Disease first caused by exotic *Ophiostoma ulmi* then replaced by more aggressive *O. novo-ulmi* in the 60s’s. From Asia via Europe via infected wood and vectoring insects (one European and one North American)
- 1000 canker disease caused by fungus *Geosmithia morbida* (exotic to Ca) vectored by native walnut twig beetle (post 2003)
- White pine blister rust caused by Cronartium ribicola introduced from Asia via France on infected western white pine in 1914 in Vancouver island
- Native *Heterobasidion* on pines, junipers, sequoias and true firs increased by change in tree species composition, logging and fire exclusion
- *Xylella*= Pierce’s disease via Mexico/Southern California

White pine blister rust:

An emergent disease caused by an introduced pathogen

The tree host: white pines

- Genus *Pinus*
- Hapoxylon subgroup
- Five-needled
- Eastern and western **white pines,**

Eastern White pine (1 species)

- Most valuable timber resource of Eastern North America
- Used especially in the shipbuilding industry to build masts
- Eastern white pine stands owned by the English crown and one of the main economic reasons for independence
- Planted in Europe where they failed and produced poor quality timber

White pines reserved for the British navy

Cone and leaves of
Pinus strobus

A ship mast made with white pine

In Western North America

- **Nine species of white pines**
- Eight are infected (*P. longaeva* is the only one without a report)
- Incidence of disease is not same across all species. E. g.: western white pine less resistant than Sugar pine. SP require wave years for infection to occur, that is years where Fall conditions have mild temperatures and rainfall

Blister rust cankers:

sugar pine

whitebark pine

Why is it called a blister rust?

Top kill in whitebark pine

Cronartium ribicola: the causal agent

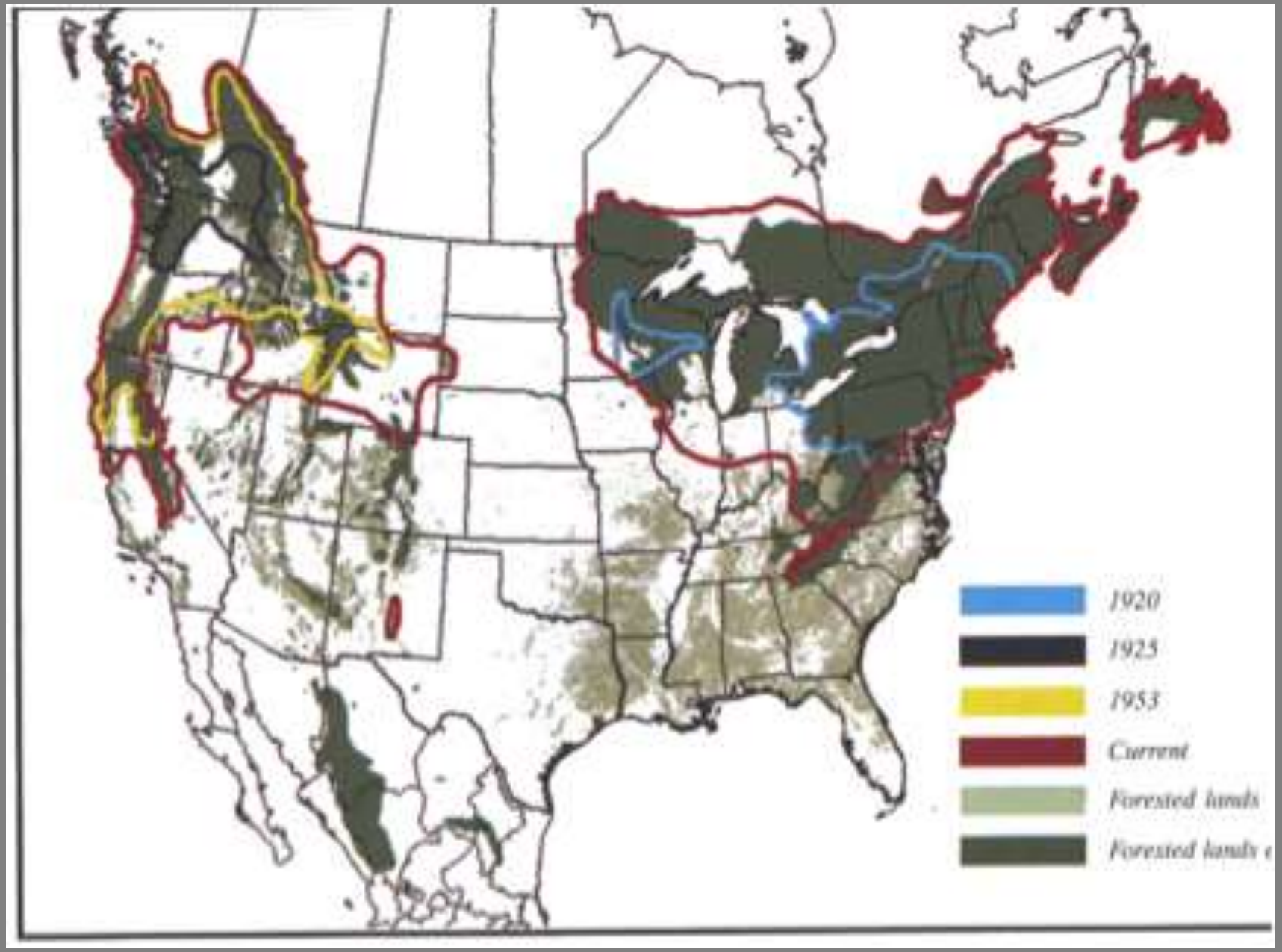
- Complex system involving 5 spore stages and two hosts
  - *Pinus* and *Ribes*
- Introduced into North America around 1900 on infected eastern white pine stock; separate introductions on east and west coasts
- Native to Asia

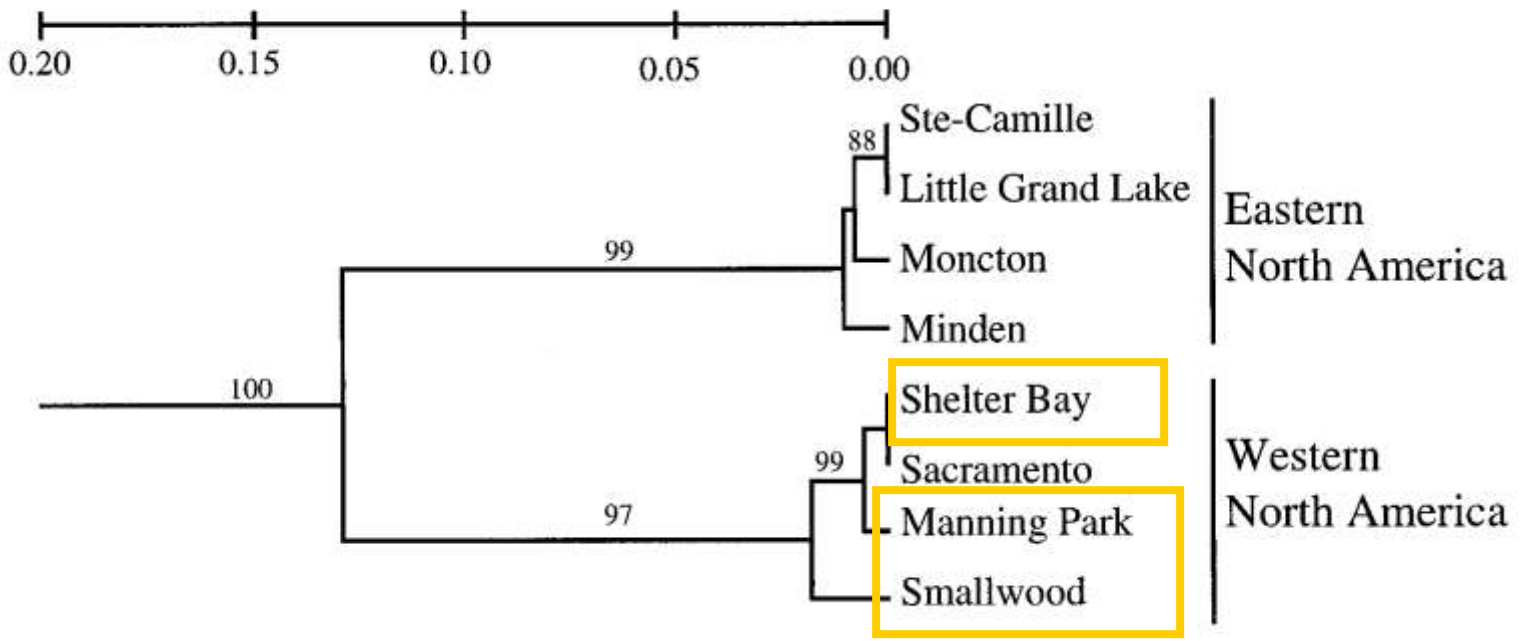
Some details about introduction

- Pre 1900 or 1906 on East Coast, but there are records of many shipments from Germany and Holland, in multiple locations including the Midwest

- 1910, Vancouver BC, One shipment documented from France but most reconstructions suggest more than a single introduction occurred

- Ribes (gooseberry, currant) also imported from Europe, but most ribes loose their foliage in fall, Introduction most likely to have happened through pines


1920
1925
1953
Current
Forested lands
Forested lands

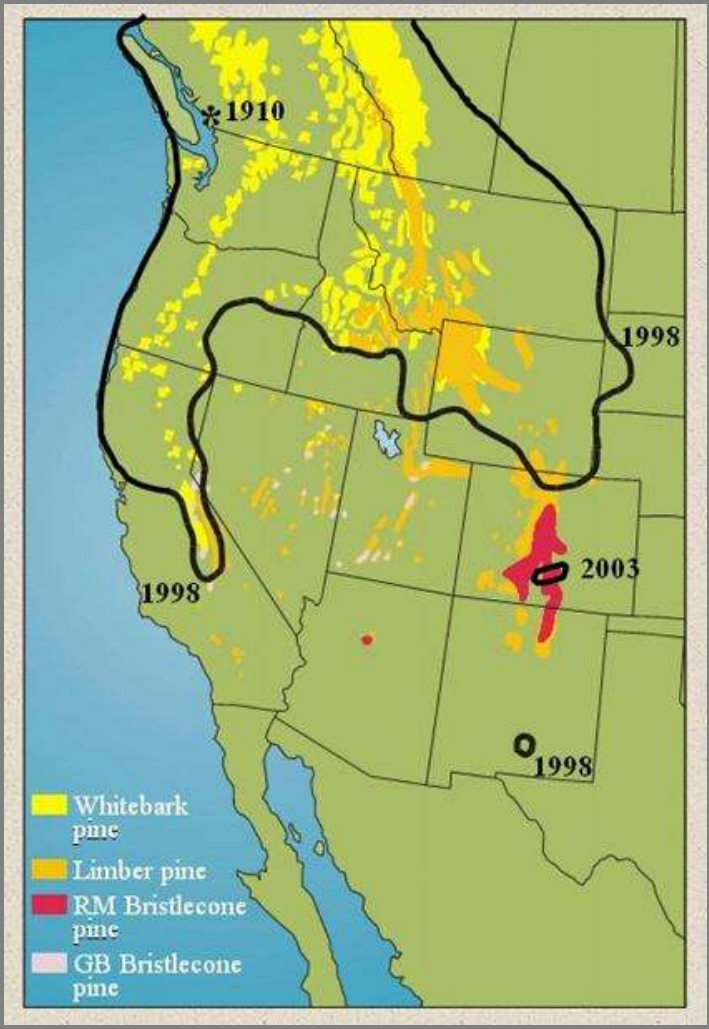


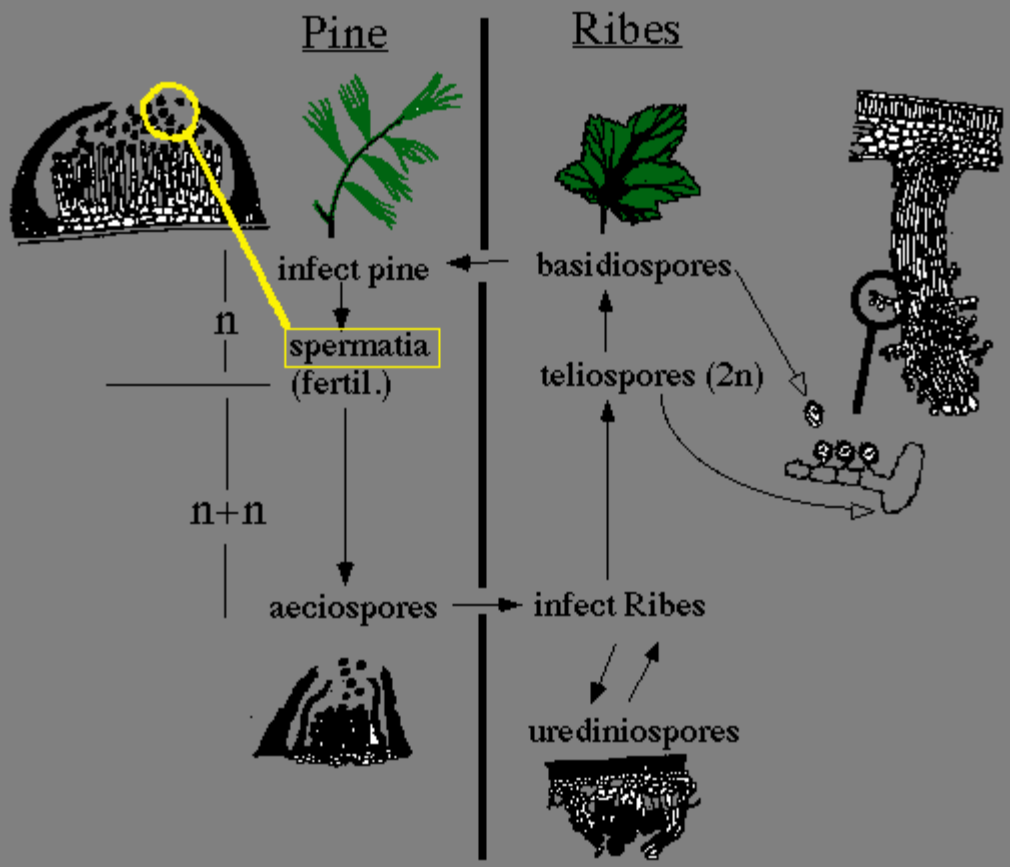
Shelter Bay = interior BC
Manning Park = interior BC
Smallwood = coastal BC

Conclusions

- Eastern and western populations are not panmictic (not sharing genes) and the two are different now because of different founders and separation

- Barrier to gene flow between eastern and western populations
  - Great Plains – intense agriculture
  - 100 km absence of aecial and telial hosts


1910
1998
1998
2003
1998
Whitebark pine
Limber pine
RM Bristlecone pine
GB Bristlecone pine


Pine
Ribes
infect pine
basidiospores
n
spermatia
(fertil.)
teliospores (2n)
n+n
aeciospores
infect Ribes
urediniospores

C. ribicola life cycle

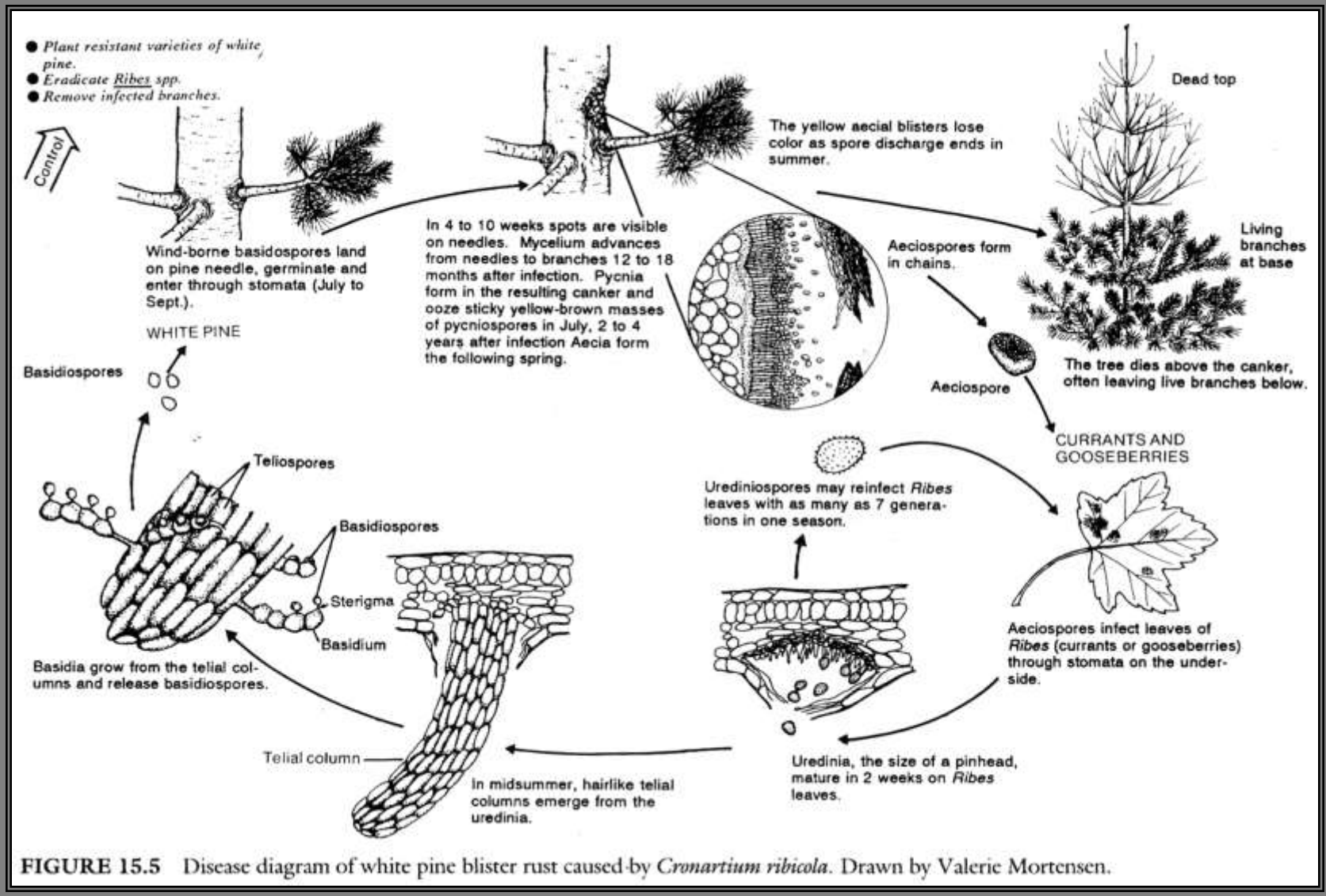
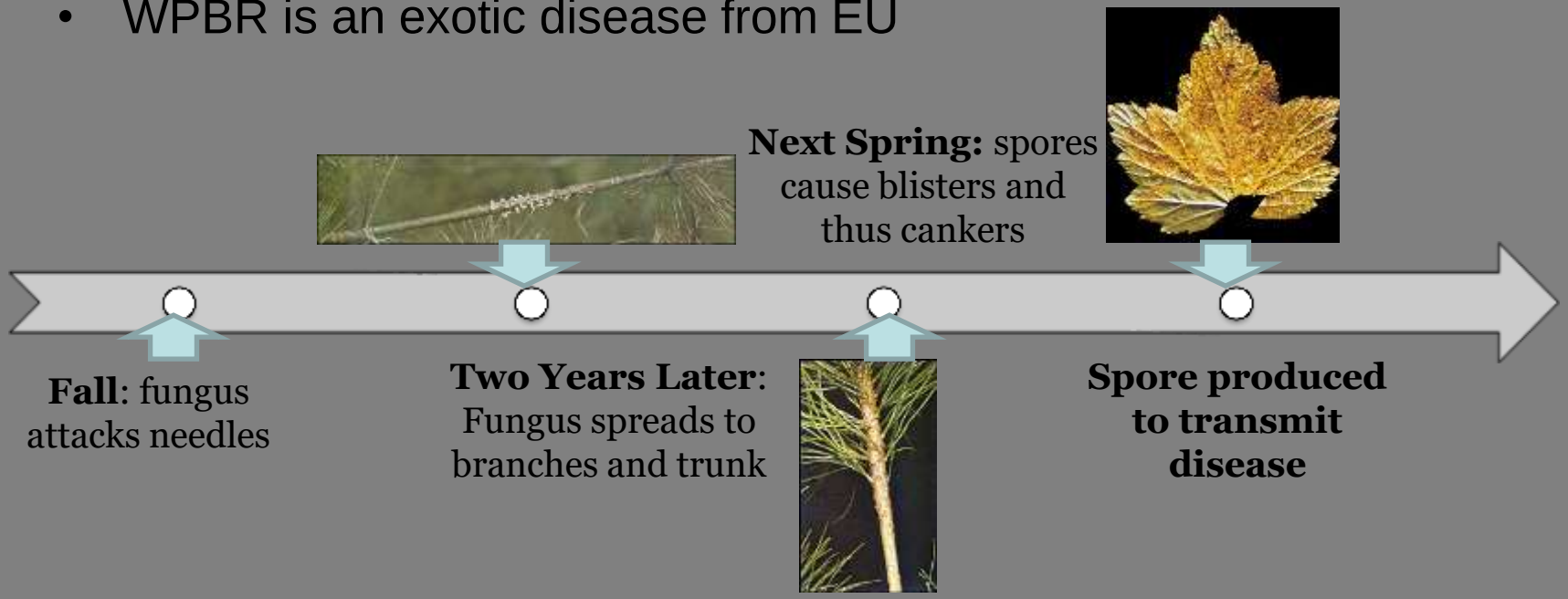


FIGURE 15.5 Disease diagram of white pine blister rust caused by *Cronartium ribicola*. Drawn by Valerie Mortensen.

Cronartium ribicola—Causal Agent of White Pine Blister Rust

- WPBR is an exotic disease from EU



- Leaves above the canker die, causing branch/stem to break
- Opens site for decay fungus

A Few Pathogen Details

- Infection occurs through stomata of needles of all age, if needle is on stem then infection directly leads to tree girdling. If needle on branch, it will cause branch death and then if it moves into stem it will cause stem girdling, if stem does not die before pathogen gets to stem…
- …Because pathogen is obligate biotroph
- Overall Low genetic diversity in N.A. Sign of introduced disease
  - Diversity between subpopulations is greater in West because of rugged topography
  - Indicative of frequent founder events and little gene flow
- Genetic center: Asia
- To infect white pines: 48 hours <68 F, 100% relative humidity

Widespread mortality in western white pine

Why mortality appears in clusters if pine to pine infection does not occur ?

1- Threshold of inoculum necessary for infections is low in western white pine, so a single source can infect trees at various distance because dilution effects with distance is not relevant

2- Resistance very infrequent (1 in a thousand)

3- Compounding effect of Mountain Pine Beetle

4- Sugar pine more resistant

Ribes Eradication

- In East:
  - effective
  - well supported
  - easy
- In Lake States:
  - variable results
- In West:
  - difficult

Detwiler, S.B. 1923. American Forestry. p. 337.

Civilian Conservation Camps during the Depression,

Attempts to control WPBR

- Ribes eradication
  - More successful in East than West
- Use of Risk Zones for planting and management
  - potential pitfalls: must also account for airflow patterns
- Pruning
  - Can be successful if infection caught 12 inches from main stem; costly; may need repeated entries; probably would not work in whitebark
- Genetics: probably most successful method
  - Sugar and western white pines
  - Whitebark pine work in progress

Pruning research in sugar pine

before...

Pruning research in sugar pine

...afte

Tree resistance

- Major gene for resistance
- Found in sugar, western white, and southwestern white so far
  - Thought to be gene-for-gene (because virulent race of pathogen neutralizes this gene)
  - Gene-for-gene typically indicates a pathosystem in which the host and pathogen have evolved over long time periods- so what is going on in this system?

Lesion types: sugar pine

RESISTANT HOST

Additional types of tree resistance

- Sugar pine
  - Slow rusting resistance - many components of resistance combined into a single phenotypic expression, exhibited as amount and type of infection with moderately strong inheritance and independently inherited expressions (low infection # and high infection abortion) MULTIGENIC

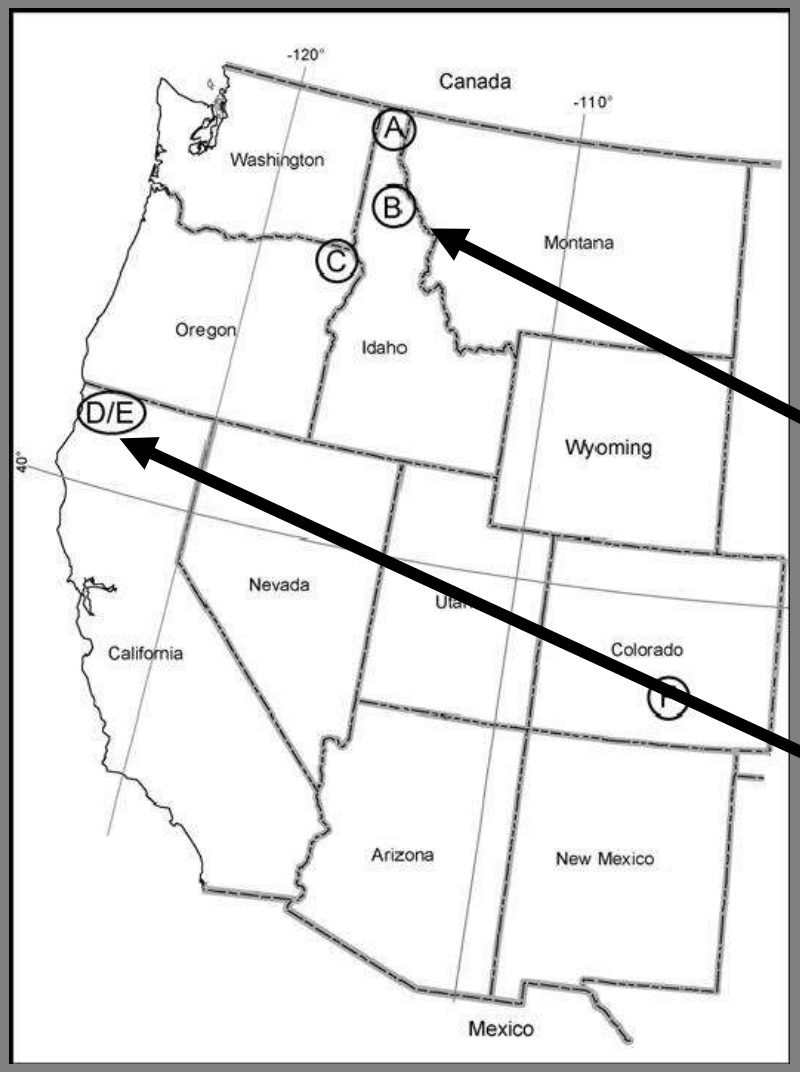
Evaluation of longevity of control practices

- Race of pathogen able to overcome major gene resistance in Sugar pine already present. Slow resistance or combination of two may be more durable approach

Influence of Host Resistance on the Genetic Structure of White Pine Blister Rust Fungus in the Western United States

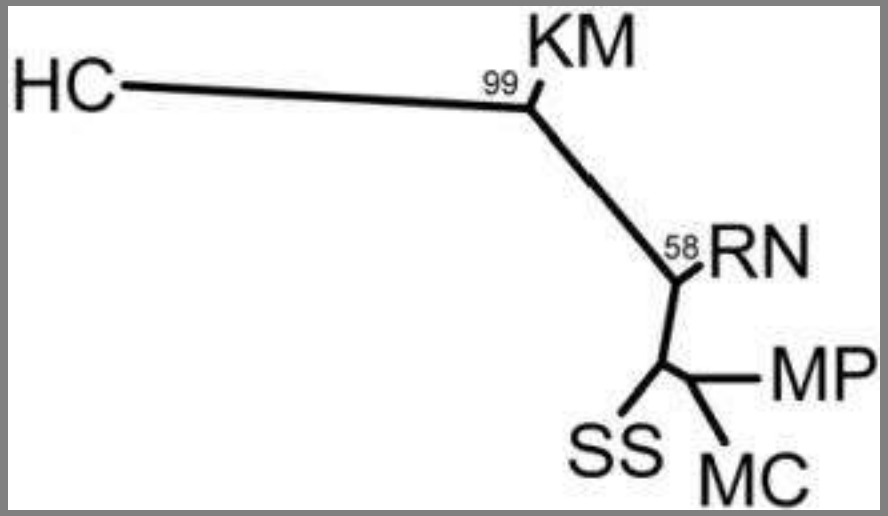
Richardson, Klopfenstein, Zambino, McDonald, Geils, Carris

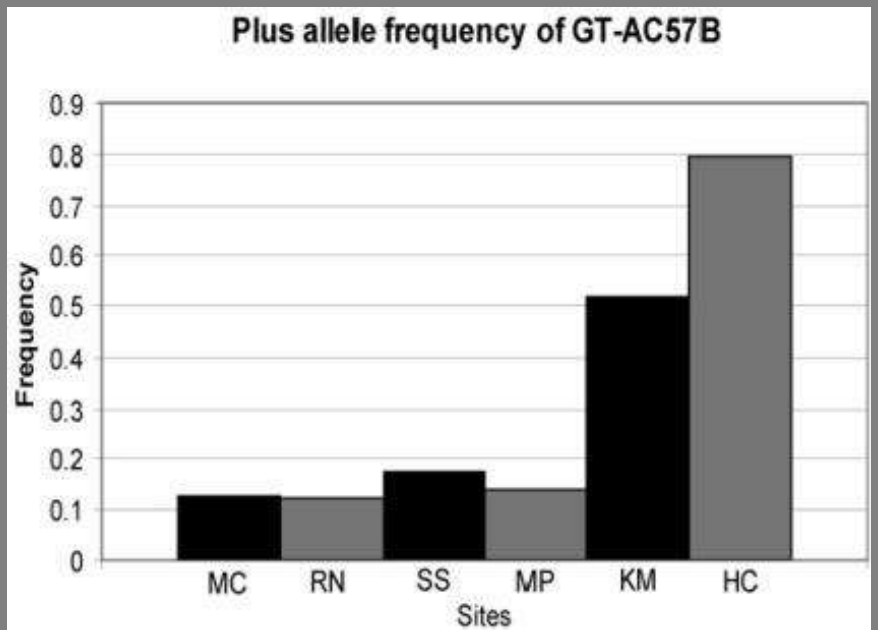
Material + Methods



- Sampling of isolates from 6 sites
- B= MC merry creek: multigenic resistant,
- D= HC happy camp: major gene resistant

Results





- Low number of polymorphic loci among 148 C. ribicola isolates
- Fst= 0.082 among sites, significant
- Heterozygosity
  - Highest at MC
  - Lowest at HC

Discussion

Effects of host resistance on C. ribicola

Merry Creek (multigenic resistant trees): had highest heterozygosity

Happy Camp (major gene resistant trees): had lower heterozygosity

- Selection for rust isolates carrying vc1 because all trees have cr1.

Mortality and decline of white pine not only due to WPBR

- Fire suppression: most wp species like open spaces created by fire and are fire-adapted. With lack of fire, site are encroached by shade tolerant species and white pine regeneration is limited

- Insect (mountain pine beetle) outbreaks. When populations of this insect become large they attack healthy trees as well. Effect of WPBT and mountain pine beetle is more than the sum of the two

- Dothistroma needle blight can cause outbreaks, however both Dothistroma and insect outbreaks may be cyclical and natural

- Global warming

Consequences of wp mortality

- Group of species that is extremely adaptable, and that in western North America, depending on latitude, goes from sea level to tree-line
- High market value: white pines timber is king. In past times it was the best timber to build ships' masts. One of the reasons for the secession of American territories
- It includes the oldest living organism on earth (Bristlecone pine)
- In the Rockies it is essential for survival of Clark's nutcracker and Grizzly bears. In the West, white pines are diversity hotspots

"In North America, white pine blister rust has caused more damage and costs more to control than any other conifer disease. Since the 1920's, millions of dollars have been spent on the eradication of the alternate host, *Ribes*, and thousands of white pine stands have been severely damaged. In the western United States and Canada, some stands have been completely destroyed. When the main stem of a tree is invaded, death is only a question of time."

Robert F. Sharpf, U.S. Department of Agriculture Handbook 521 (p.85)

Dutch Elm Disease

- Wilt disease caused by ascomycete fungus in the genus *Ophiostoma*

Overview: Dutch Elm Disease

- Why “Dutch”? First isolated in 1920 by a Dr. Schwarz in the Netherlands
- Wilt disease that attacks elm (*Ulmus* ssp) and spreads through the vascular system
-
- Caused by ascomycete fungi (genus *Ophiostoma)*
- Vectored by beetles (family *Scolytidae*) and root graft

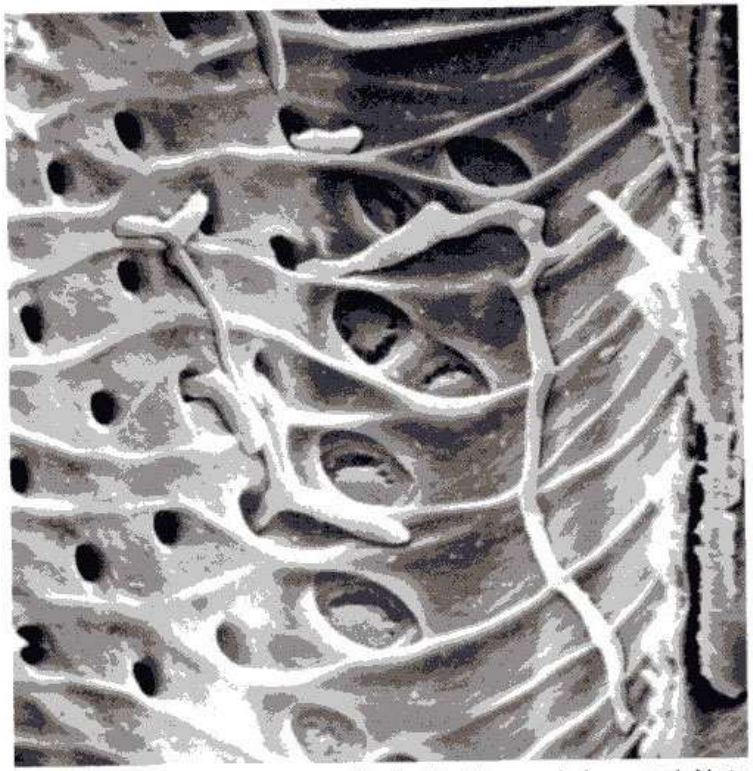


Fig. 22. Hyphae of *Ceratocystis ulmi* in diseased elm wood. Note passage of fungus through pit openings between vessels. (Courtesy D. M. Elgersma)

Host: the Elms (genus *Ulmus*)

- >30 species in genus. Europe has 5; N. America 8; Asia has 23 or more
- 6 species native to the northeastern U.S., including *Ulmus americana*, the American elm
- New species are still being found in China, the center of diversity

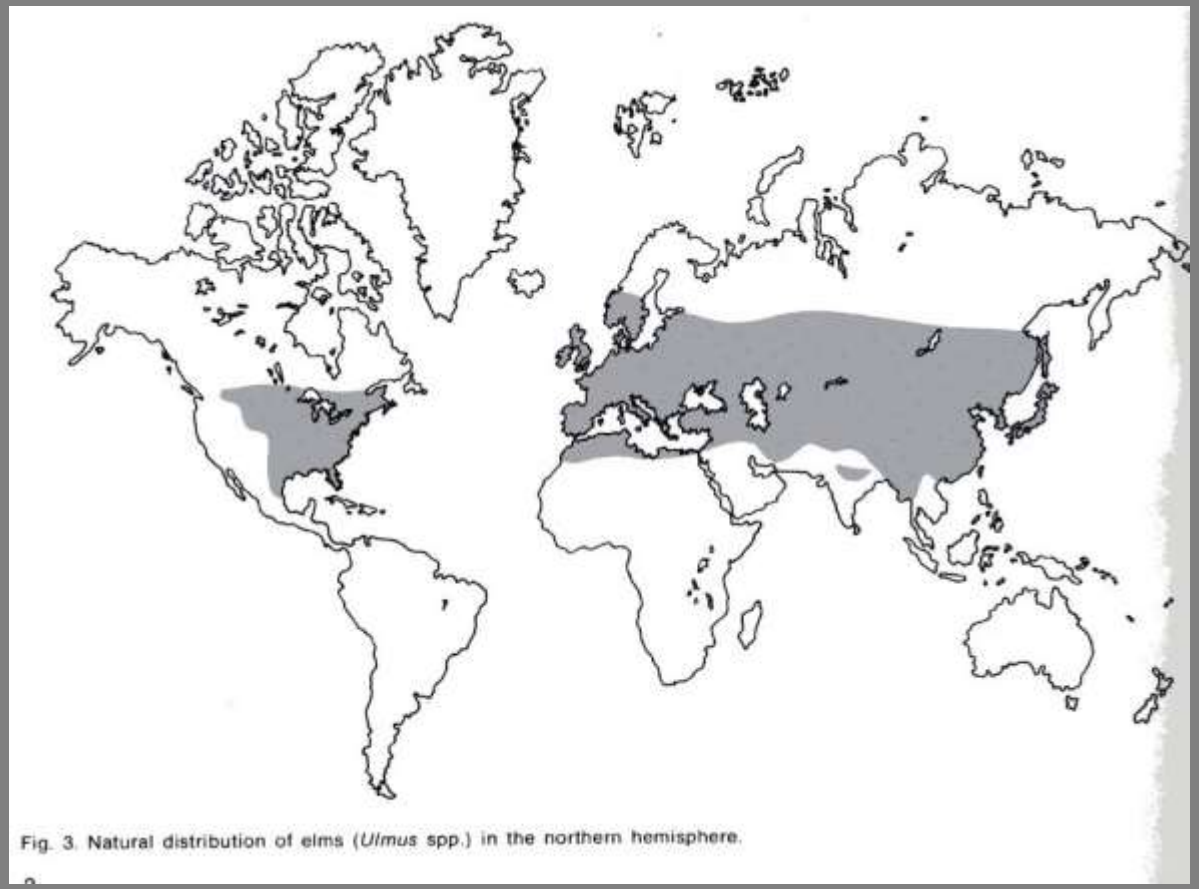


Fig. 3. Natural distribution of elms (*Ulmus* spp.) in the northern hemisphere.

Asian elms are more resistant to DED

Elms: the perfect shade tree

- Used as street-liners
- Fast-growing, easily transported, tolerant of soil compaction and different soil types
- Shade trees, with branches high above ground. When planted in rows, they overhang the street forming a Gothic-style arch. Good for windbreaks

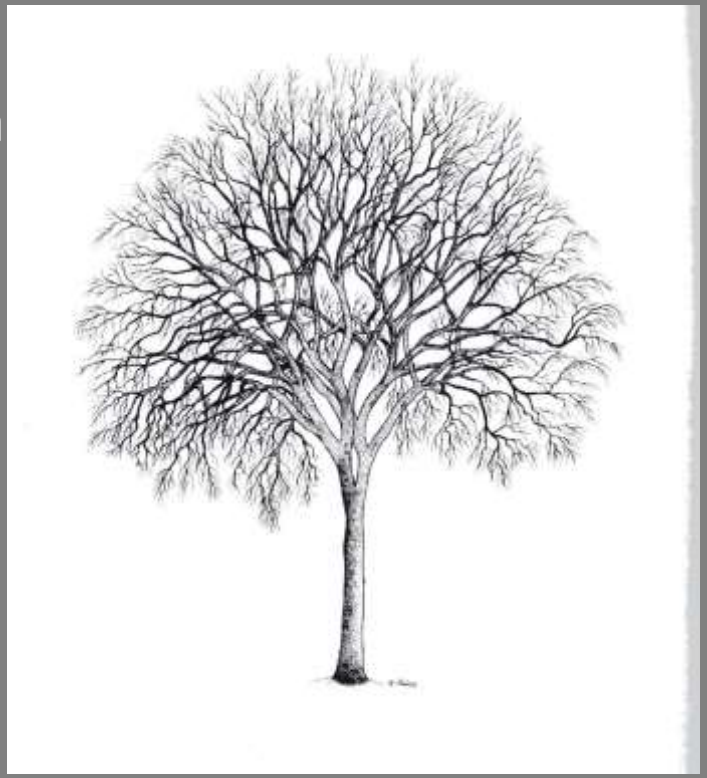
Fig. 25. Street scene of arching American elms in Evanston, Illinois (1976). (Courtesy E. B. Himelick)

- #1 urban tree in U.S east of the Rockies, and in large parts of Europe and Asia (Heybroek, 1993)

Elms: rural and natural Settings

In rural settings:

- In coastal western Europe, used as windbreaks
- The Siberian Elm was planted as “shelterbelts” to prevent erosion during the Dustbowl in the 30’s in the U.S.



In Natural Settings:

•A generally riparian, river bottom group that can survive periods of anoxia, explaining tolerance to over-watering and soil compaction

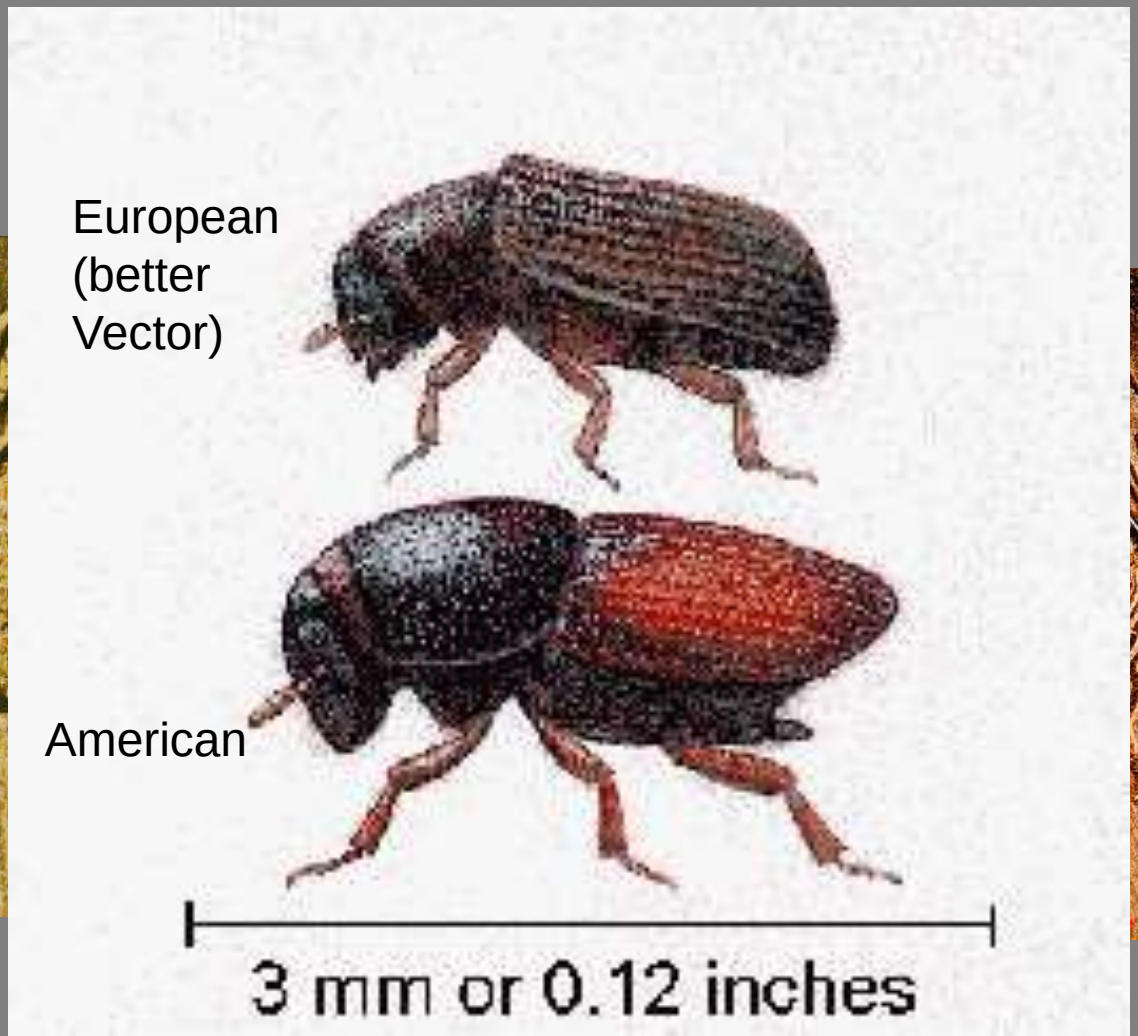
Vectors of disease

- Insects: 1) the native elm beetle 2) the smaller European elm beetle. The beetles can fly for several miles, allowing the disease to spread over a wide area

- Root grafts: when elms are within 50 feet of one another, their roots can grow together and disease passes easily along. Important in urban settings

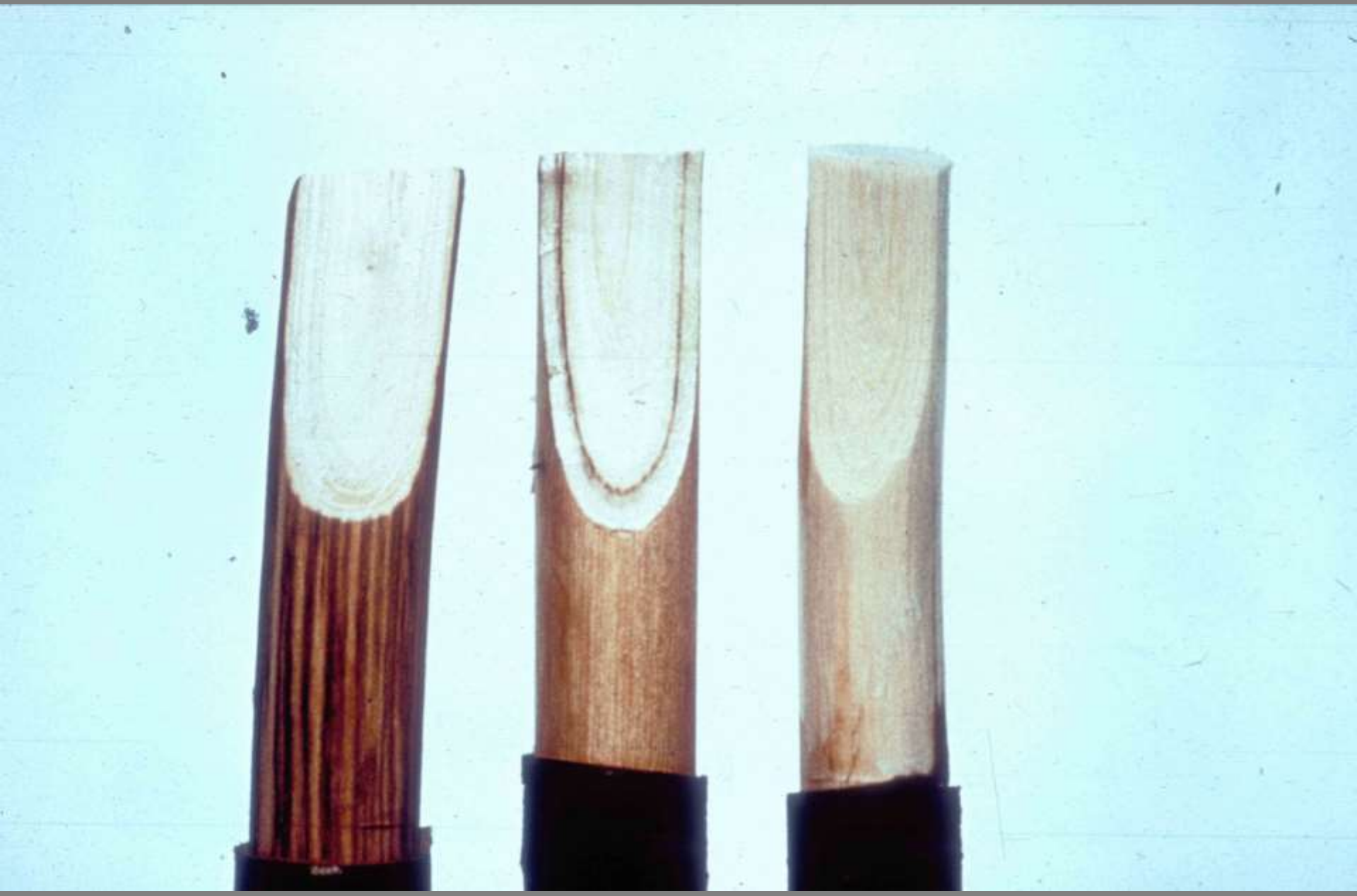
- Infected logs: Often transferred long distances

- Transmitted by *Scolytus* bark beetle
  - Beetle carves larval galleries in sapwood and carries fungus from tree to tree



Dutch elm disease – crown symptoms

Dutch elm disease – vascular discoloration



Elm root grafts

Elm bark beetle galleries

Maturation feeding

1970

1976

1977

1978

1991

Management: Sanitation

- Includes removing bark from elm logs which are being stored for use as fuel and/or covering or burning all downed wood (so that beetles can't get in it). AND, removing dead or diseased branches of standing trees (again because of the beetles).

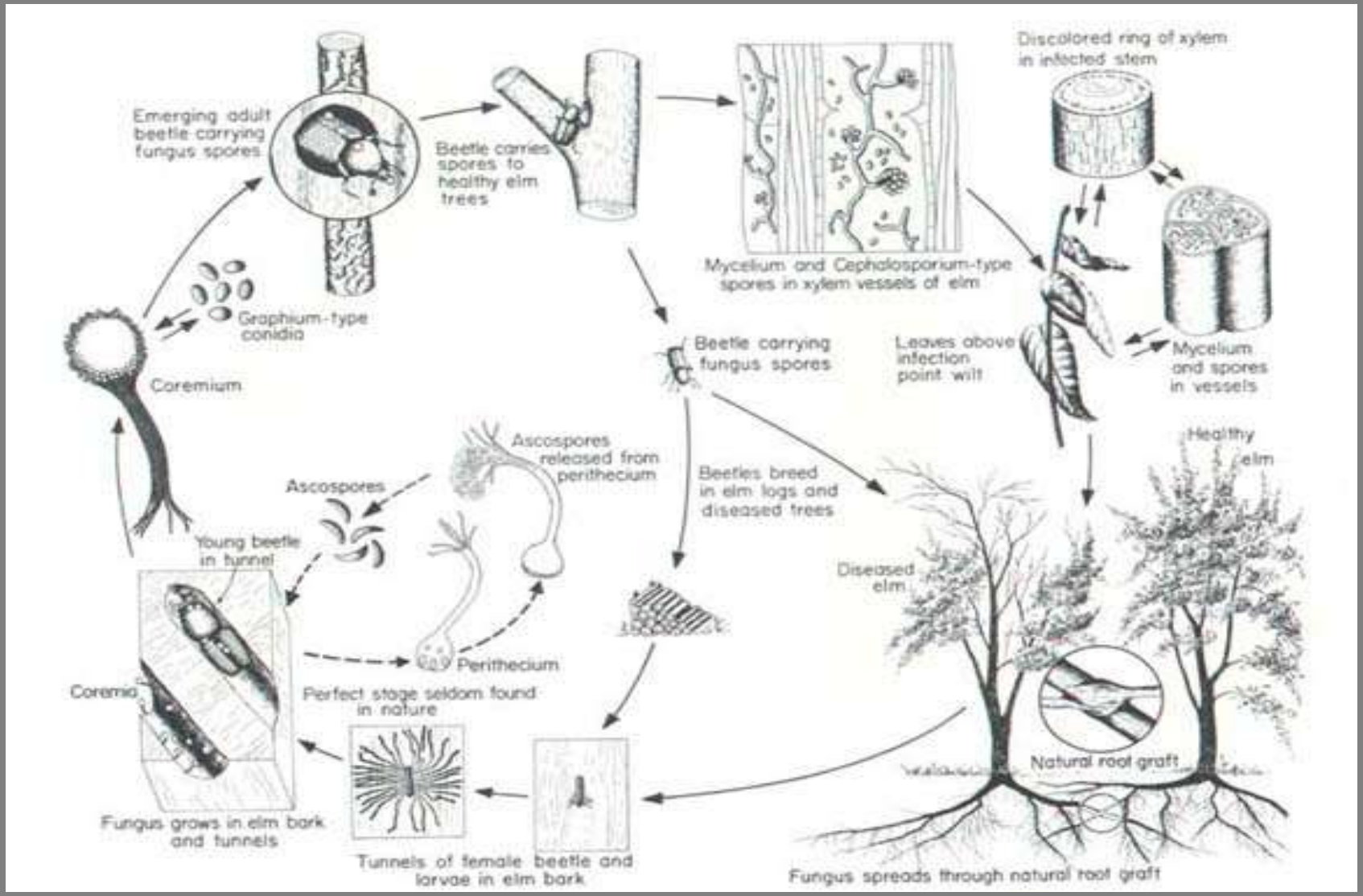
- Needs to be community-wide (all trees must be treated) and coupled with fungicide and insecticides, both injected (fungicide also sprayed)

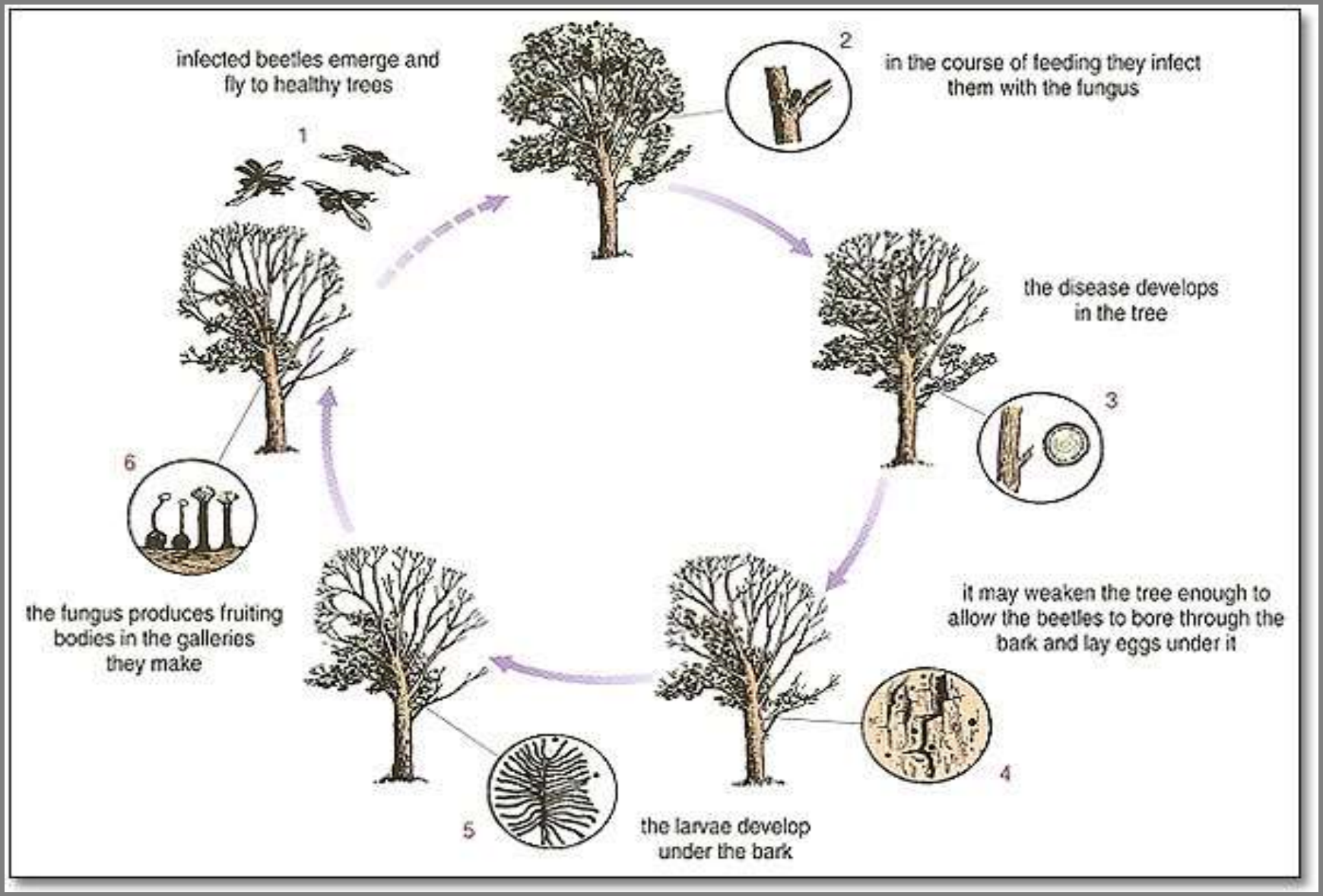
- Thought of as the most effective way of curbing DED, but timing is essential (for insecticides before flights, for fungicides before 10% of canopy shows dieback)

Other Management Methods

- Development of resistant hybrid elms
- Additional treatments: breaking up root grafts is commonly used and efffective.
- Timing of pruning: wounded trees attract the bark beetle vectors of DED (Byers et al., 1980), so routine pruning should be done in the dormant season or during periods of beetle inactivity.

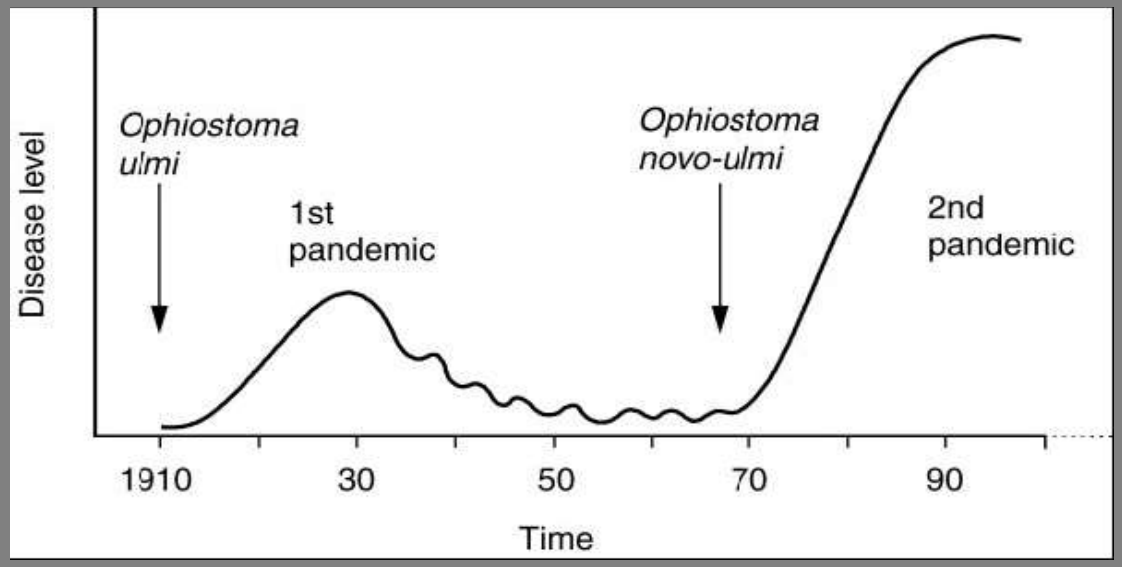
Life cycle with beetle vector



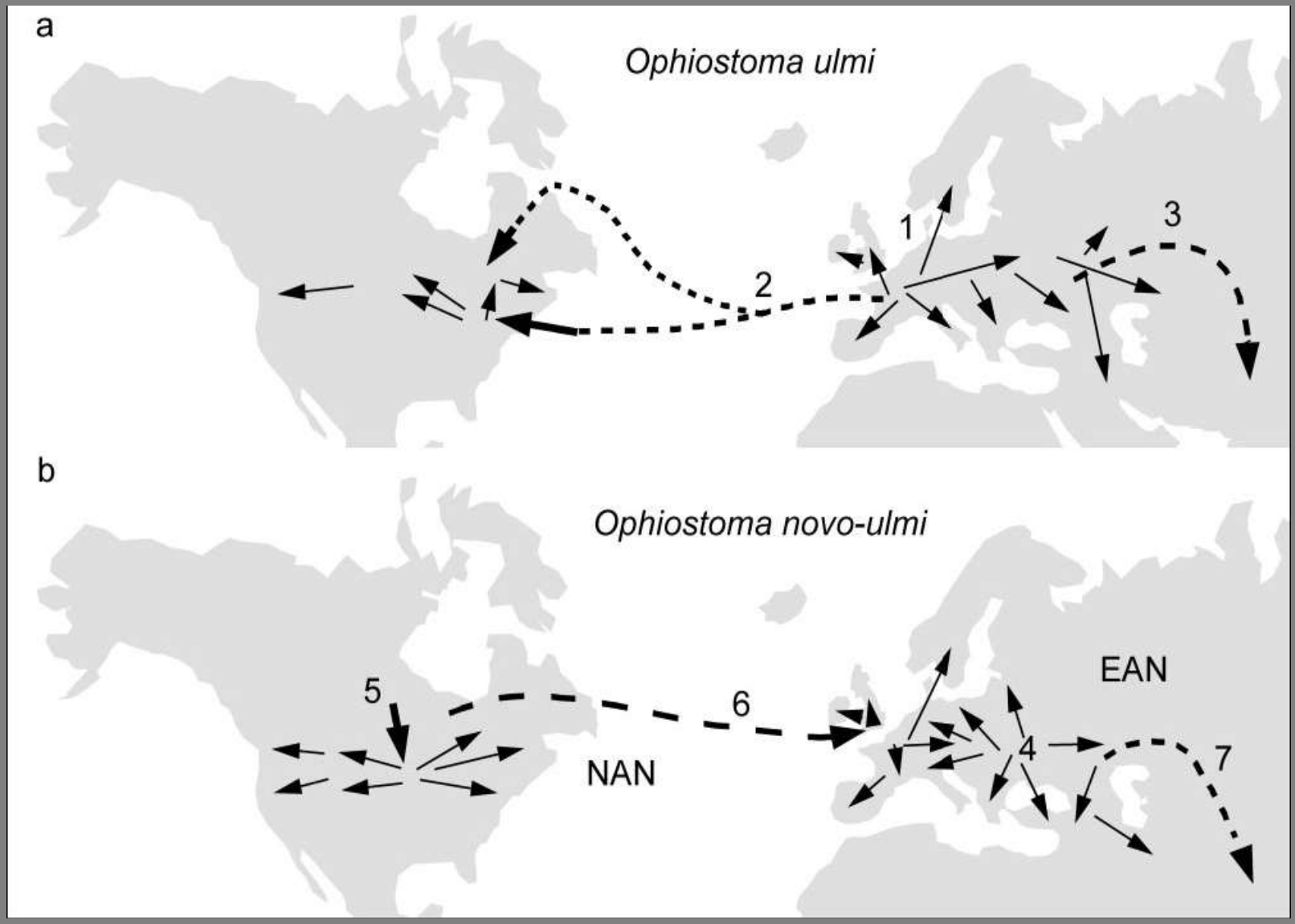

infected beetles emerge and fly to healthy trees
1
2
in the course of feeding they infect them with the fungus
the disease develops in the tree
3
it may weaken the tree enough to allow the beetles to bore through the bark and lay eggs under it
4
the larvae develop under the bark
5
the fungus produces fruiting bodies in the galleries they make
6

- Two separate pandemics caused by two different species
- *Ophiostoma ulmi*
- ***Aggressive O. novo-ulmi***
- Origins still unknown

Two Pandemics



- *O. ulmi* arrives in Europe and expands outward on infected timber both within Europe and to North America, kills 10-40% elms then stops…**Virus affecting the fungus!**
- *O. novo-ulmi, two* different strains introduced in Europe and N. America
- North American strain of *O. novo-ulmi* spread to Europe


a
Ophiostoma ulmi
1
2
3
b
Ophiostoma novo-ulmi
5
6
NAN
EAN
4
7

Two species differ in…

- Optimal growing temp
  - *O. ulmi* 28 C subtropical origins
  - *O. novo-ulmi* 22 C temperate origins
- Colony morphology
- Genetics
- Pathogenicity to elms
  - *O. ulmi* moderately aggressive
  - *O. novo-ulmi* highly aggressive

Reproductively Isolated?

- Not completely…
- Hybrids do not survive but allow for genes to be shared among species through backcrossing (hybrids mating with one of the two parents)
- O. novo-ulmi has aquired genes from O.ulmi that make it more resistant to viral spread

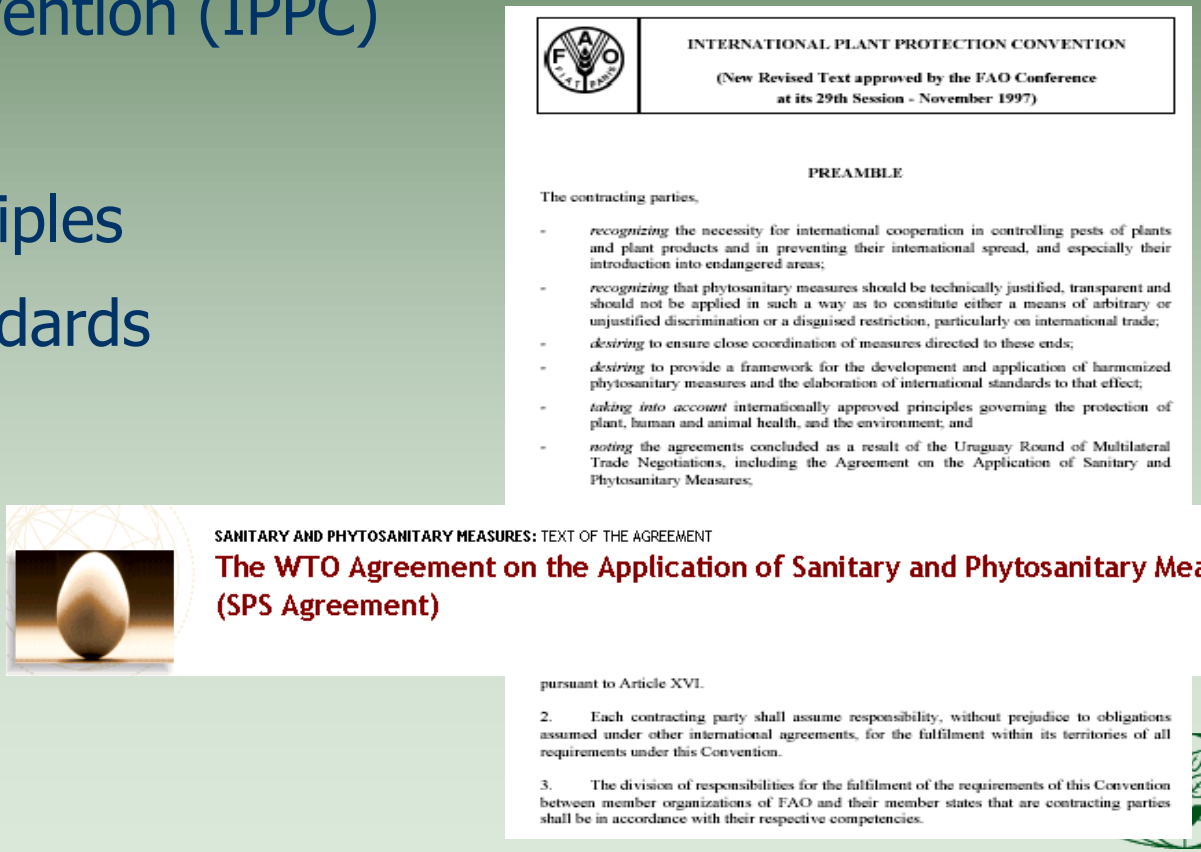
WOW!!!

- *O. novo-ulmi* outcompeted *O. ulmi* in Europe
- *O. novo-ulmi* caught virus from *O. ulmi* that would have killed it off BUT….
- At the same time *O. novo-ulmi* acquired genes from *O. ulmi* that made it less susceptible to virus

The End

Outline

- The Convention (IPPC)
- Scope
- Key Principles
- PRA Standards



INTERNATIONAL PLANT PROTECTION CONVENTION

(New Revised Text approved by the FAO Conference at its 29th Session - November 1997)

PREAMBLE

The contracting parties,

- *recognizing* the necessity for international cooperation in controlling pests of plants and plant products and in preventing their international spread, and especially their introduction into endangered areas;
- *recognizing* that phytosanitary measures should be technically justified, transparent and should not be applied in such a way as to constitute either a means of arbitrary or unjustified discrimination or a disguised restriction, particularly on international trade;
- *desiring* to ensure close coordination of measures directed to these ends;
- *desiring* to provide a framework for the development and application of harmonized phytosanitary measures and the elaboration of international standards to that effect;
- *taking into account* internationally approved principles governing the protection of plant, human and animal health, and the environment; and
- *noting* the agreements concluded as a result of the Uruguay Round of Multilateral Trade Negotiations, including the Agreement on the Application of Sanitary and Phytosanitary Measures;

SANITARY AND PHYTOSANITARY MEASURES: TEXT OF THE AGREEMENT

The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement)

pursuant to Article XVI.

2. Each contracting party shall assume responsibility, without prejudice to obligations assumed under other international agreements, for the fulfilment within its territories of all requirements under this Convention.

3. The division of responsibilities for the fulfilment of the requirements of this Convention between member organizations of FAO and their member states that are contracting parties shall be in accordance with their respective competencies.

IPPC

What is the IPPC?

- Multilateral treaty for international cooperation in plant protection
  - Nearly 160 countries
  - From Albania to Zambia
- A standard setting organization

Aim of the IPPC

- Prevent introduction & spread of pests
- Promote fair & safe trade
- Protect plant life and biodiversity

Key principles

- Countries have the right to use phytosanitary measures
- Measures should be:
  - only applied when necessary
  - technically justified
  - no more restrictive than necessary to address risk
  - non-discriminatory
  - transparent

Obligations

- National Plant Protection Organization (NPPO =USDA APHIS in USA) have the following obligations
  - Regulate imports
  - Publish phytosanitary requirements
  - Conduct surveillance, treatments and certify exports
  - Share information on pests and regulations
  - Notify trading partners of non-compliance

PEST RISK ASSESSMENT
PRA

Definition: PRA

- The process of evaluating biological or other scientific and economic evidence to determine whether a **pest** should be regulated and the strength of any **phytosanitary measures** to be taken against it - *Glossary of phytosanitary terms, ISPM No. 5*

What is PRA?

- Science-based process that provides rationale for implementing phytosanitary measures for a specified area
- Systematic approach to decide if a pest should be managed using legislation
- Public process shared with stakeholders

What is a plant pest?

- Plant pest
  - Any species, strain or biotype of plant, animal or pathogenic agent injurious to **plants** or **plant products** - *Glossary of phytosanitary terms, ISPM No. 5*
- organism harmful to plants including bacteria, fungi, insects, mites, other plants, nematodes and viruses.
- IPPC recognizes direct and indirect plant pests

IPPC pests of plants

- IPPC recognizes two categories of regulated plant pests
  - Quarantine pest: A pest of potential economic importance to the area endangered thereby and **not yet present there, or present but not widely distributed** and being officially controlled
  - Regulated non-quarantine pest: present in an area but regulated to curb effects

Why is PRA done?

- Answers following questions:
  - **1. Is the organism a pest**?
  - **2.** What is the **likelihood of the entry** and establishment?
  - **3.** Might the pest have an **unacceptable impact?** (economic, environmental, social)
  - **4.** If so, **what can be done** to avoid / inhibit unacceptable impacts?

When is PRA done? (Initiation)

3 Ps to initiation

- **Pest**: stop one specific pathogen
- **Pathway**: stop one pathway (movement of ornamental plants)
- **Policy:** verify products from a Nation

Pitch canker disease of pines

- **Threat to native populations of Monterey pine**
- **Threat to exotic plantations overseas**

THE PRINCIPAL HOST TO PITCH CANKER IN CALIFORNIA

***PINUS RADIATA* (MONTEREY PINE)**

Just in case you were wondering why it is called pine pitch canker…

Where does it come from?

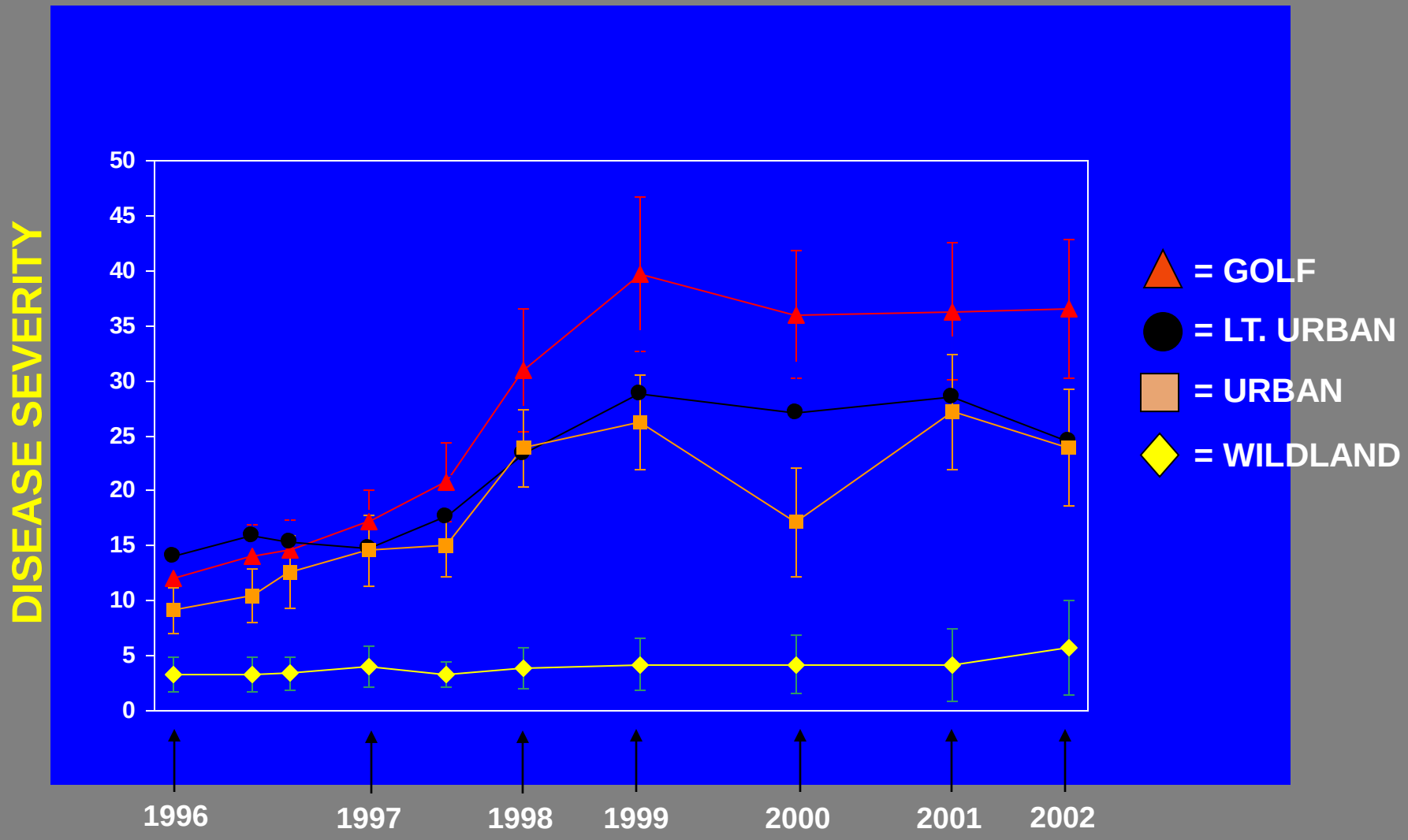
- Maximum genetic diversity found in Mexico
- East Coast of US has relatively high diversity, suggesting longer exposure
- South Africa, California and Japan have very low diversity, with California and Japan being quite similar presumably because infestations have the same source

Careful when interpreting data:

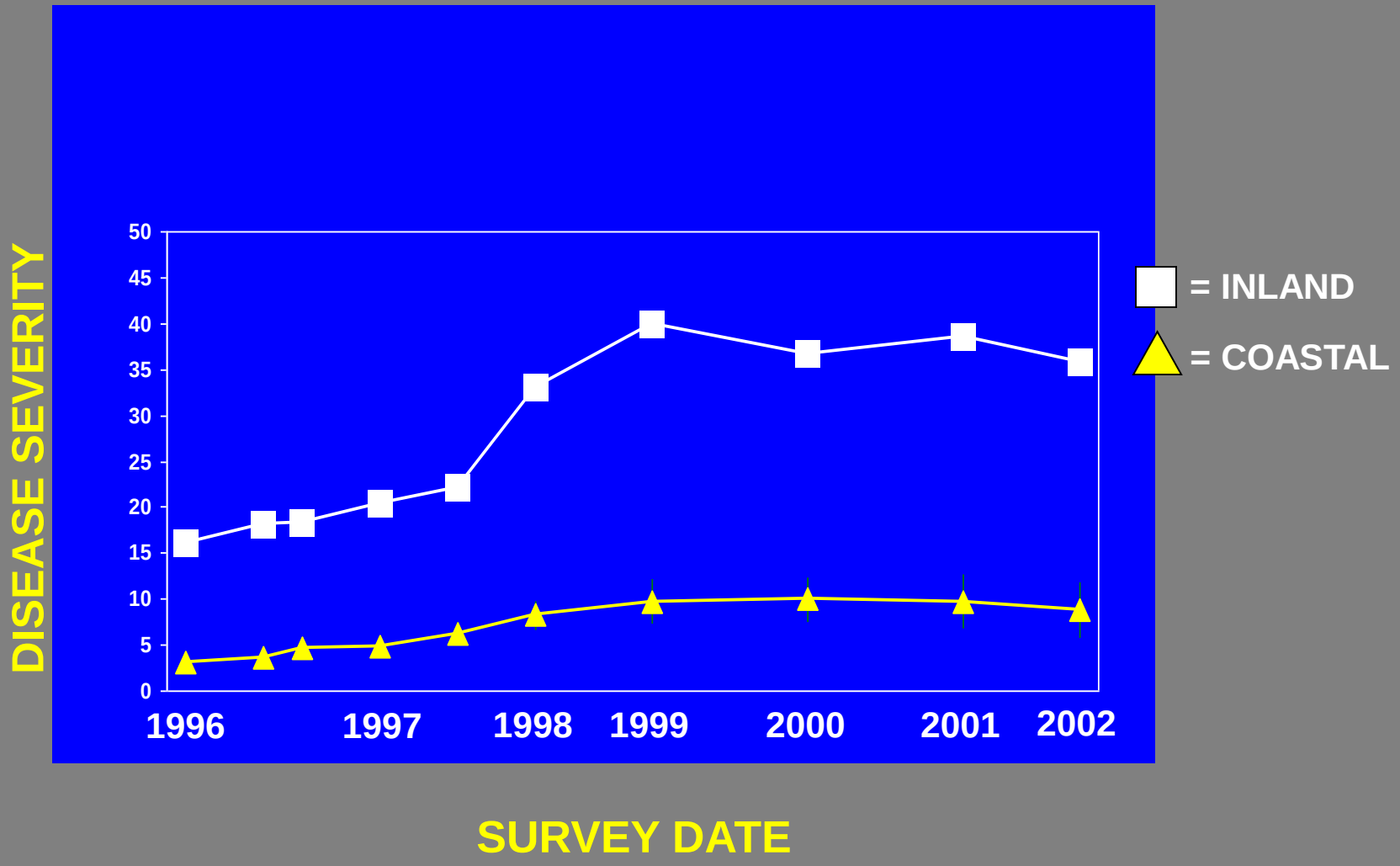
- Genetic similarity between two sites does not necessarily imply a source-sink relationship, but can indicate a third location was the source for both

- Observational correlations, especially in new systems (like new host-pathogen combinations) may be misleading. The pathogen was found on many insect species but this was an accidental not a causal correlation, meaning that insects were not vectoring the disease, but rather they were accidentally contaminated in correlation with the significant outbreaks due to the novelty of the association between Monterey pine and *Fusarium circinatum*

DISEASE PROGRESS BY LANDSCAPE TYPE



DISEASE PROGRESS BY LOCATION



HOW MANY TREES WILL DIE?

MORTALITY DUE TO PITCH CANKER IN A PLANTED STAND OF MONTEREY PINE

1989: 8% OF TREES INFECTED (N =50)

1993: 96% OF TREES INFECTED

1999: 14 TREES WERE DEAD, NEARLY DEAD OR HAD BEEN REMOVED

MORTALITY RATE = 28%

MORTALITY RECORDS FROM MONTEREY PENINSULA PLOTS

TOTAL NUMBER OF TREES LOST SINCE 1996:

138

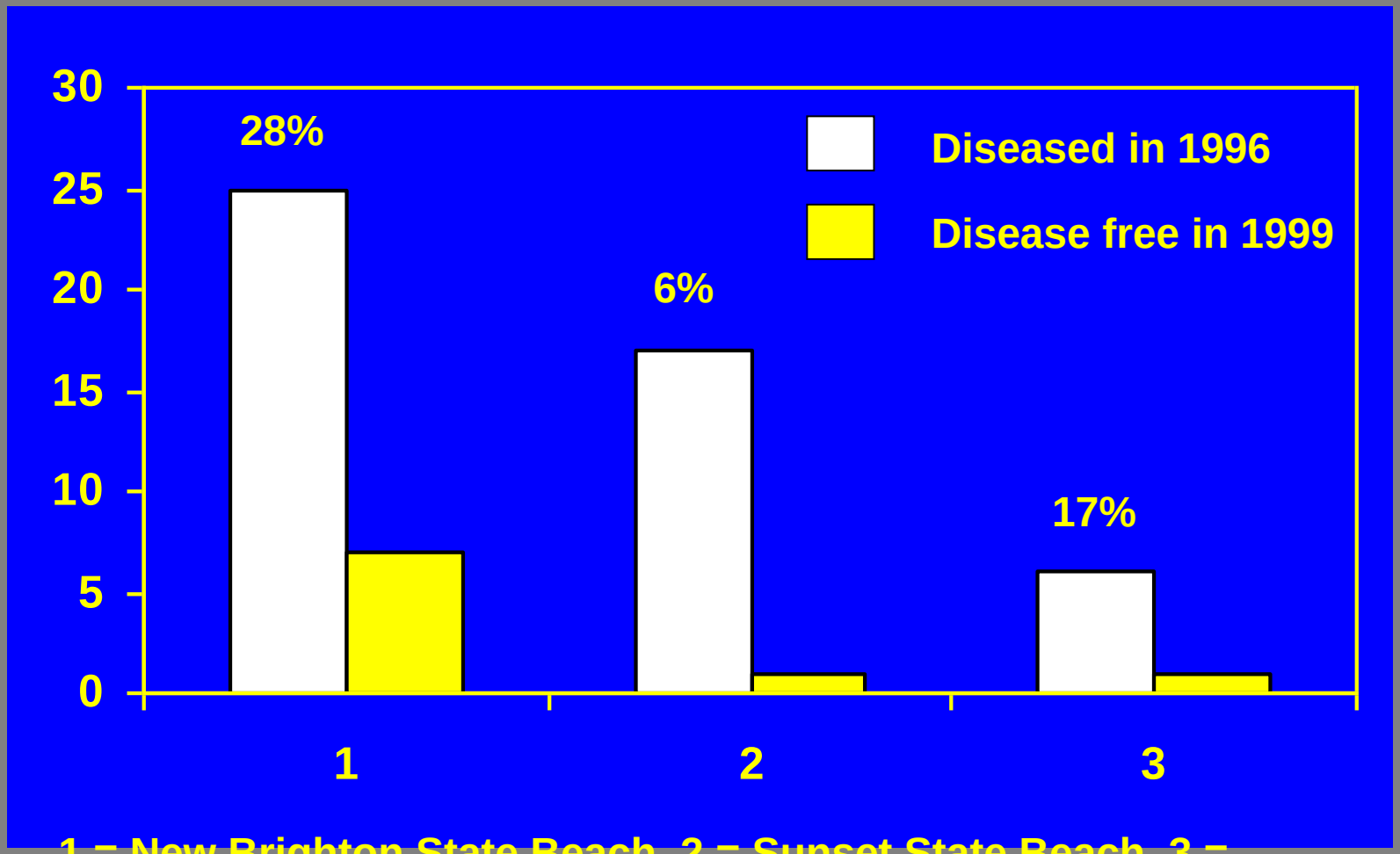
CONFIRMED PITCH CANKER DEATHS:

5

% MORTalITY DUE TO PITCH CANKER = 3.6%

LONG TERM IMPACTS

CHANGE IN DISEASE STATUS FROM 1996 TO 1999

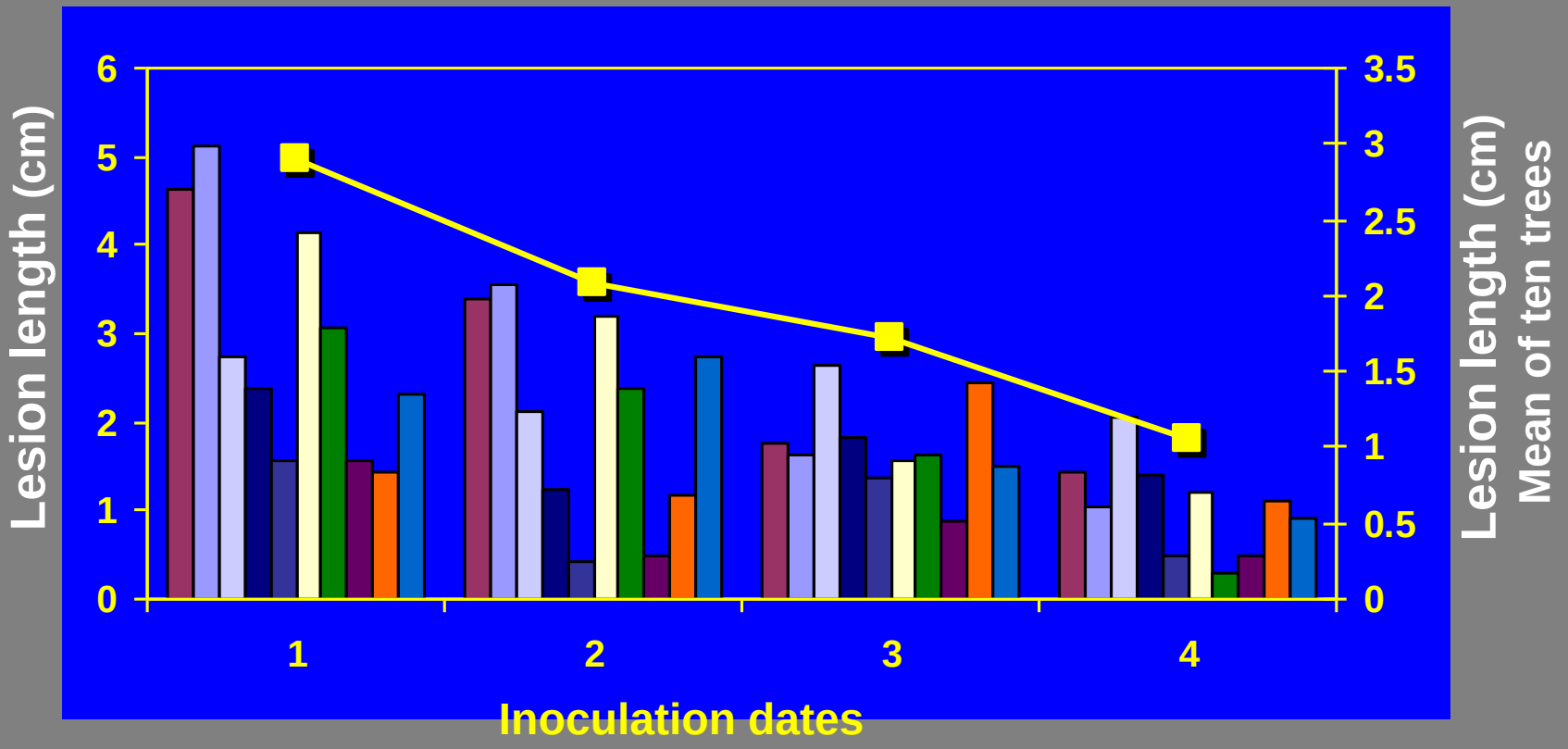


1 = New Brighton State Beach, 2 = Sunset State Beach, 3 = DeLaveaga golf course

DISEASE REMISSION COULD BE DUE TO ELEVATED RESISTANCE RESULTING FROM REPEATED INFECTIONS

= INDUCED RESISTANCE

EFFECT OF REPEATED INOCULATIONS ON SUSCEPTIBILITY



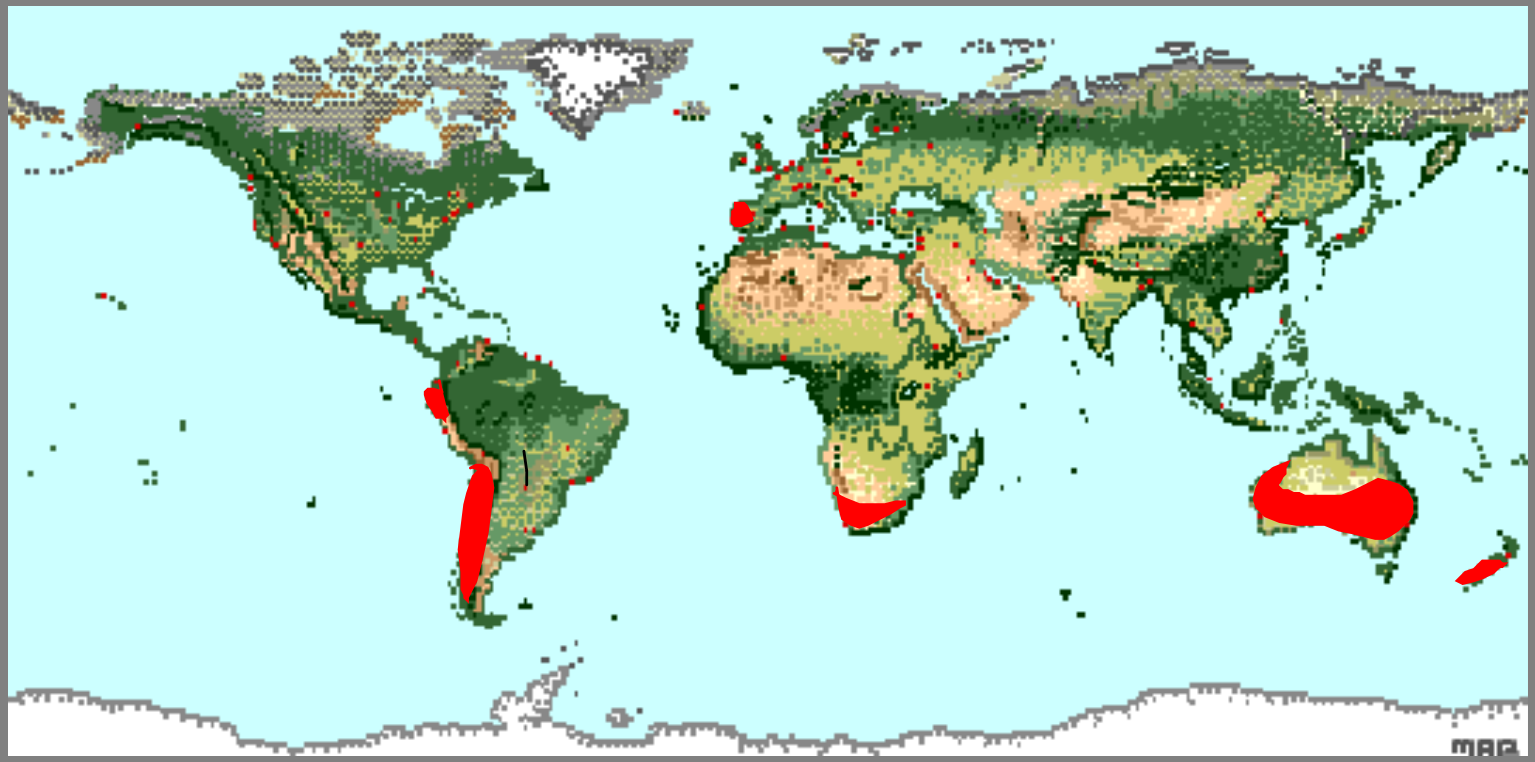
PITCH CANKER IN OTHER SPECIES:
At this point significant only in Bishop pine: however, in order to understand impact we need to ensure exposure has been long enough, and in areas with significant host density. With time:
-Mortality rates may decrease
- Mortality rates may increase

BISHOP PINE
KNOBCONE PINE
DOUGLAS-FIR

Pitch canker disease of pines

- **Introduced in California**
- **Spread around by Christmas tree trade**

Regions in red are characterized by significant presence of Monterey pine plantations

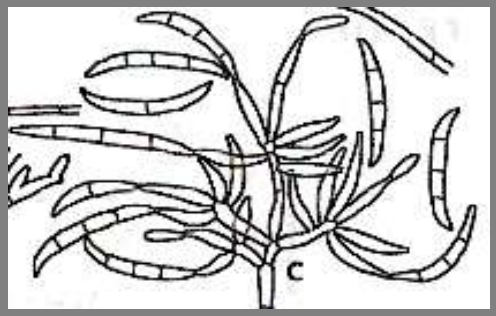


PITCH CANKER AS A SEEDLING DISEASE

Spreading of the disease

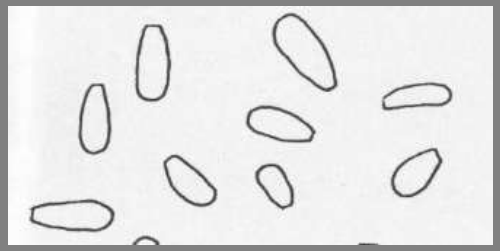
- Vectors ?
- Infected nursery material ?

- Aerial spores ?



macro conidia

micro conidia



Unusual mortality of Aleppo pine in SoCal

First Report of *Fusarium circinatum*, Causal Agent of Pitch Canker Disease, from the Roots of Mature Aleppo Pines in California

M. Garbelotto and **W. Schweigkofler,** Department of ESPM-ES, 137 Mulford Hall, University of California, Berkeley 94720; and **D. Shaw,** and 5555 Overland Avenue, Suite 4101, University of California Cooperative Extension, San Diego 92123

Trees infected in nursery before being outplanted

Fig. 1. The chlorotic crown of an Aleppo pine (left) whose roots are colonized by *Fusarium circinatum*.

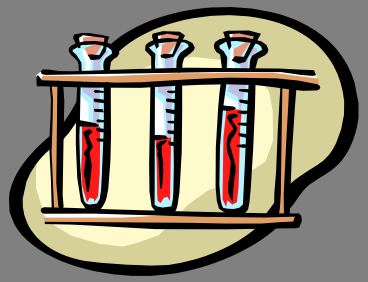
Fig. 2. Resin-soaked sapwood was observed under bark of primary-woody roots and root collars. *Fusarium circinatum* was always isolated from such lesions.

Fusarium sampling to monitor presence and quantify aerial spores

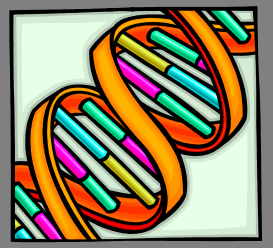
Real-time Quantification
Working Scheme

Spore trap
with filter paper

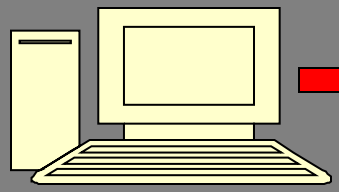
suspend in
20 ml 4X TE 65ºC



Centrifugation
Spore concentration

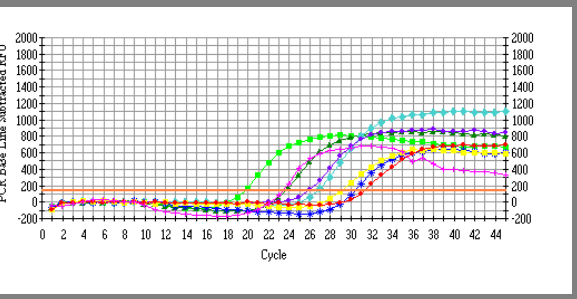


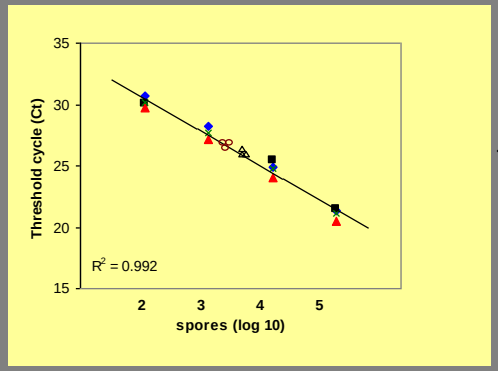
DNA-extraction



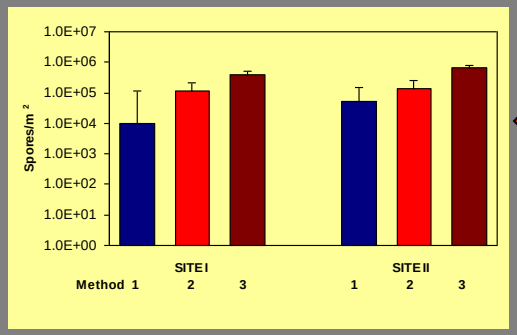
Mating type
determination

RT-PCR using
CIRC1A-4A



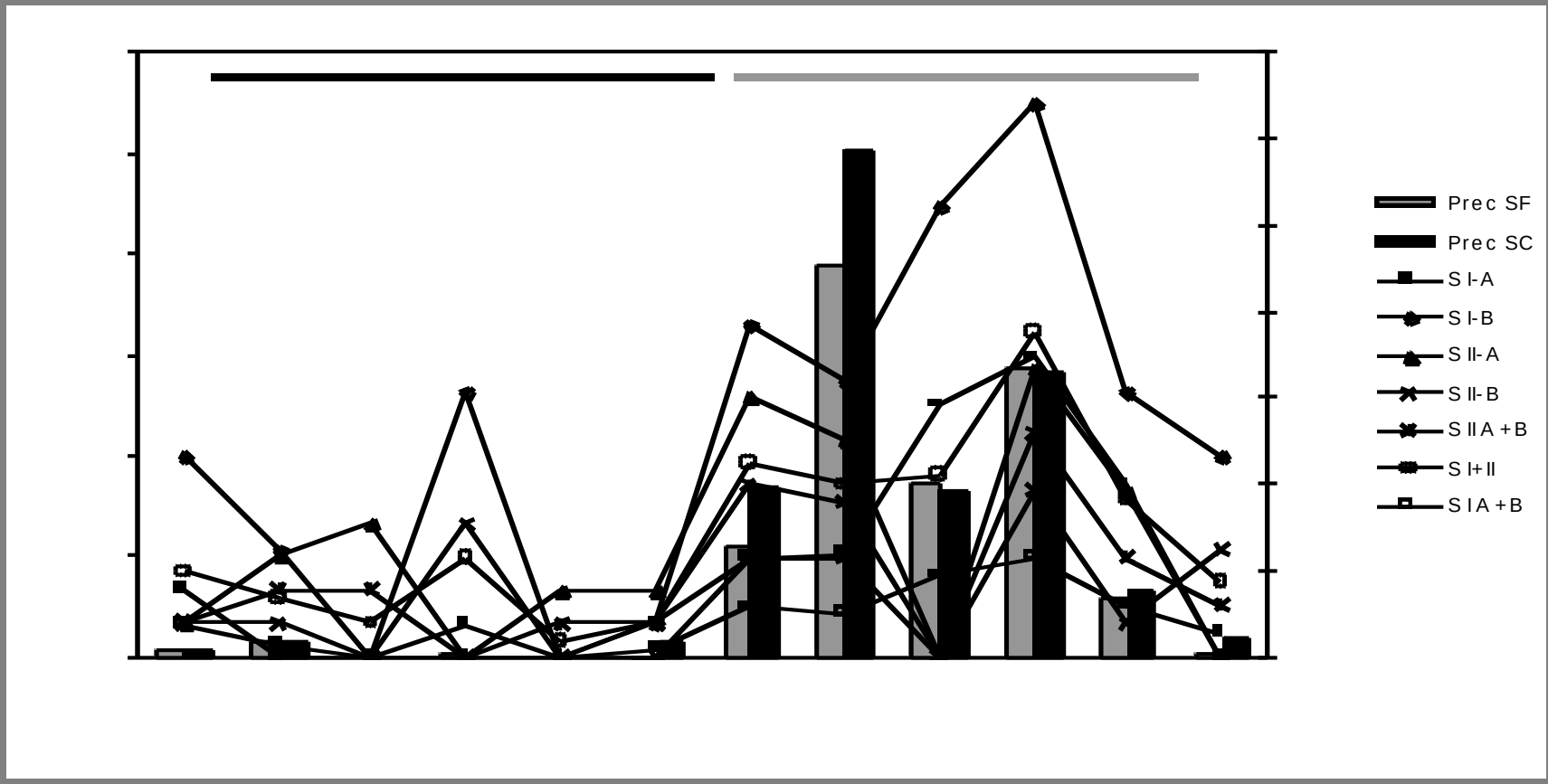


Compare with Spore (DNA) standard



Calculate spores/m^2

Seasonal differences



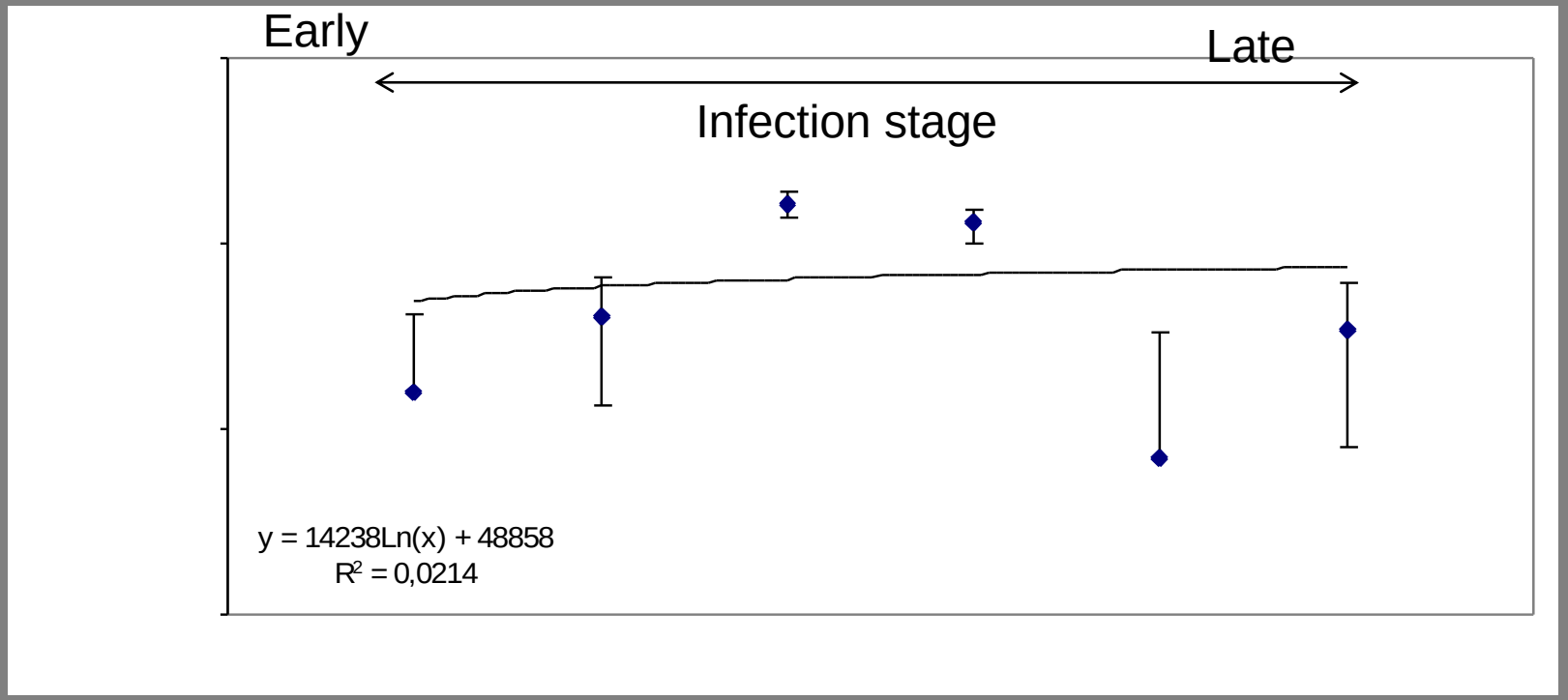
Dry season: May-October
Wet season: October-April

PCR+ : Wet:Dry = 3:1

What do trapping results tell us:

- Precipitation or high fog levels are both conducive to sporulation
- Warmer temperatures seem to favor sporulation: rainfall in late spring generate the best spreading conditions. Places with rainy summers may be very conducive
- When temperatures approach the zero, sporulation is completely interrupted (not a good Sierra pathogen). This insight was gained by comparing higher elevation and colder SC plots with lower elevation SF plots

Correlation between symptoms level and inoculum load

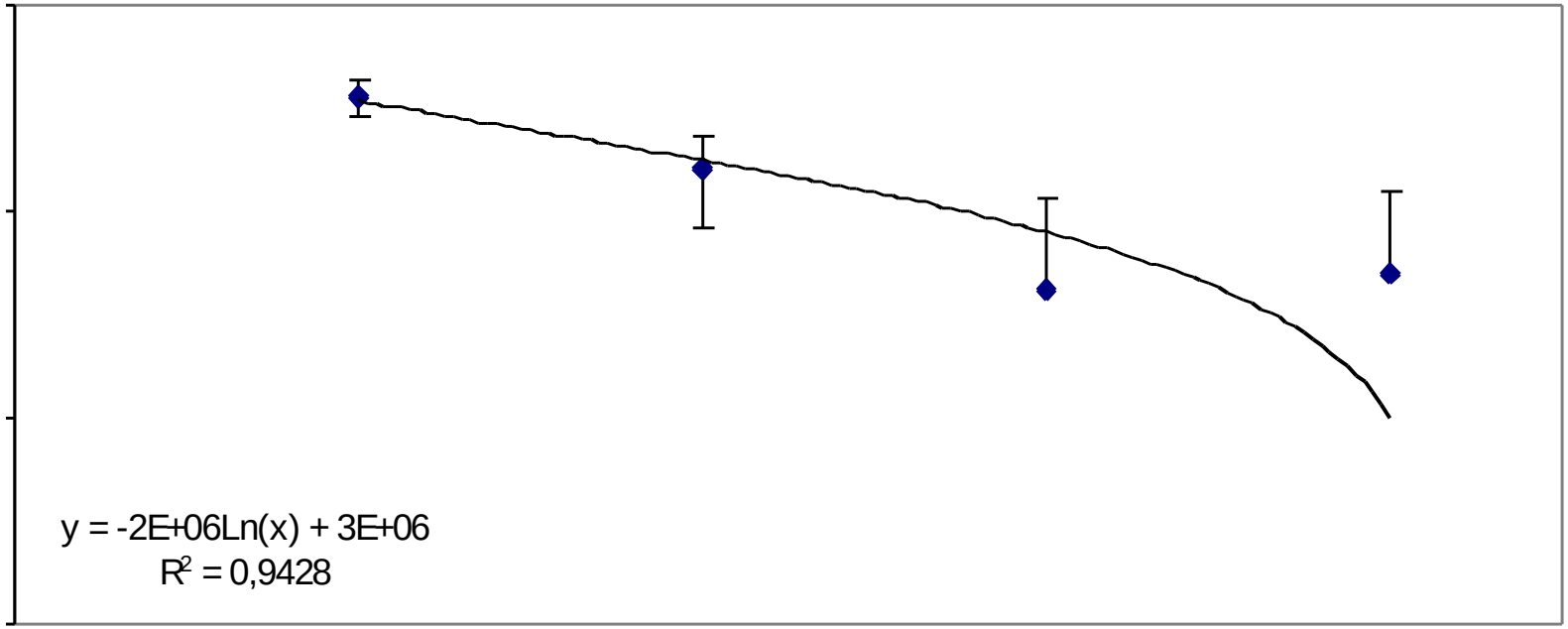


Epidemiology

- Artificial movement through plant material
- Spores are sticky and long lived (tools, insects), tools can be infectious even if they “look” clean
- Insect vectoring (facultative), it seems to be particularly important in association with cone-insects on Monterey pines
- Wounding? Insect feeding increases infection rates
- Airborne relatively long distance, each year we see an advancing disease front in Northern California, North-South movement favored by frequency of hosts and by warmer temperatures, as opposed to East-West movement

CURRENT DISTRIBUTION OF PITCH CANKER IN CALIFORNIA

Inoculum dilution analysis



Surprising “late” findings:

- Pathogen reported in roots of mature Aleppo pines in Southern California
- Pathogen transported to New Zealand on Douglas fir seedlings from Placerville (CA)
- Recently, second mating type introduced in California. How=?
- Found as an endophyte of grasses