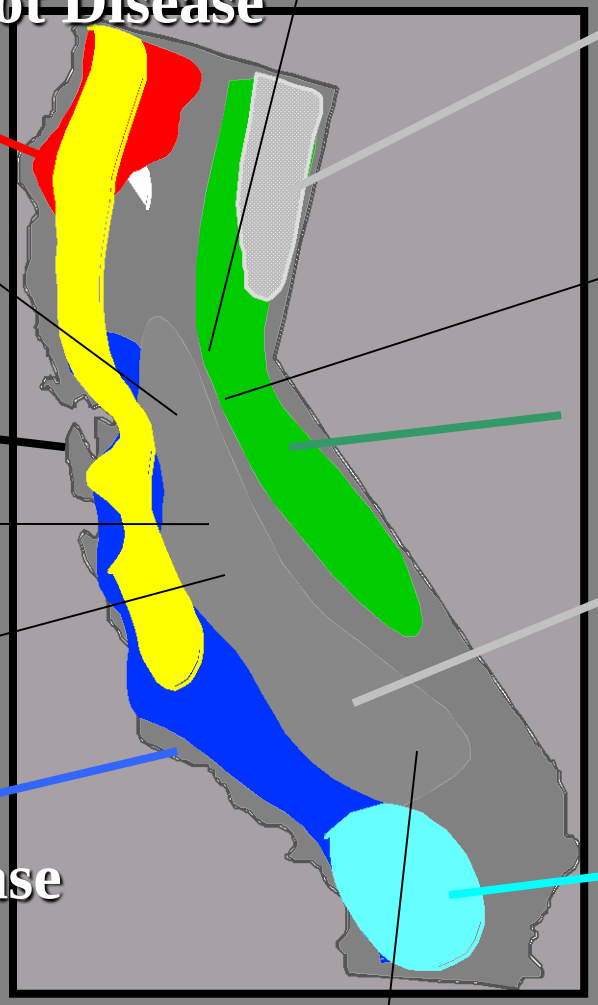
Do you remember the 5 life stages of Cronartium ribicola, including time of year and host they are produced on?

What are the environmental conditions for infection of pines by the WPBR fungus. Where are they frequent and where less frequent

Do you remember a few management options for WPBR.

What happened to the pathogen population at Happy Camp (CA) and why

California invaded: 1849 A.D.



Xylella scorch of maples 2000s

Port Orford Cedar Root Disease 1950s

Expansion of root pathe 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 the introduced basidiomycete

Cronartium ribicola

A few remarks

- Introduction occurred multiple times on the East coast/Lake and maybe 1 or 2 times on the West Coast. One would expect more genetic variability in the East coast, but high gene flow within the East/lake regions homogenizes genetic makeup. In the west, gene flow is often minimal due to rugged topography, and isolation leads to more variability among populations

A few remarks

- Easter and Western populations of Cronartum ribicola are genetically very different because they were started by different founders. There is concern that gooseberry farms may allow the two to merge, allowing for genetic variability to be shared leading to more rapid evolution

Dutch Elm Disease

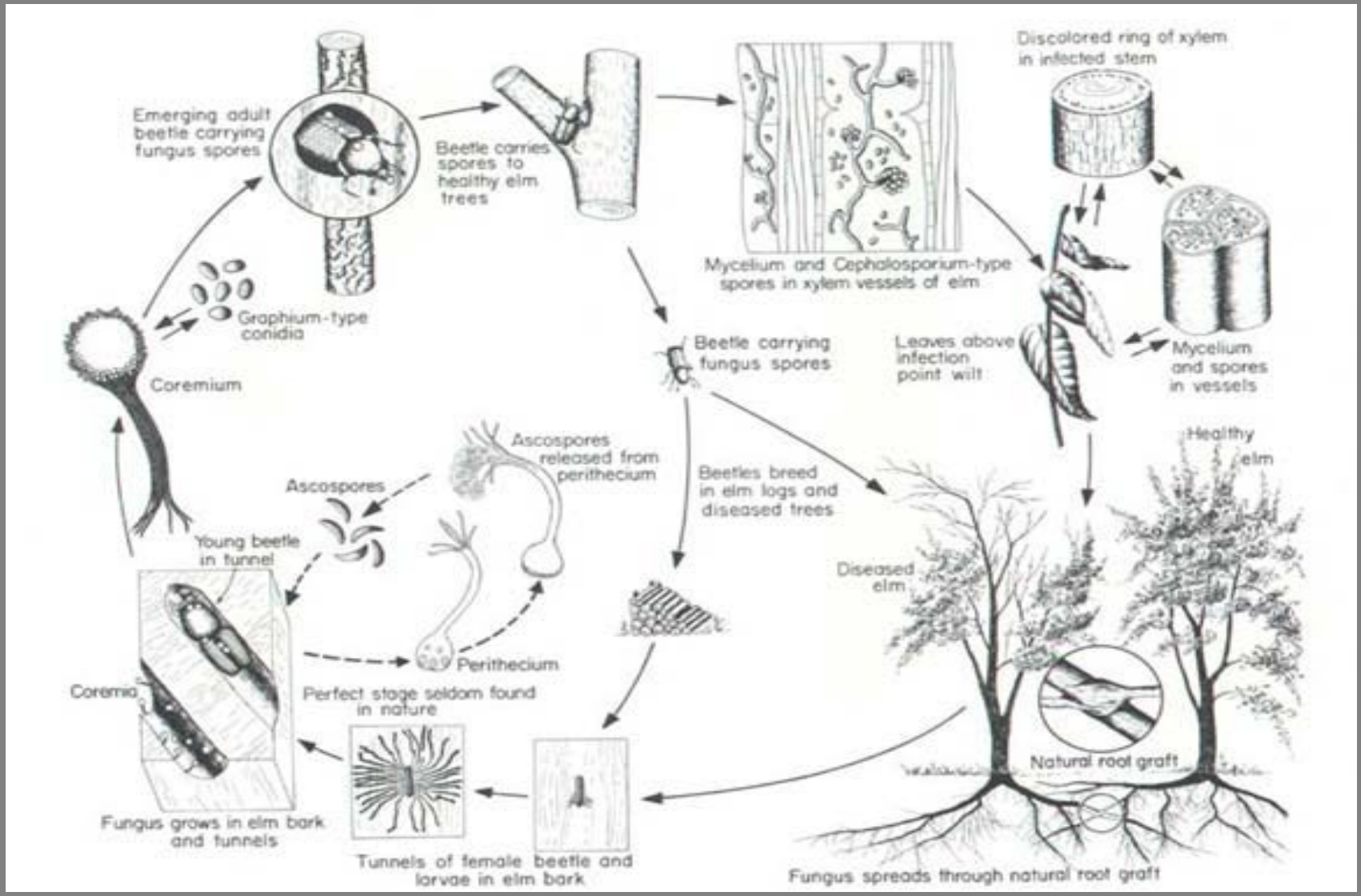
- Wilt disease caused by ascomycete fungus in the genus *Ophiostoma*

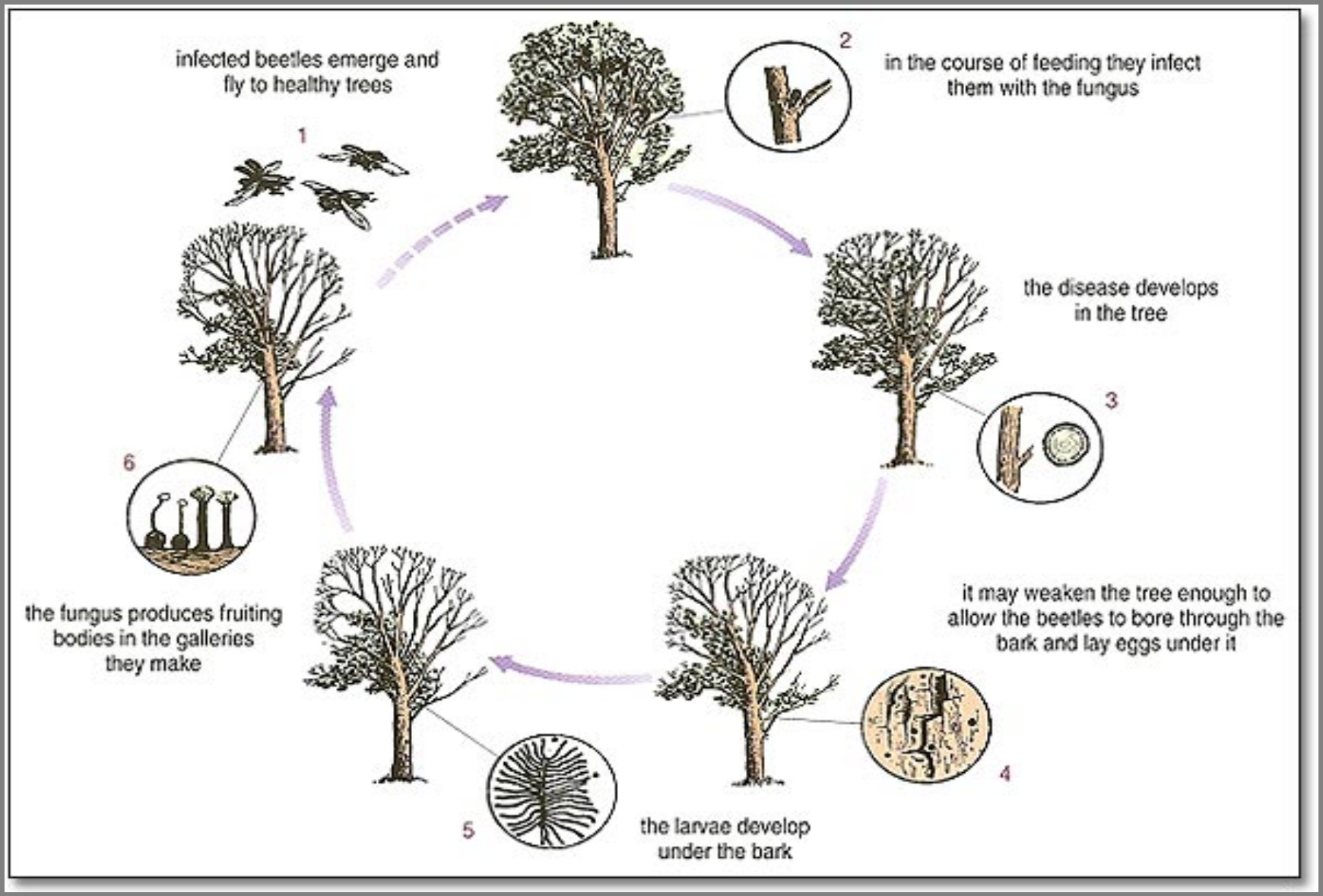
- Transmitted by *Scolytus* bark beetle
  - Beetle carves larval galleries in sapwood and carries fungus from tree to tree

- Spreads through trees vascular system
- Tree tries to slow fungus by plugging its own xylem tissue with tyloses
- Plugged xylem causes branch dieback

- Toxins force stomata to open
- Increased evapotranspiration causes desiccation and rapid death of tree

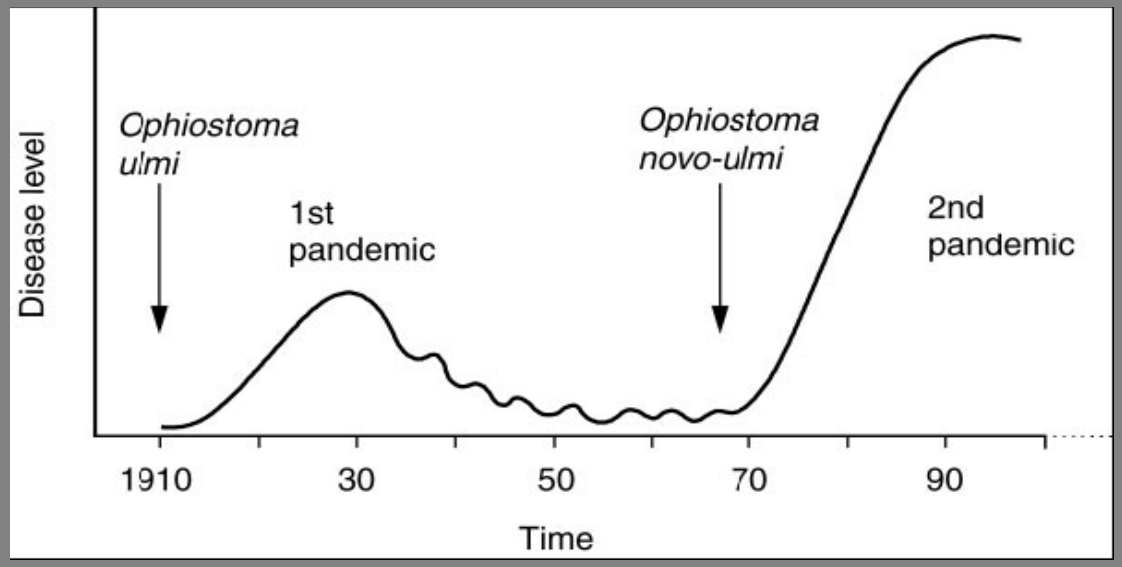
Life cycle with beetle vector



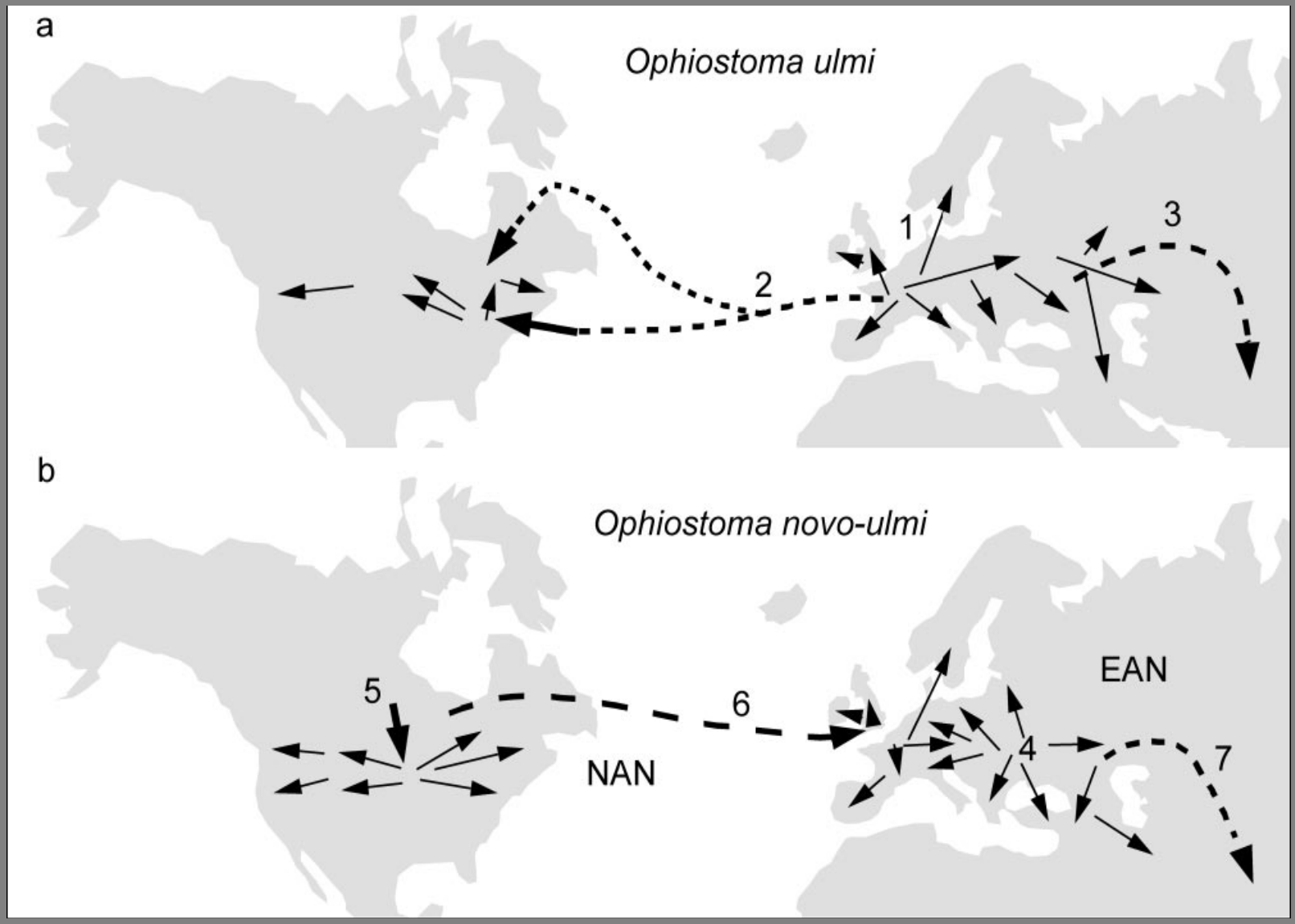

infected beetles emerge and fly to healthy trees
1
2
in the course of feeding they infect them with the fungus
the disease develops in the tree
3
it may weaken the tree enough to allow the beetles to bore through the bark and lay eggs under it
4
the larvae develop under the bark
5
the fungus produces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

- Two separate pandemics caused by two different species
- *Ophiostomata ulmi*
- *Ophiostomata nova-ulmi*
- Origins still unknown

Two Pandemics



- *O. ulmi* arrives in Europe and expands outward on infected timber, kills 10-40% elms then stops…Virus!
- *O. novo-ulmi* strains introduced in both Europe and N. America-radiates further
- Now both species overlap in 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
- Molecular fingerprint
- Pathogenicity to elms
  - *O. ulmi* moderately aggressive
  - *O. novo-ulmi* highly aggressive

Reproductively Isolated?

- Not completely…
- Both species have two mating types and crosses within species are fertile
- Between species…
  - O. ulmi can not fertilize O. novo-ulmi
  - O. novo-ulmi CAN fertilize O.ulmi
- Progeny include
  - Sterile females
  - Offspring with low vigor and fitness
    - Basically out-competed by stronger parent species

When the two species meet…

- O. ulmi usually present when O. novo-ulmi arrives and is quickly replaced
- Two species meet in bark surrounding beetle galleries
- Chance for interspecific genetic exchange
- Hybrids don’t survive or are transient BUT…
- Act as GENETIC BRIDGE

Definitions

- Interspecific hybrid
  - Mating between two species of same genus produces a sterile or transient progeny to prevent movement of genes and thus keeps species separate
- Introgression
  - Backcrossing of an interspecific hybrid with one of it’s parents leading to movement of genes in between species

Methods of Detecting Gene Flow

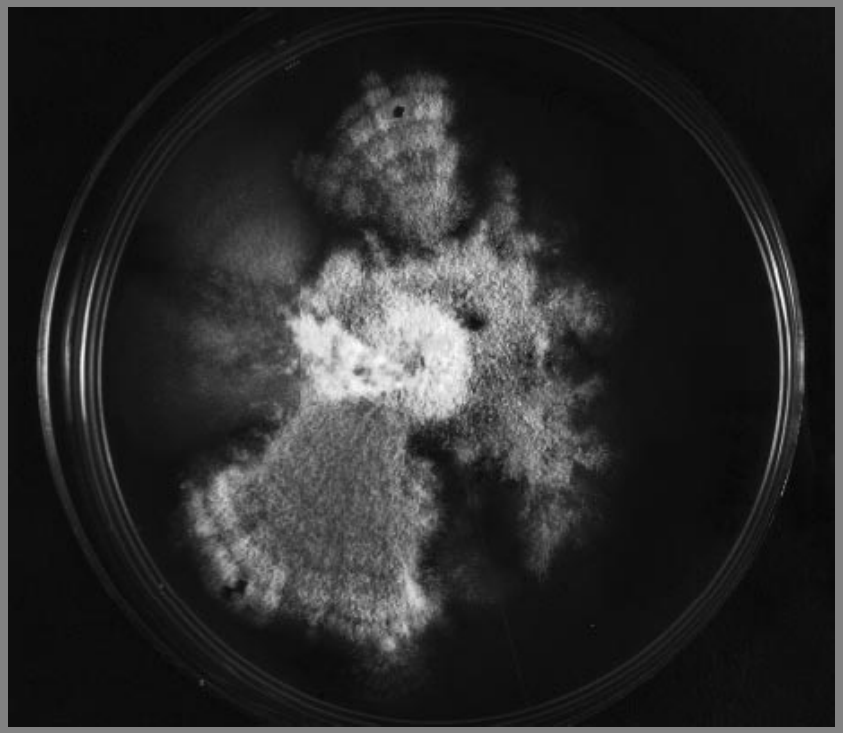
- DNA Fingerprinting
  - Probed with cloned dna fragments to distinguish between two species
  - Some *O. novo-ulmi* isolates had rare *O. ulmi* like polymorphisms
    - Acquired through introgression
  - 15 of 50 O. novo-ulmi isolates had *O. ulmi* gene
  - 1 had altered phenotype
    - Less aggressive
    - AFLP showed gene was involved with pathogenicity

Gene flow? More clues…

- Sudden increases of Vegetative Compatibiliy (VC) types
  - Necessary to prevent spread of “cooties” (viral factors) between adjacent colonies
  - Controlled by many genes with many alleles; only isolates that have the same alleles at all VC genes fuse their hyphae because they recognize each other as selves
  - Viruses will spread through fused cells of same VC types

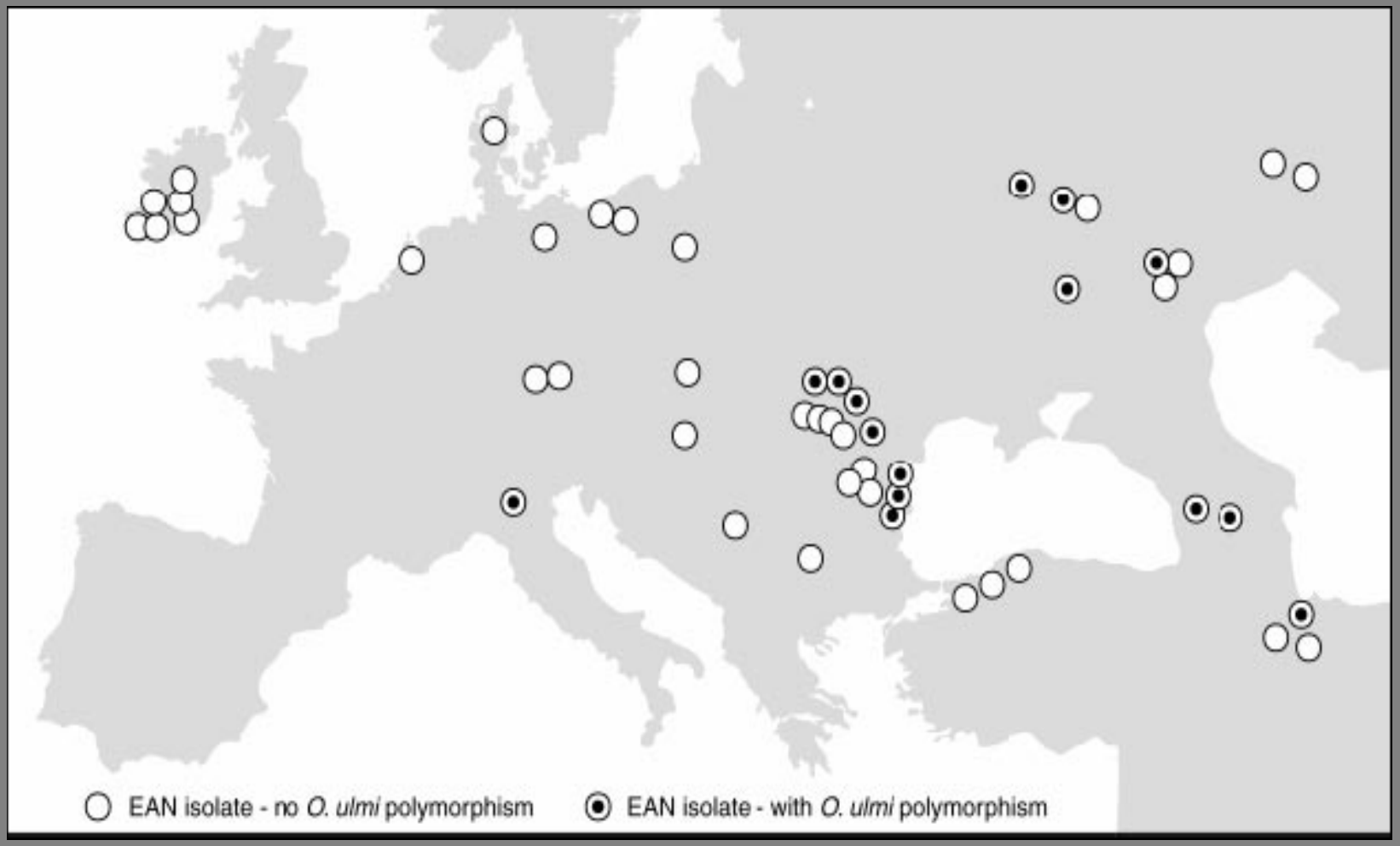
Europe

- Single clones of VC types with single mating type introduced and spread through Europe
  - High rate of viral spread through pop
- After a few years population diversifies in VC type and mating type
  - Spread of viruses declines
    - Effect slower in North America due to less pressure from virus



Conclusions

- *O. novo-ulmi* VC clones diversify only where *O. ulmi* was already present
- Only when virus activity is high will clones diversify rapidly
- Novel VC genes are acquired by *O. novo-ulmi* from *O.ulmi*
- Selection pressure from viruses favors novel VC types



O. novo-ulmi with single VC type-black

As it changes to many VC types in grey

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 VC genes from *O. ulmi* that made it less susceptible to virus

O. Himal-ulmi

- Found in Himalayas while searching for origins of pathogens in Asia
- Appears to be in natural balance with elms and bark beetles
- Very aggressive on European Elms
- Importance of regulating timber trade

The End