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
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)
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
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. →
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
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
• 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
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 effective.
- 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

in the course of feeding they infect them with the fungus

the disease develops in the tree

it may weaken the tree enough to allow the beetles to bore through the bark and lay eggs under it

the larvae develop under the bark

the fungus produces fruiting bodies in the galleries they make
• 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
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 $O. \text{ novo-ulmi}$ isolates had rare $O. \text{ ulmi}$ like polymorphisms
    • Acquired through introgression
  – 15 of 50 $O. \text{ novo-ulmi}$ 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 Compatibility (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 Himalayanas 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