Summary of previous lecture

- The disease triangle
  - HOSTs: their distribution, density, species or variety composition, resistance type and frequency of resistance, competence, presence of alternate hosts, generation time, metapopulation structure
  - PATHOGENs: genomic structure, genetic diversity, reproductive strategy, population size, ability to move (human but also natural). What will affect dispersal ability of pathogens?
  - HUMANs: monocultures, history of introductions, use of multiple varieties, use of resistance, exposure to chemicals

“Anthropogenic effects in time: by shortening forest rotation times we increase pathogen virulence and disease incidence”

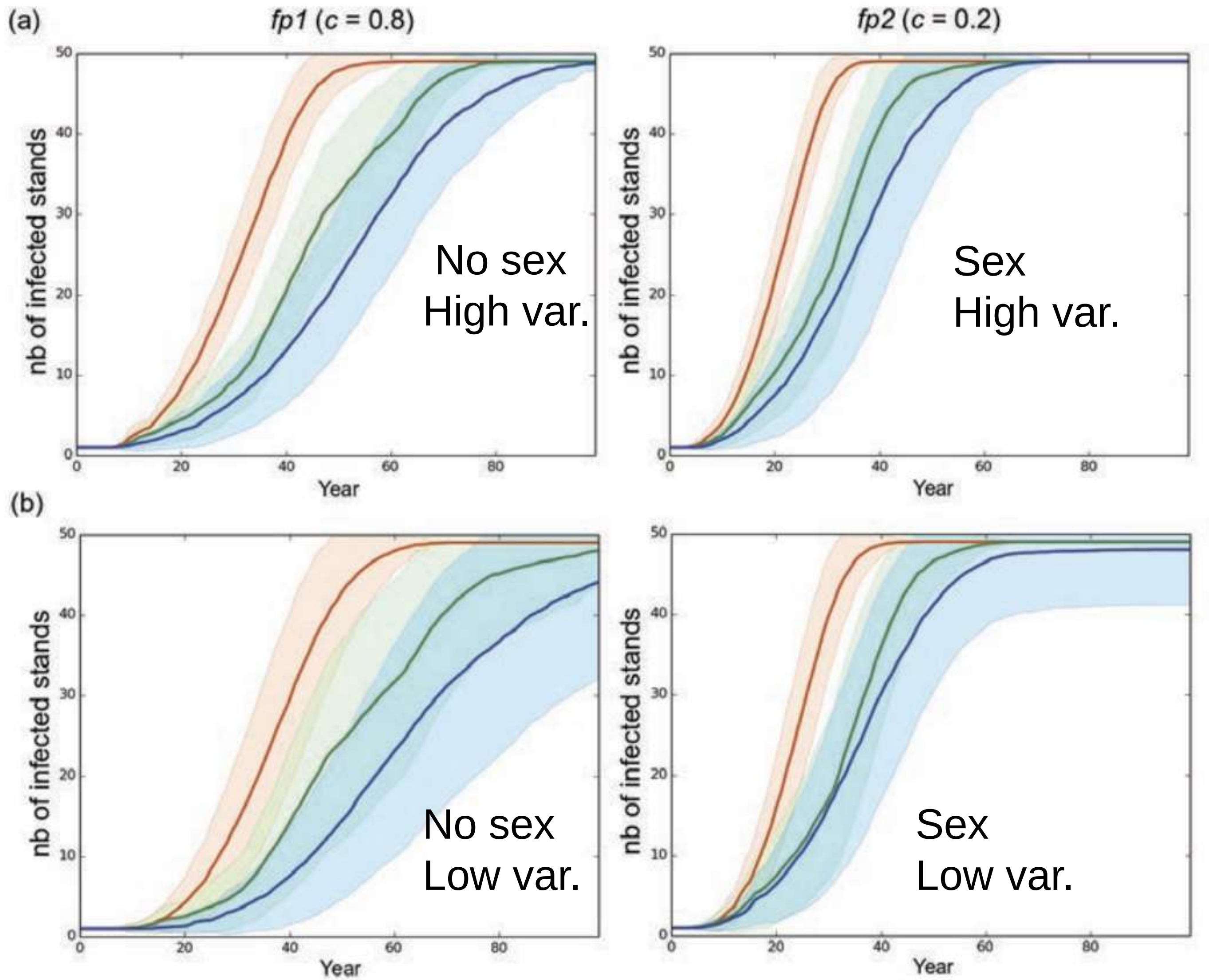


Figure 3. Effect of the rotation length on the propagation of the pathogen. (**a**) high initial genetic variance V_0 of 4.06 in the starting fungal population (default scenario); (**b**) reduced initial genetic variance V_0 of 1.63 in the starting fungal population. Left column: mostly clonal fungal profile *fp1* (clonality rate $c = 0.8$). Right column: mostly sexual fungal profile *fp2* ($c = 0.2$). Red, green and blue represent a rotation length of 15, 30 and 50 years, respectively. Each line is the mean of 50 indepe… replicates simulated. Each colored area represents the standard deviation of the 50 replicates.

Article

Short Rotations in Forest Plantations Accelerate Virulence Evolution in Root-Rot Pathogenic Fungi

An interesting example of “human x time” effects

Red line=15 years
Green line=30 ys
Blue line= 50 ys

Climate changes and directly benefits (or hurts) plant pathogens

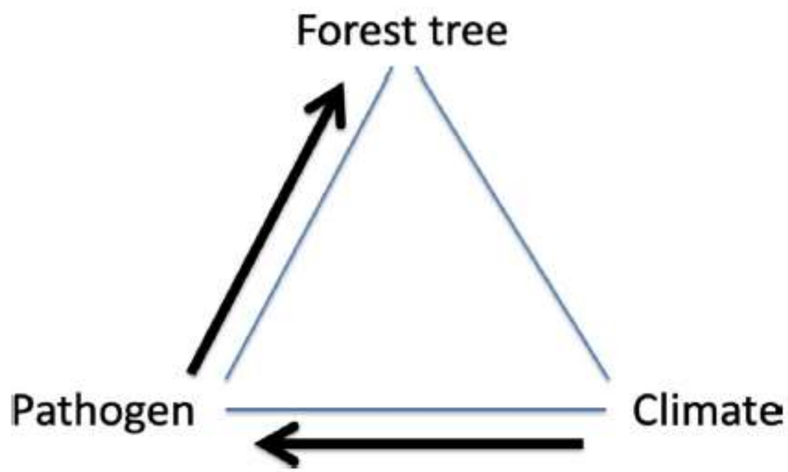


FIGURE 2 Type 1. Climate-pathogen disease. Modified plant disease triangle to show how climate can favour a pathogen to increase forest tree disease

1)- Rainfall increases and temperatures are milder and relative humidity higher because of increased cloud cover then pathogen will produce more infectious propagules (spores) having a positive effect on pathogen and a negative effect on plant

2)- Climate is milder in winter thus extending the growing season of a pathogen that does not do well in cold, having a positive effect on pathogen and a negative effect on plant

3)- In warm areas climate gets too hot, having a negative effect on pathogen and a positive effect on plant

A framework to evaluate climate effects on forest tree diseases

Climate changes and by stressing plants, indirectly benefits (or hurts?) pathogens

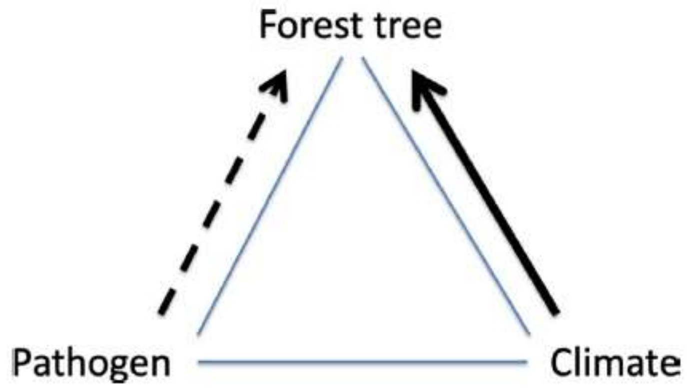


FIGURE 4 Type 2b. Climate-stress disease with one or more secondary agents. Modified plant disease triangle to show how climate can directly stress a forest tree but secondary pathogens (or insects) are required to cause tree

1)- Altered plant physiology due to reduced water availability: increase In gaseous phase in plant causes Dr Jekyll-Mr Hyde shift in endophytic fungi.

2)- Reduced photosynthesis causes reduced defense

3)- Extreme weather creates flooding that facilitate waterborne pathogens or increases damage to plants (via hail or frost injury) which in turn facilitates infection by wound pathogens

4)- Effects of smoke?

A framework to evaluate climate effects on forest tree diseases

Interesting examples of host-mediated effects of climate change on disease

- Climate changes host phenology;
  - Flowering is anticipated and by the time a pathogen of flowers is ready to infect, it is too late
  - Synchronicity among host susceptibility, and pathogen sporulation is lost

Evidence for the role of synchronicity between host phenology and pathogen activity in the distribution of sudden oak death canker disease

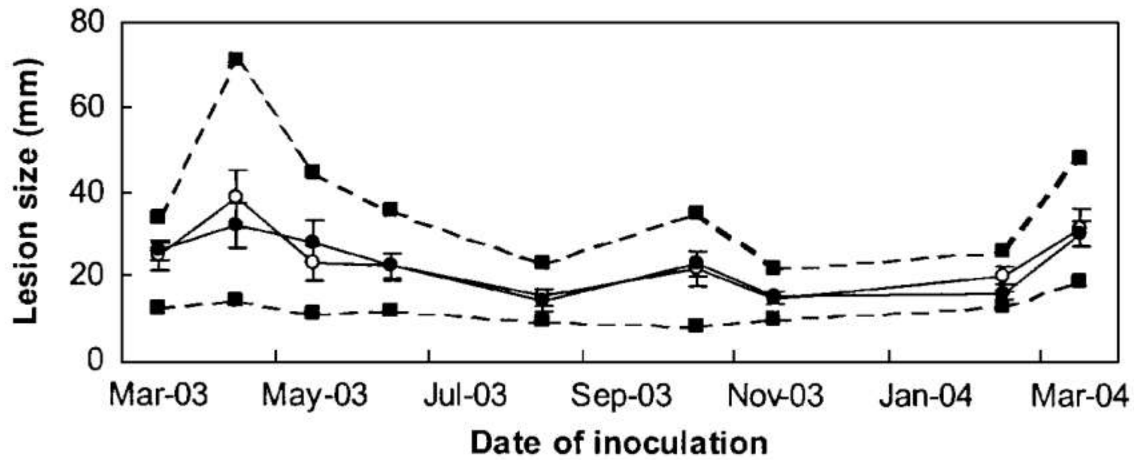


Fig. 1 Size of lesions at different inoculation dates in coast live oak (*Quercus agrifolia*) after inoculation with *Phytophthora ramorum*. Open circles, Chicken Coop site; closed circles, Miwok site. Overall maximum and minimum lesion sizes are shown as dotted lines with closed rectangles. Standard errors are shown as vertical bars.

Pathogen sporulating

Pathogen sporulating

Evidence for the role of synchronicity between host phenology and pathogen activity in the distribution of sudden oak death canker disease

DISEASE AS THE RESULT OF CLIMATE CHANGE AS A DISTURBANCE: ARE THE CONSEQUENCES PERMANENT (RED LINE) , TEMPORARY (DOTTED LINE) OR CYCLICAL WITH A TREND (YELLOW LINE)?

Forests **2017**, *8*, 147

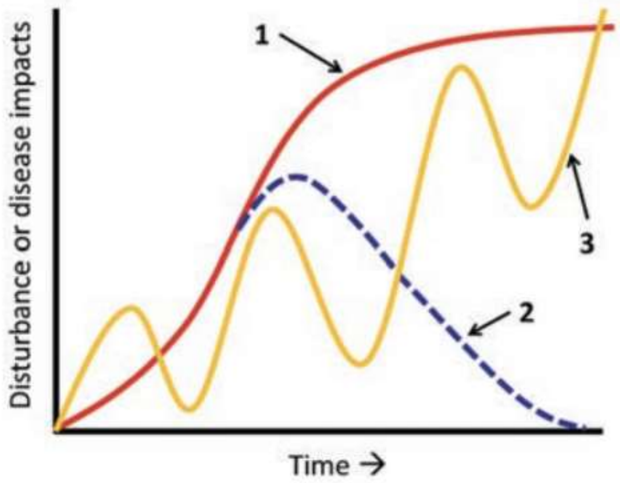


Figure 2. Several examples of disturbance and disease interactive outcomes over time. Impacts may increase and reach a new stable state (1—red); increases may gradually recover to pre-outbreak levels (2—blue dashed); or feedbacks between disease and disturbance could create fluctuating dynamics over time, here depicted as an oscillating, but increasing impact (3—yellow).

Review

Tree Diseases as a Cause and Consequence of Interacting Forest Disturbances

Decrease in disease, whether permanent or cyclical, means also recovery

Disease thus has to be seen as a dynamic process affected by infection rates, pathogen population size, host population size and distribution, changes in virulence of pathogen and in resistance of host, climatic changes and recovery of host

Transmission rates: competency of host (sporulation support), infectiousness of pathogen, pathogen reproductive rate R, weather

Host population size and its density across the landscape: higher density more disease, as number of host decreases, escape become more likely

Resistance in host populations: how many individuals carry some level of resistance, and how short or long is generation time. Shorter generation time, resistance more likely to increase

Virulence in pathogen: how many pathogens carry virulence genes and generation time. Faster generation time , faster increase in virulence

Migration rates of host: if host receives migrants from outside the zone of infestation, less likely to increase its resistance.

Recovery: the Sudden Oak Death example . Repeated sampling over 10 years shows that:

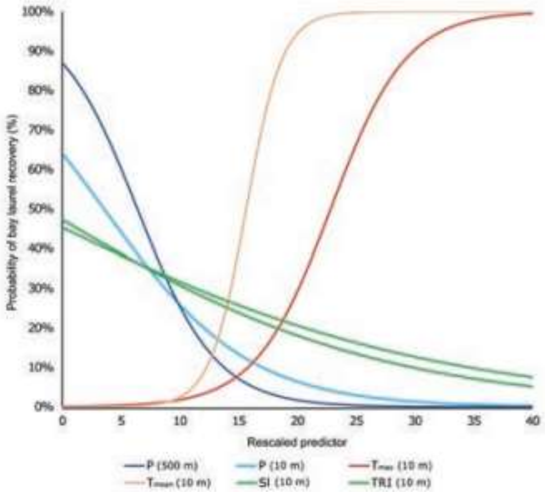


Figure 6. Graphs of the logistic equations modelling the probability of bay laurel recovery based on the single significant predictors detected in scenario-500 m (500 m) and scenario-10 m (10 m). The abscissa (rescaled predictor) represents each factor eventually rescaled so that one unit equals: 100 mm for precipitations (P), 1 °C for temperatures (T), 1% for slope (Sl) and 10 points of terrain ruggedness index (TRI). For more details about factors acronyms, see the main text.

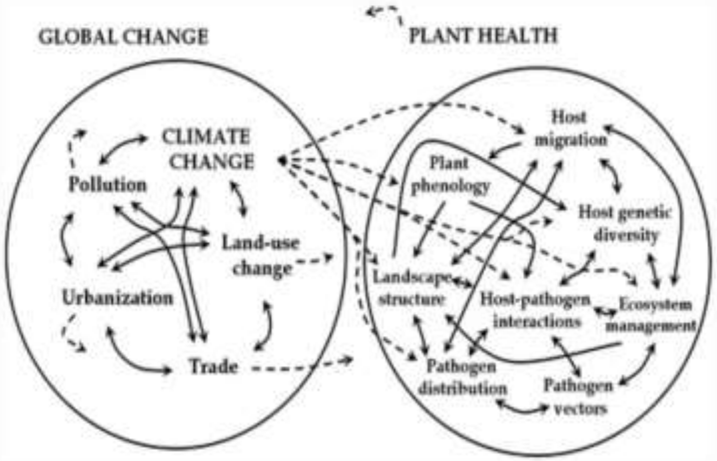
The more rain the less recovery
The hotter it is the more recovery
The steeper the landscape slope the less recovery

Article

Environmental Factors Driving the Recovery of Bay Laurels from *Phytophthora ramorum* Infections: An Application of Numerical Ecology to Citizen Science

GLOBAL CHANGE AND ITS EFFECTS ON PLANT HEALTH

From: Impacts of climate change on plant diseases—opinions and trends



Global change impacts on plant health. Global change is composed of the interactions of various drivers (climate change, increased trade, land-use change, pollution, urbanization). All these factors will have an impact on plant health, through direct effects on host-pathogen interactions, and via indirect effects on host migration, genetic diversity and phenology, as well as on disease distribution, insect pests, vectors and landscape structure. There is a feedback from plant health to global change. To be successful in the face of global change, ecosystem management will have to consider this complexity of interactions (modified from Pautasso 2012)

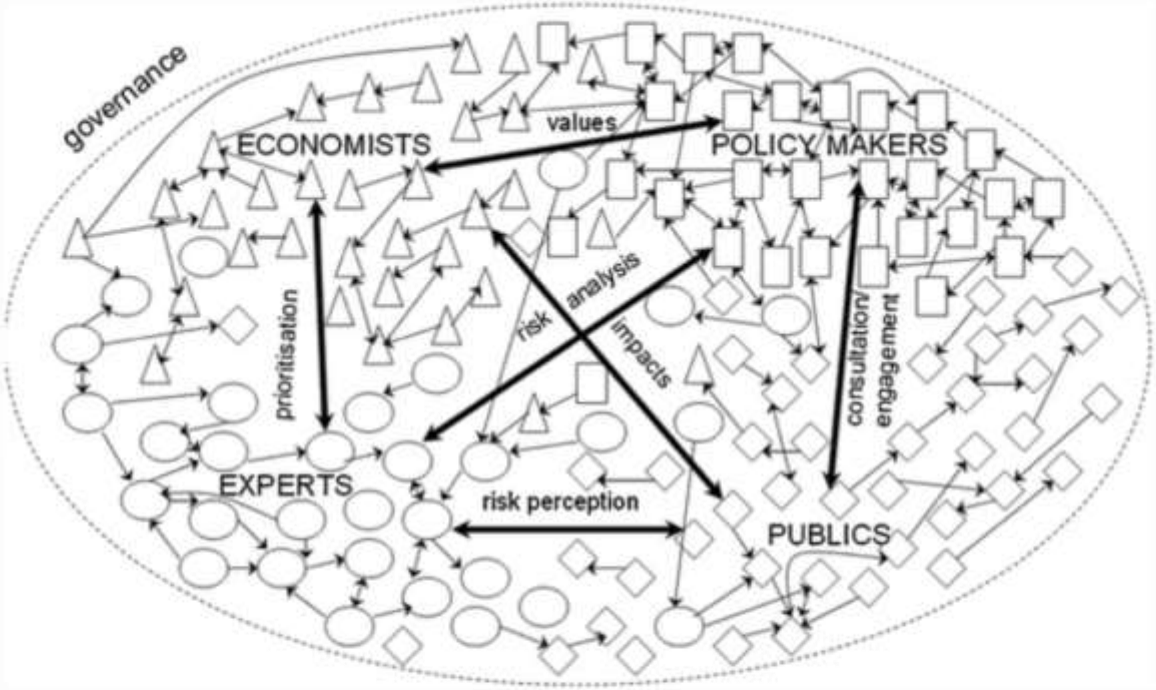
Impacts of climate change on plant diseases—opinions and trends

Marco Pautasso, Thomas F. Döring, Matteo Garbelotto, Lorenzo Pellis & Mike J. Jeger

European Journal of Plant Pathology 133, 295–313 (2012) | Cite this article

There is no easy solution

Fig. 4



Network of interactions among experts (*circles*), economists (*triangles*), publics (*diamonds*) and policy makers (*rectangles*) in the plant health governance landscape. For a successful management of plant health problems in a changing environment, there is need for better information flow among the components of this network. Modified from Mills et al. (2011)

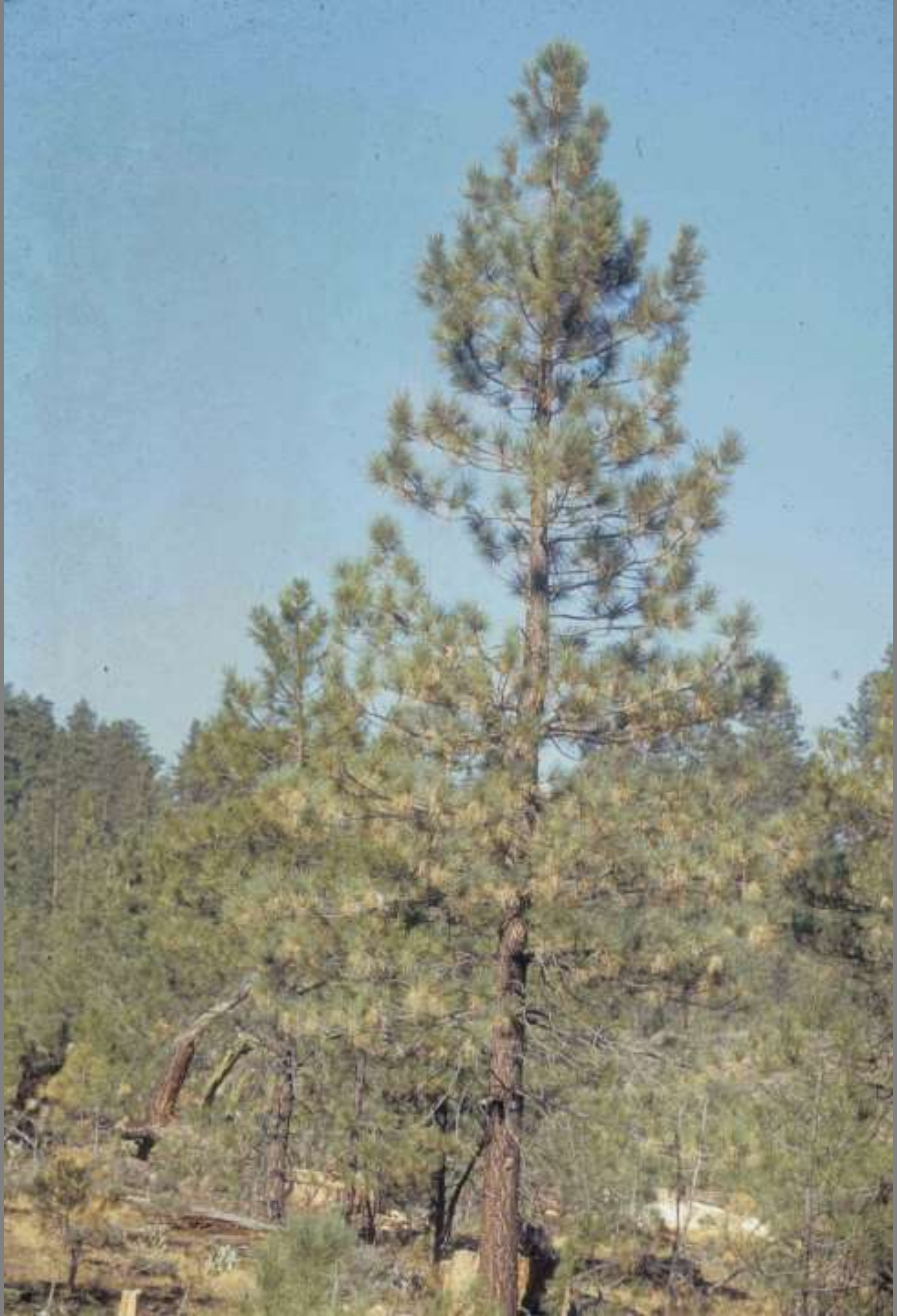
ABIOTIC DISEASES

Maple scorch

Premature needle yellowing and loss on ponderosa pine

Ozone mottle

Loss of vigor in ponderosa pine exposed to ozone



Smog symptoms on ponderosa pine in southern California

Advanced smog symptoms on ponderosa pine

Acute SO_2 injury

Ash

Persimmon

BIOTIC DISEASES caused by:

Parasitic plants
Bacteria
Fungi
Oomycetes
Viruses

Nematodes

Biotic diseases can be grouped by:

- Agent causing disease (fungus, oomycete, virus, bacteria, plant)
- Host specificity of pathogen: generalist, specialist or “in between” (e.g. limited to a plant family or to conifers)

- Plant part affected (flower , fruit, leaves, branches, stems, roots, vessels, cambium)
- Scale of infection (from one tree to a whole forest)

- Age of host (juvenile vs. adult vs. mature)
- Whether plant tissue is dead or alive: biotroph, hemibiotroph, necrotroph,

- Type of hosts1: whether it affects primary (source) and secondary (sink) hosts
- Type of hosts 2: whether it has transmissive and dead-end hosts

- Type of hosts 3: whether it needs to alternate between different host
- Virulence: whether it is primary, secondary (opportunistic) or a latent pathogen that can change lifestyle

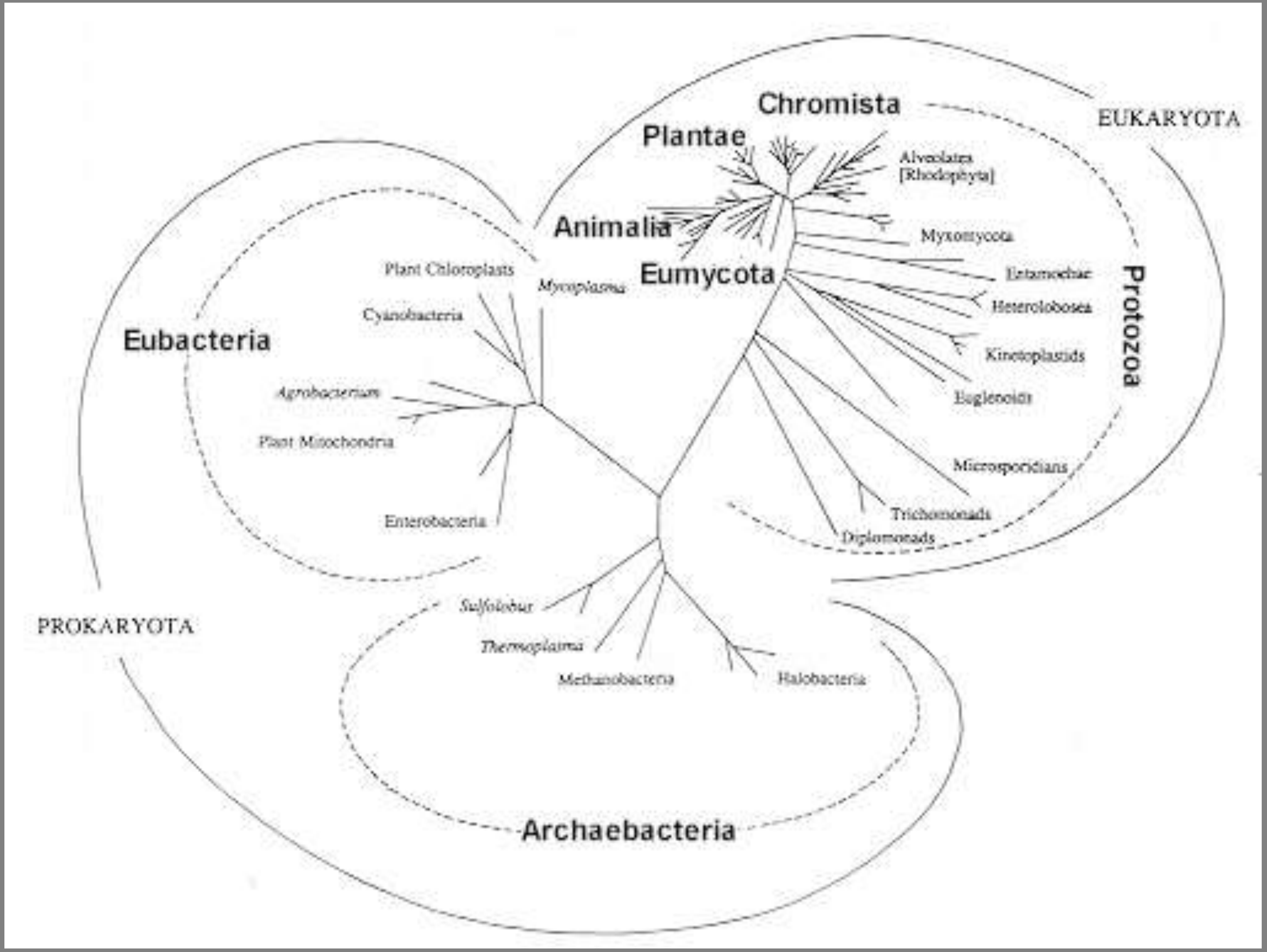
- Wound vs non-wound pathogen
- Airborne vs waterborne and/or soilborne

- Vectored by animals or not
- Pathogen’s reproductive mode: clonal, sexual , mixed

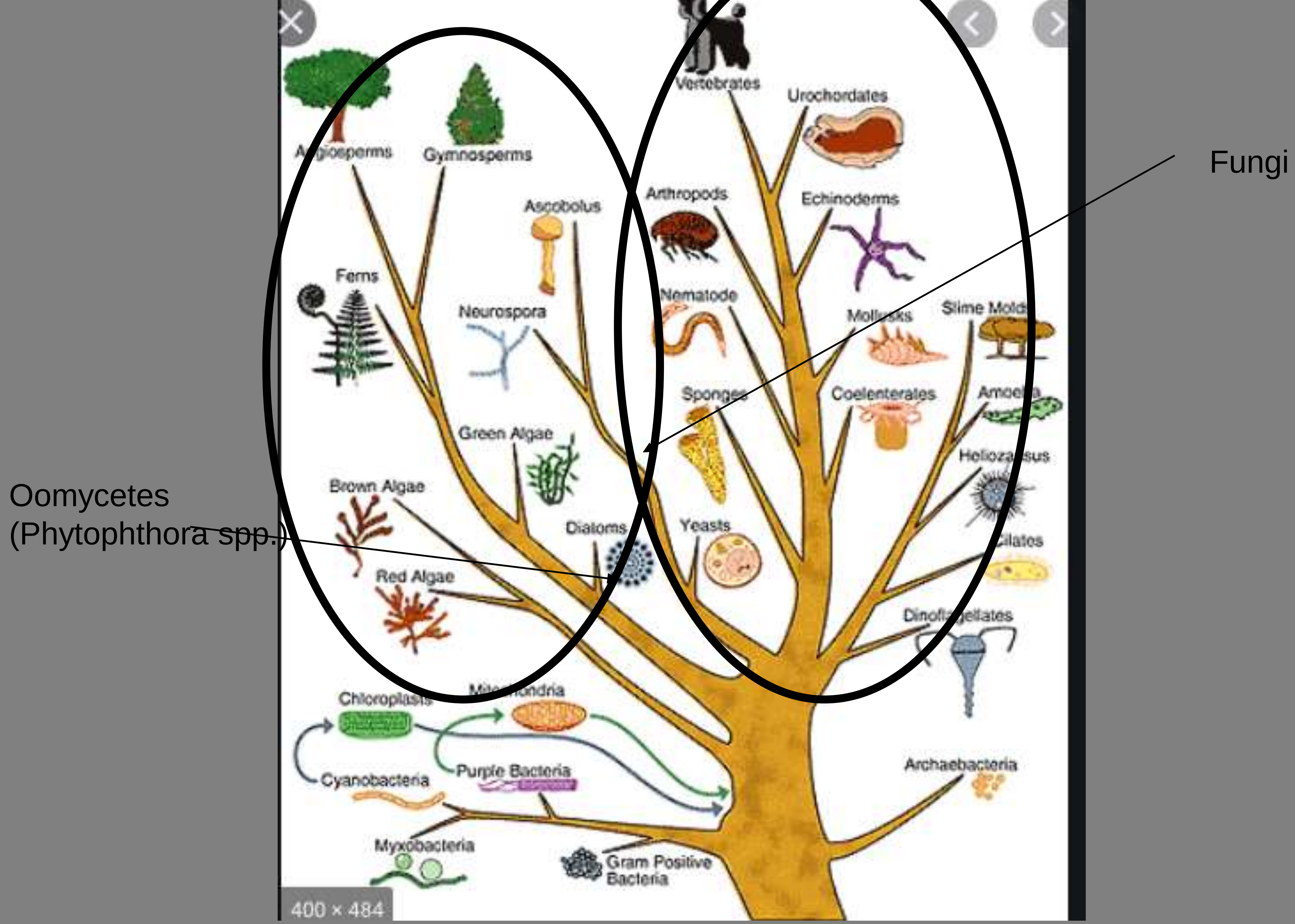
Definitions

- Biotroph: a plant pathogen which establishes a long term feeding relationship with the living cells of a host, without killing it as part of the i infection process.(unculturable!)
- Hemibiotroph: An organism that is parasitic in living tissue for some time and then continues to live in dead tissue
- Necrotroph:a parasitic organism that kills the living cells of its host and then feeds on the dead matter

Tree of Life, from Patterson & Sogin, 1992



CHROMISTA now referred to as STRAMINIPILA



Fungi
Oomycetes
(Phytophthora spp.)
Vertebrates
Urochordates
Gymnosperms
Ascobolus
Arthropods
Echinoderms
Ferns
Neurospora
Nematode
Mollusks
Sponges
Coelenterates
Amoeba
Green Algae
Brown Algae
Diatoms
Yeasts
Red Algae
Dinoflagellates
Chloroplasts
Cyanobacteria
Purple Bacteria
Archaebacteria
Myxobacteria
Gram Positive Bacteria
400 × 484