Dutch Elm Disease

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

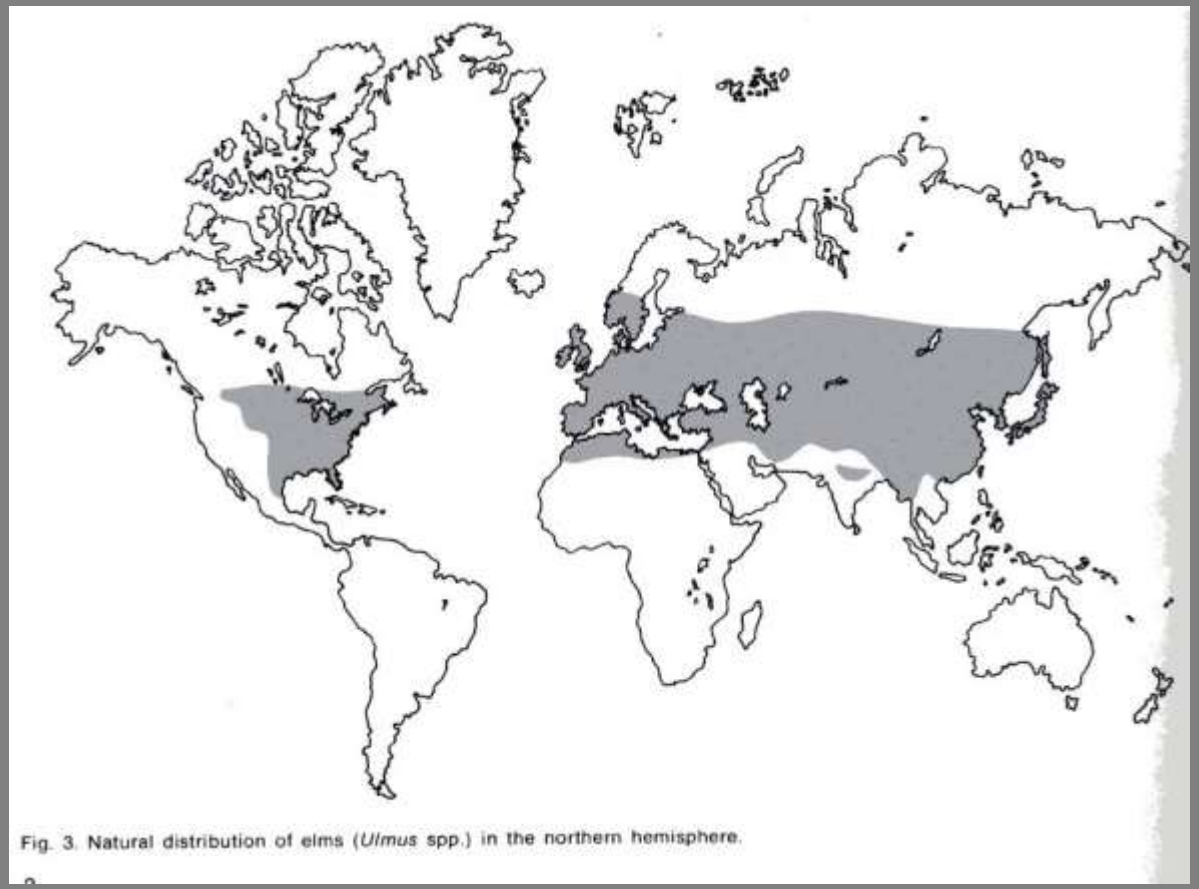


Fig. 3. Natural distribution of elms (*Ulmus* spp.) in the northern hemisphere.

Elms: the perfect shade tree

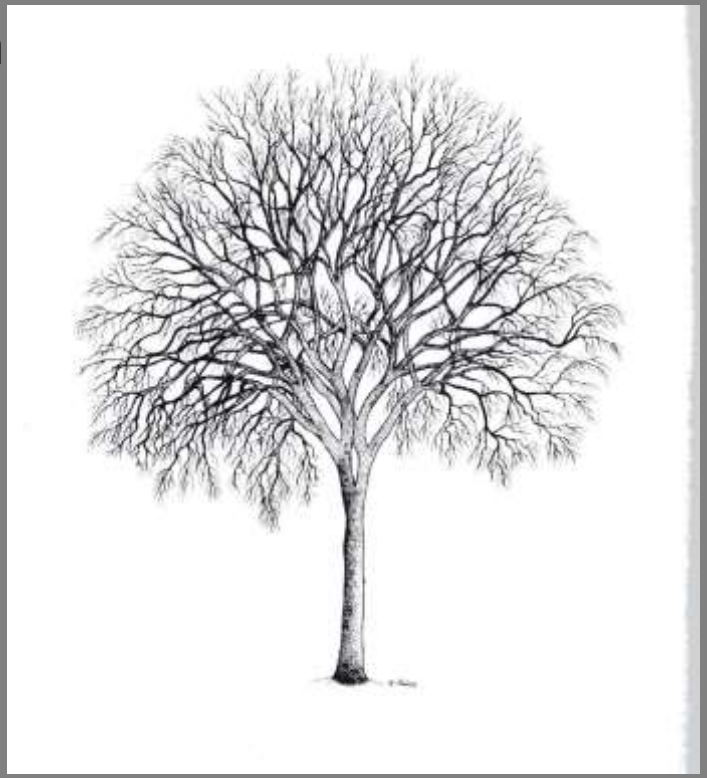
- Used as street-liners
- Fast-growing, easily transported, tolerant of soil compaction and different soil types
- Shade trees, with branches high above ground. When planted in rows, they overhang the street forming a Gothic-style arch. Good for windbreaks
- #1 urban tree in U.S east of the Rockies, and in large parts of Europe and Asia (Heybroek, 1993)

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

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

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

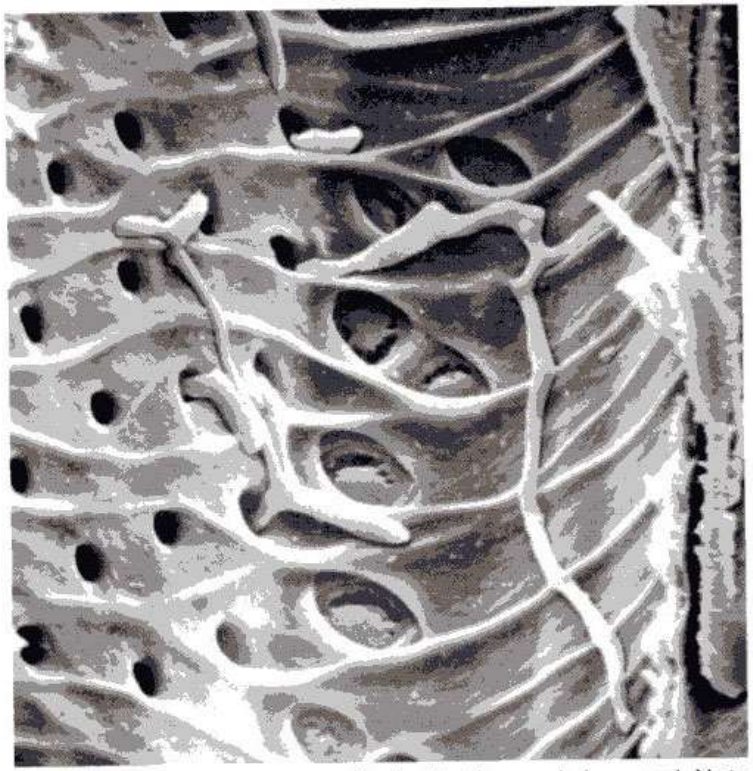


Fig. 22. Hyphae of *Ceratocystis ulmi* in diseased elm wood. Note passage of fungus through pit openings between vessels. (Courtesy D. M. Elgersma)

Dutch Elm Disease

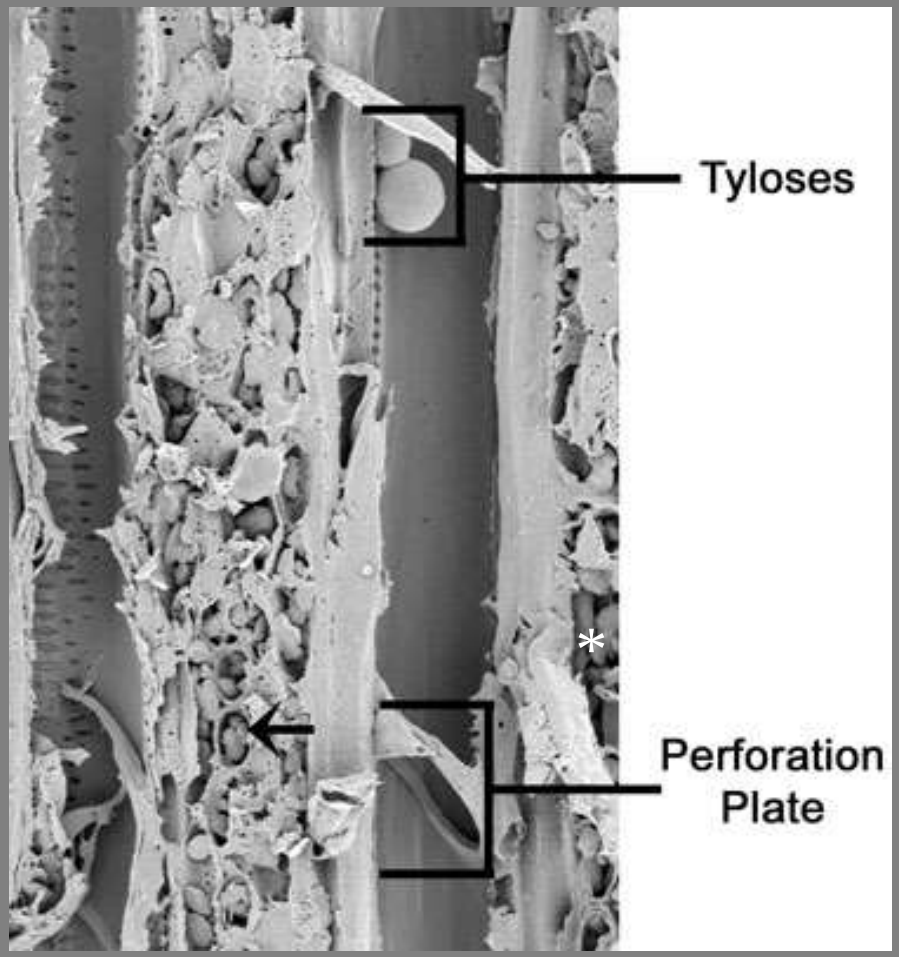
- Wilt disease caused by ascomycete fungus in the genus *Ophiostoma*

patogenesi vascolare

presenza, nei vasi (primaverili), di micelio e di una anamorfo lievitoide

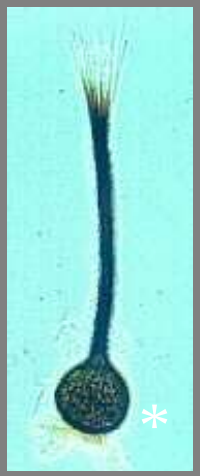
presenza, nella linfa, di enzimi, tossine e materiale vegetale di varia origine

tillosi



teleomorfo

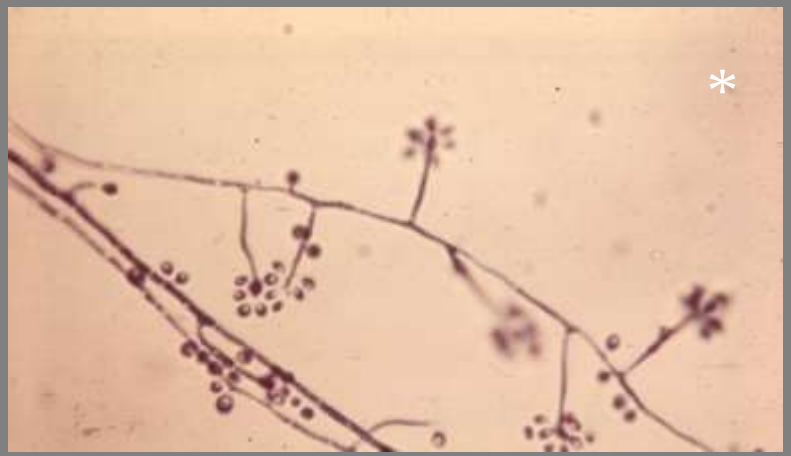
Ophiostoma sp. → periteci

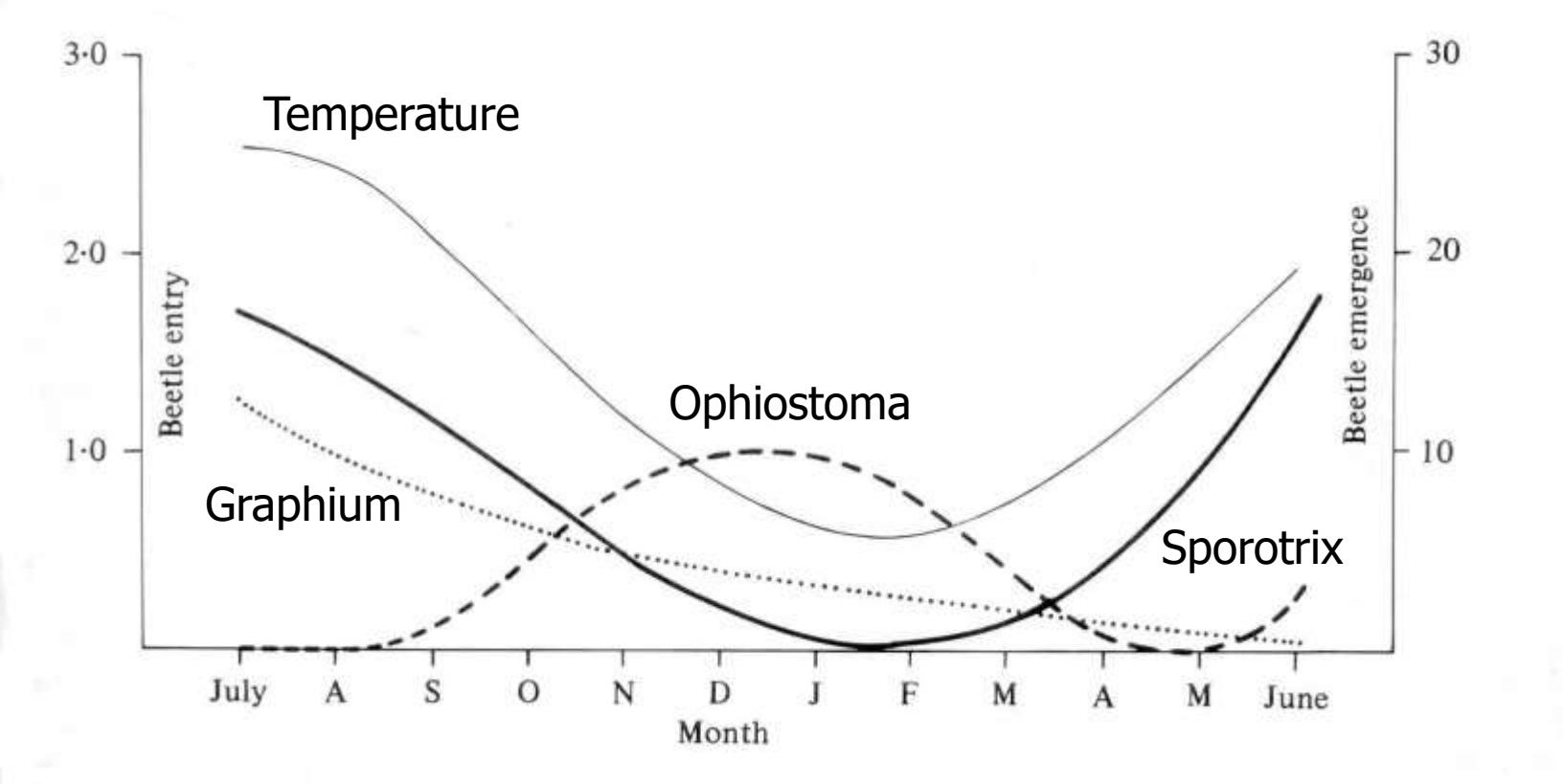


anamorfi

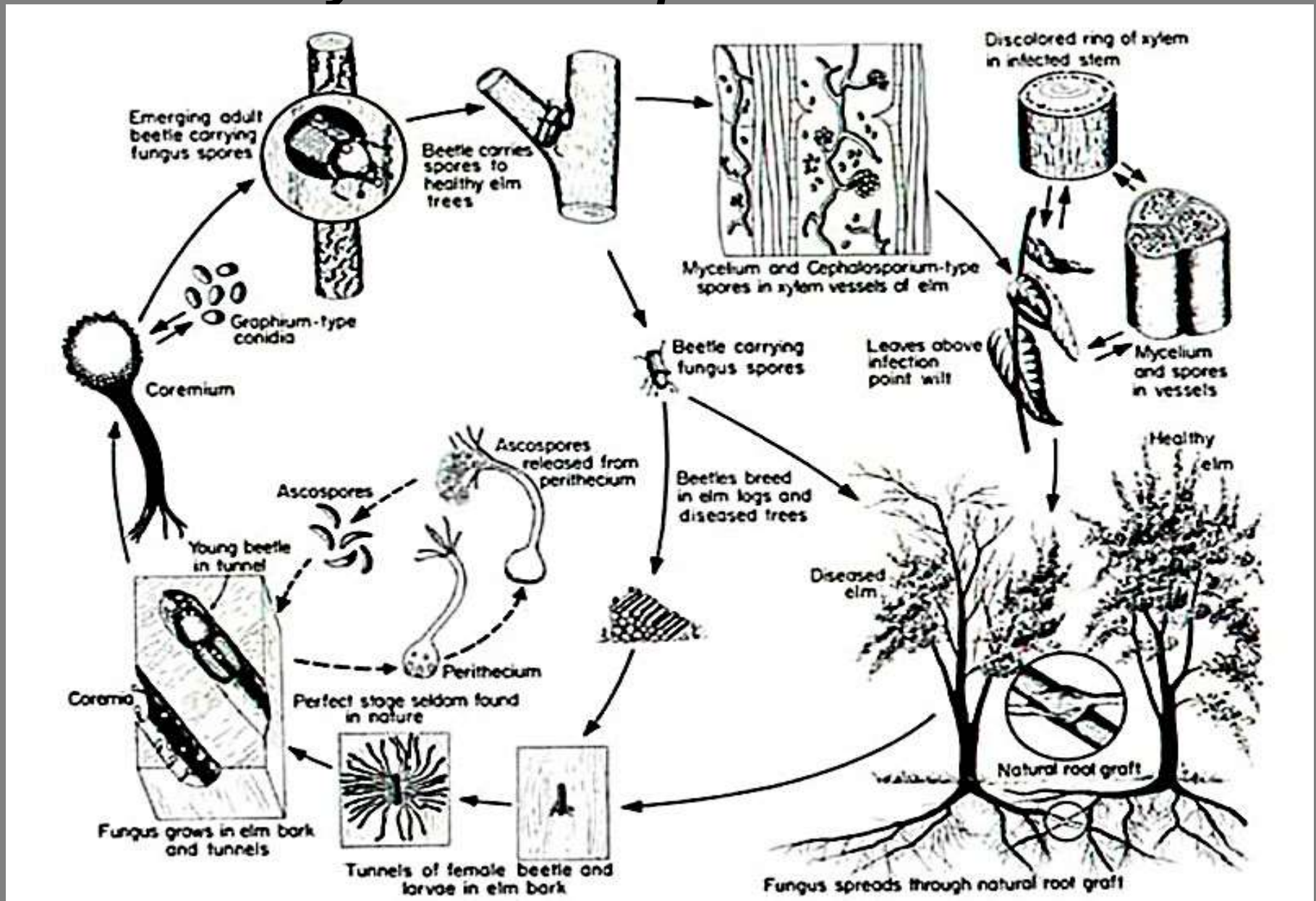
Graphium ulmi →

Sporothrix sp. →




Temperature
Ophiostoma
Graphium
Sporotrix
3·0
2·0
1·0
Beetle entry
30
20
10
Beetle emergence
July
A
S
O
N
D
J
F
M
A
M
June
Month

Life Cycle of *Ophiostoma ulmi*



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

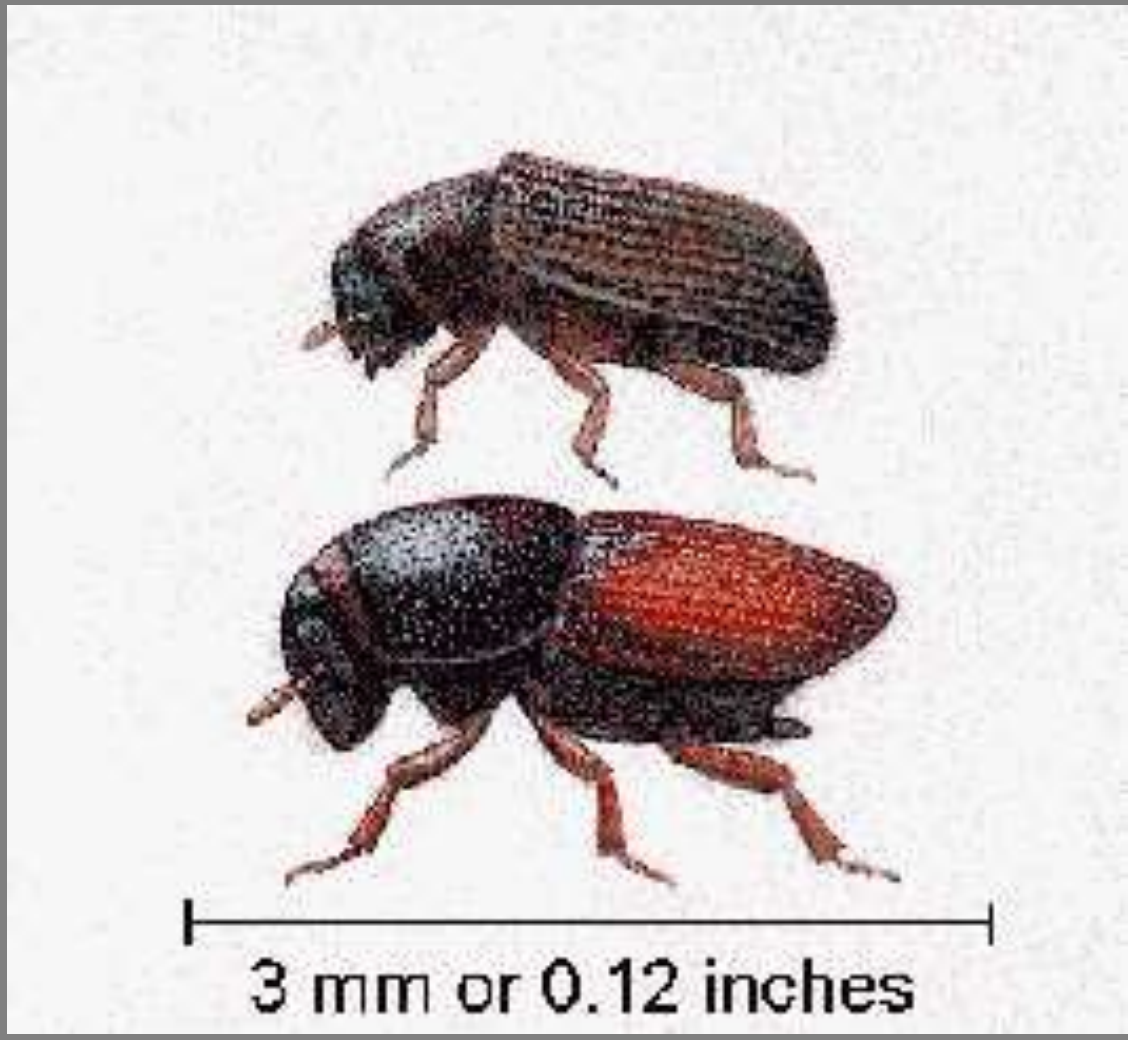
- Infected logs: Often transferred long distances

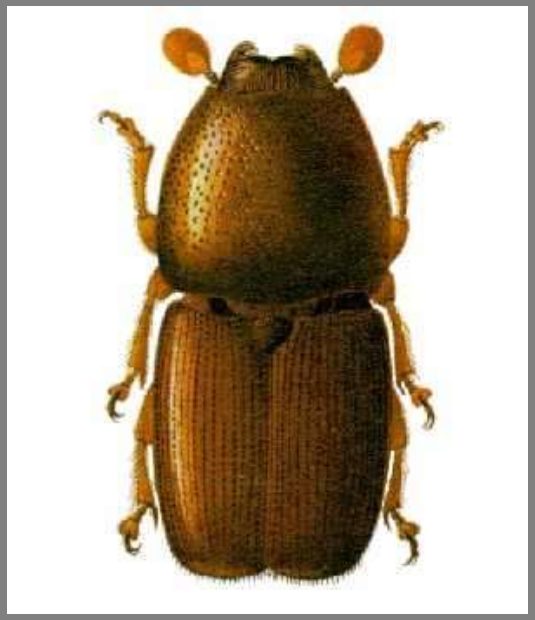
Beetles: key disease vector

1) Native elm bark beetle (*Hylurgopinus rufipes*) (above) is the primary vector in parts of the northern United States, New England, and all of Canada.

However, temperatures below -6F kill the larvae.

2) European elm bark beetle (*Scolytus multistriatus* Marsh.) (below) is the major vector of the disease.





Scolytus scolytus
S. sulcifrons
S. multistriatus
S. pigmaeus
S. laevis

Tracheomicosi

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

Tracheomicosi

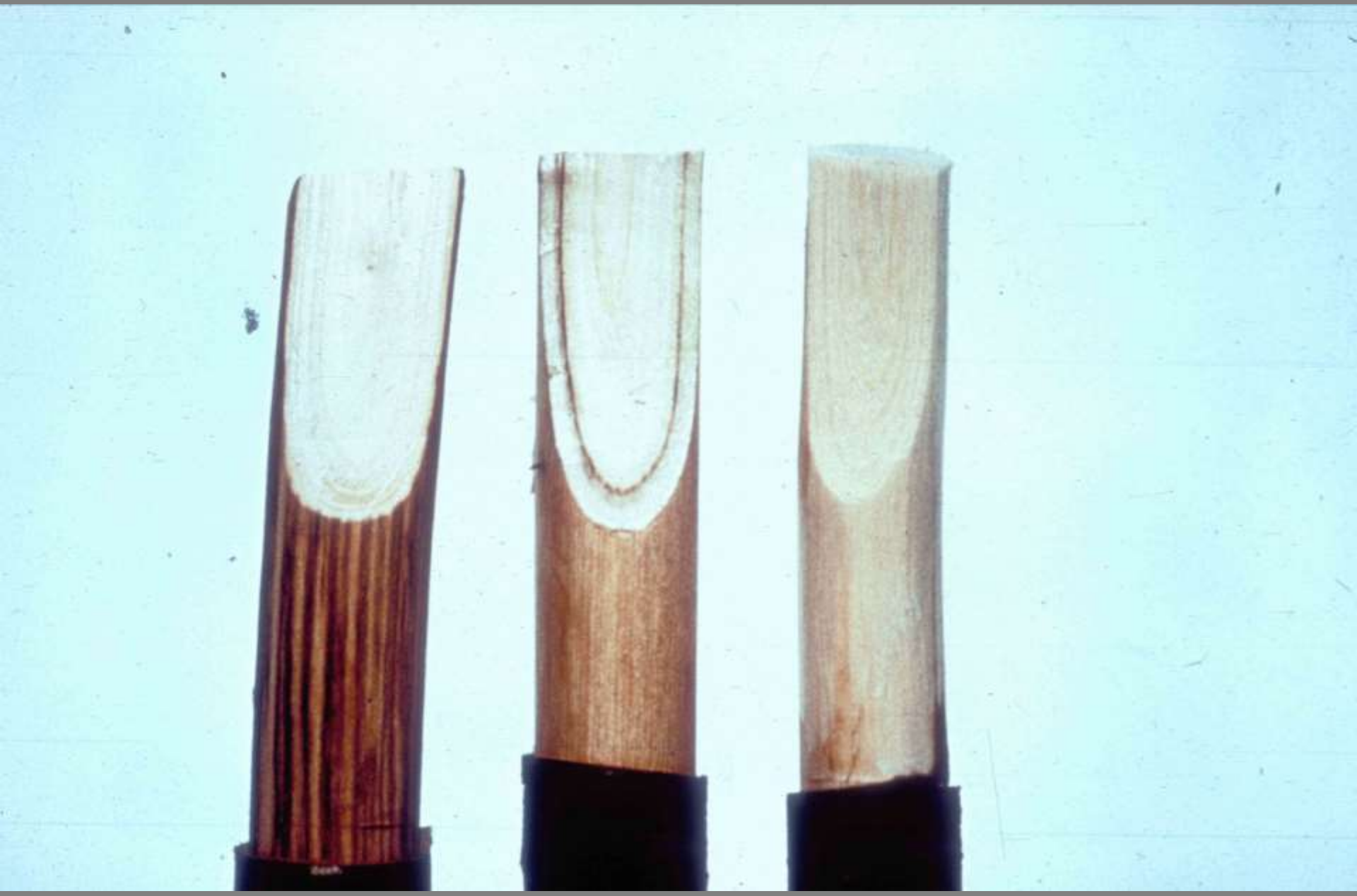
Elm bark beetle galleries

Maturation feeding

Elm root grafts

Dutch elm disease – crown symptoms

Dutch elm disease – vascular discoloration



- 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

Tracheomicosi

1970

1976

1977

1978

1991

History of the Disease

- Disease was unknown in Europe and N. America before 1900

- Since 1910, two pandemics
- Pandemics caused by two different species:
  - 1) *Ophiostoma ulm*
  - 2) *Ophiostoma novo-ulmi*

- In both cases, geographic origins are still unknown (probably Asia)

Ospiti

Ulmus carpinifolia
U. glabra
U. hollandica
U. campestris
U. laevis
U. americana

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, and coupled w/fungicide use.

- Thought of as the most effective way of curbing DED.

Management: injections

- Systemic fungicides labeled for preventative control, injected into root flares. Effective on trees showing < 5-10% crown symptoms.

- Need new injections every 3 years, expensive.

Management: Spraying

- Best when coupled w/sanitation methods.
- Timing of spraying is important

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.

Selezione di piante resistenti

•"Lobel" e "Plantyn": zone fresche dell'Italia settentrionale o in ambienti montani e collinari dell'Appennino;

•"Columella": portamento fastigiato, ha un buon livello di resistenza;

•"Prospector" (selezione di *Ulmus wilsoniana*) e "Dynasty" (selezione di *U. parvifolia*) adatte anche alle zone calde;

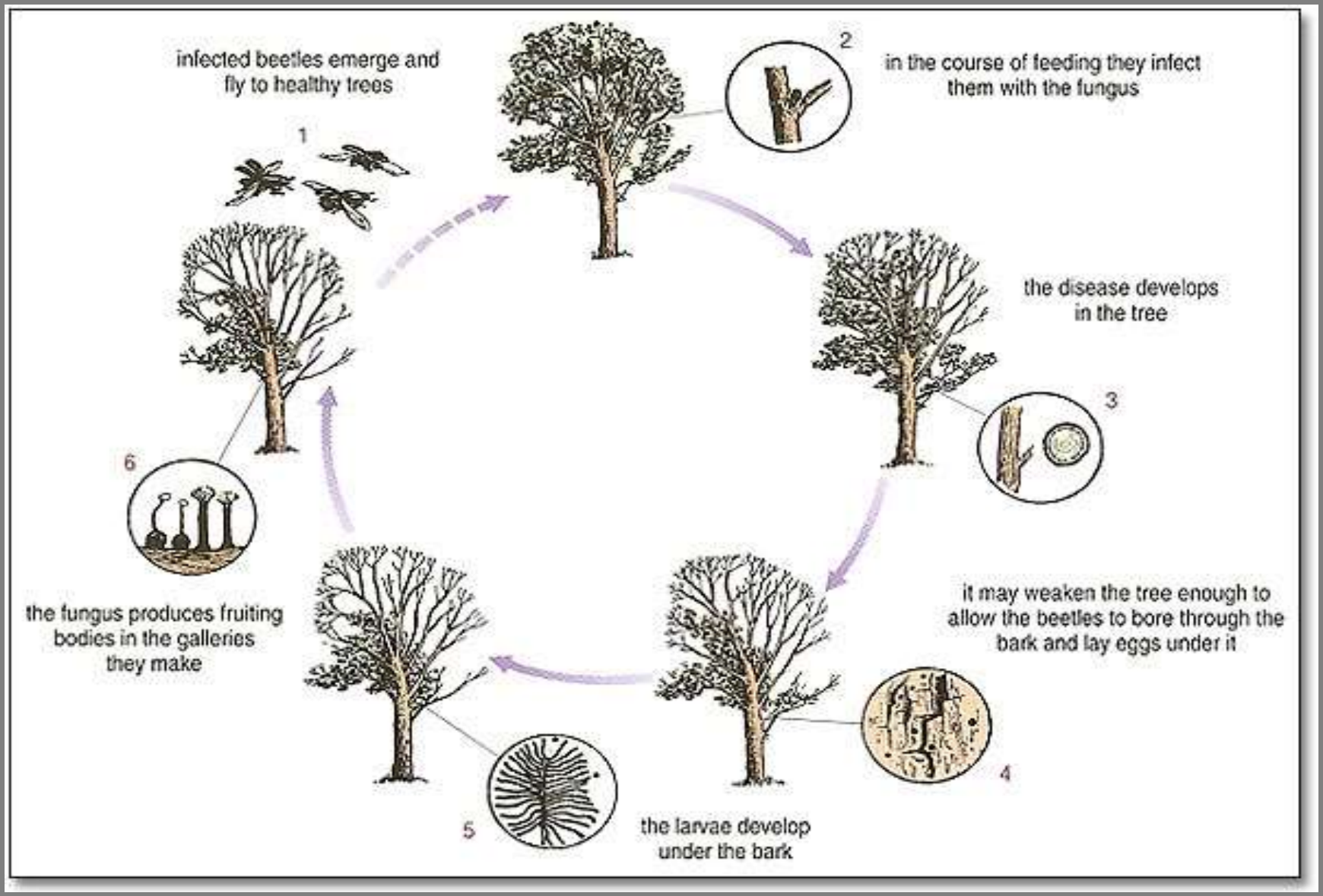
•"Sapporo Autumn Gold": alto livello di resistenza ma di crescita piuttosto disordinata.

Lotta chimica contro il fungo

prodotti sistemici benzimidazolici

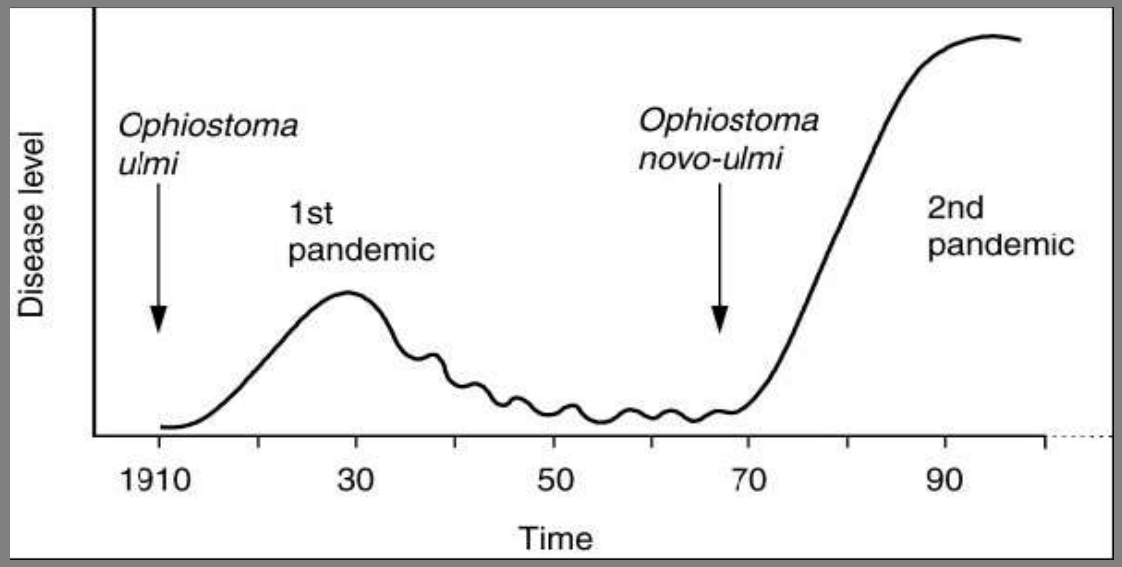
Lotta al vettore

tronchi esca/feromoni/insetticidi

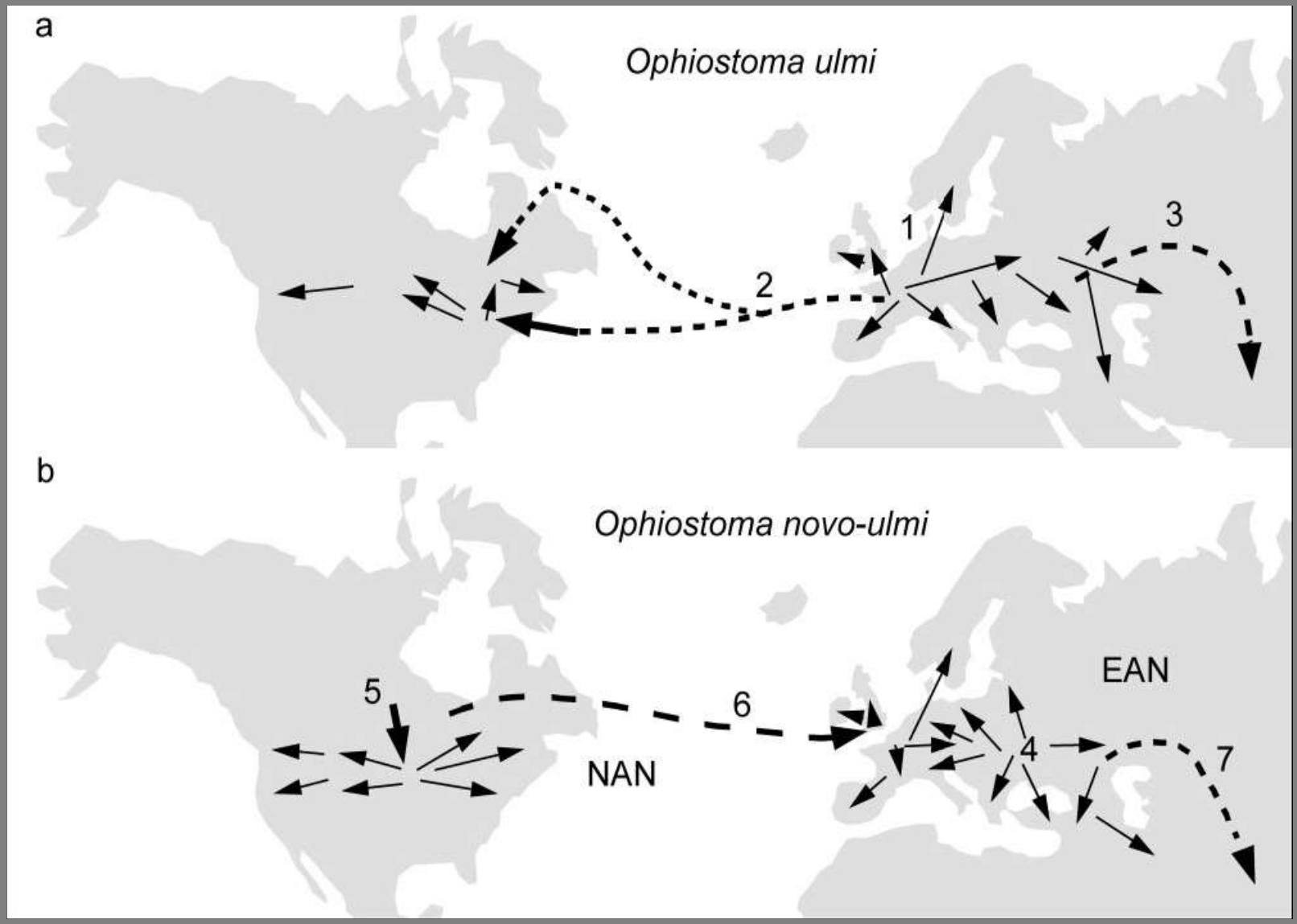

infected beetles emerge and fly to healthy trees
1
2
in the course of feeding they infect them with the fungus
the disease develops in the tree
3
it may weaken the tree enough to allow the beetles to bore through the bark and lay eggs under it
4
the larvae develop under the bark
5
the fungus produces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

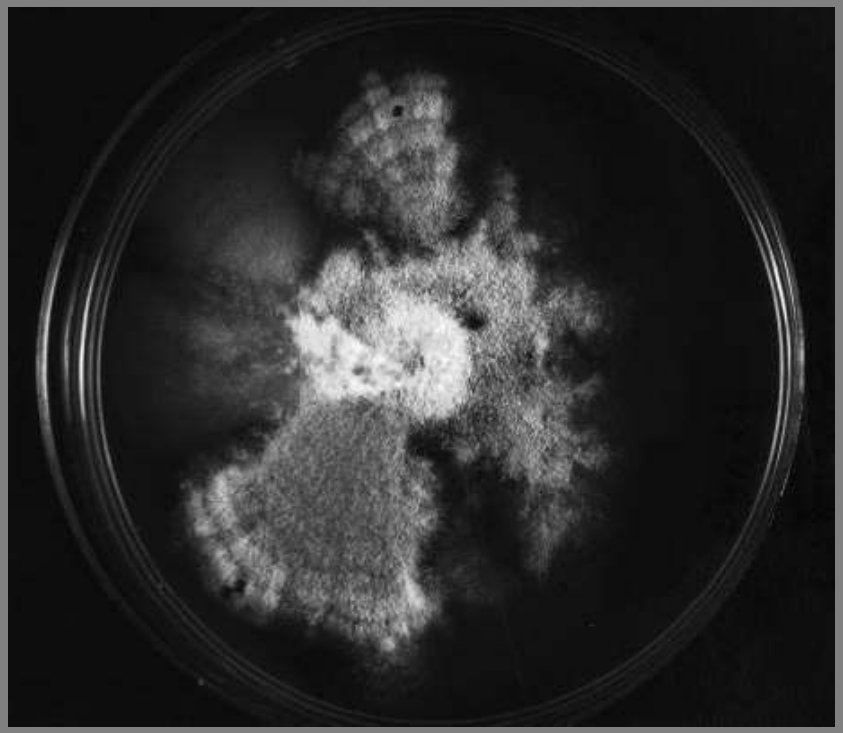
- DNA Fingerprinting
  - Probed with cloned dna fragments to distinguish between two species
  - Some *O. novo-ulmi* isolates had rare *O. ulmi* like polymorphisms
    - Acquired through introgression
  - 15 of 50 O. novo-ulmi isolates had *O. ulmi* gene
  - 1 had altered phenotype
    - Less aggressive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

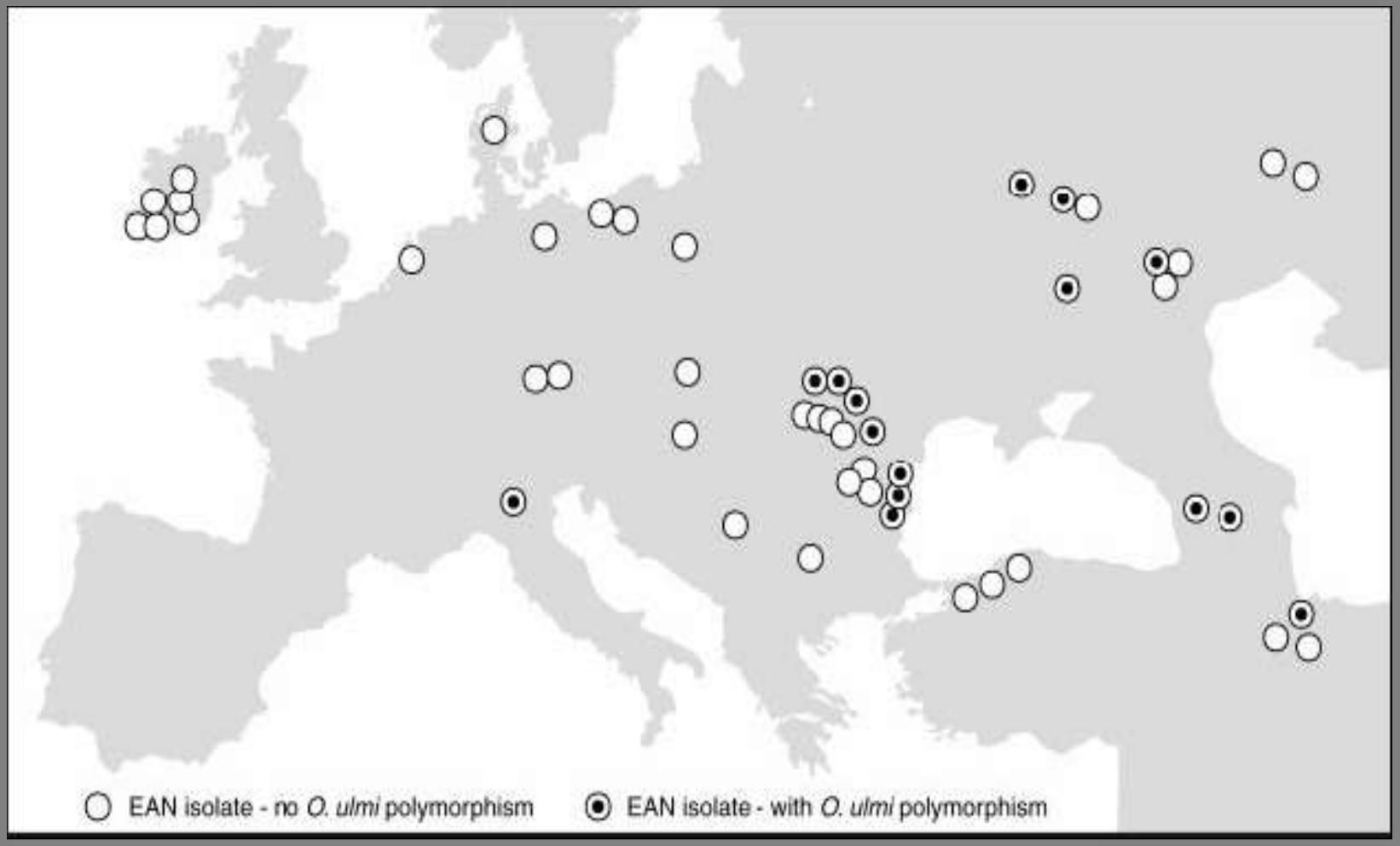
Europe

- 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