GENOMICS IN SOCIETY

Genetic Resistance to Swiss Needle Cast (SNC)

What are forest diseases?

- Similar to how humans can become sick due to bacterial or viral infections, trees can be infected by various types of fungi that cause illness or long-term disease
- When humans are sick, the symptoms may include coughs, colds, fevers, etc. that affect our daily metabolism & functions – trees also experience symptoms which inhibit their ability to function & metabolize
    - Examples: diseases can inhibit water transport through the tree stem, inhibit photosynthesis by causing leaves to decay, or inhibit water uptake from the soil by causing root rot
    - Symptoms on trees include, but are not limited to, crown dieback, leaf spots, dead branches, decaying wood & bark, stem girdling, rotting roots, leaf wilt, browning/yellowing leaves, and more

→ Unlike humans, there is no medicine trees can take to cure their illness, so we need to use forest management to help trees overcome disease & prevent the spread of aggressive pathogens that cause forest diseases

Forest disease symptoms – examples

A ‘bleeding canker’ is a common symptom on trees with sudden oak death disease caused by the oomycete pathogen *Phytophthora ramorum*.

Dead/dying crowns are a common symptom on larger pine trees with white pine blister rust caused by the pathogen *Cronartium ribicola*.

Browning & dead needles are a symptom on pine trees with Dothistroma needle blight caused by the fungal pathogen *Mycosphaerella pini*.

Dead & thinning crowns are a symptom on trees with annosus root rot disease caused by the pathogen *Heterobasidion annosum*.

Chlorotic & necrotic leaf spots are symptoms on poplar trees with septoria canker & leaf blight caused by the pathogen *Sphaerulina musiva*.

What is Swiss Needle Cast (SNC)?

- SNC is a foliage disease which occurs specifically on Douglas-fir trees and it is caused by a fungal pathogen that infects the needle-leaves of Douglas-fir
- Symptoms include:
  - Yellowing (chlorotic) needle-leaves
  - Crown-thinning, reduced needle retention, i.e. a ‘cast’ disease indicates that it causes hosts to prematurely shed (cast) their leaves
  - Reduced growth (diameter & height)
  - Reduced photosynthetic capacity due to the fungal fruiting bodies blocking the stomata of needle-leaves on infected hosts

SNC Signs & Symptoms

- Signs of SNC are visible under a microscope and consist of the fruiting bodies of the fungal causal agent that clog the stomata of needle-leaves on Douglas-fir:

- Visible symptoms of SNC include yellowing (chlorotic needles), thinning crowns, and reduced growth (diameter & height):

Causal agent of SNC

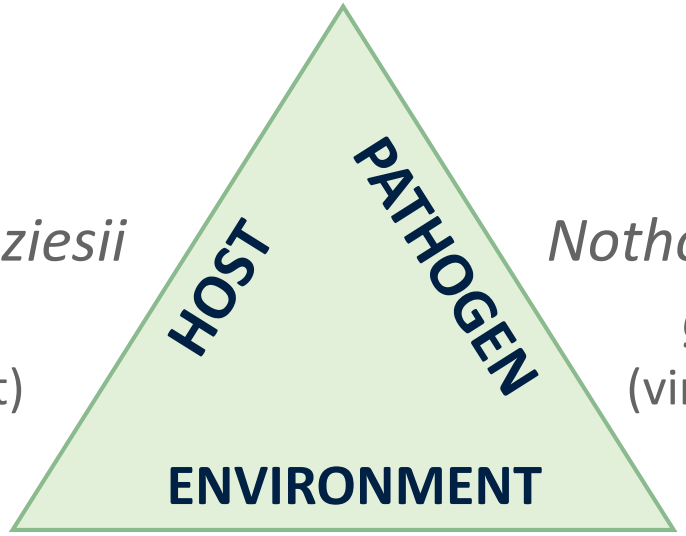
- SNC is caused by the fungal pathogen *Nothophaeocryptopus gaeumannii*
- The fungal spores enter through the stomata on the needle-leaves and grow fruiting bodies which occlude the stomatal pores, preventing gas exchange necessary for photosynthesis
    - If 30-50% of the stomata are occluded, it is more energetically efficient for the tree to shed (cast) the needle(s)
- *N. gaeumannii* is non-invasive and historically, it occurred naturally throughout the native range of Douglas-fir without posing much threat to survival of the host tree species
- Native pathogens are a natural component of a forest's disturbance regime, but under certain conditions, the impacts & spread of these disease can be amplified & exacerbated, leading to epidemics that threaten host species

→ This has been the case with SNC throughout the range of Douglas-fir due to climate change & other factors

SNC Disease Triangle

- The forest disease triangle consists of 3 main parts:

Pseudotsuga menziesii
Douglas-fir
(susceptible host)



Nothophaeocryptopus gaeumannii
(virulent pathogen)

Moist, warm winter + wet springs,
dense stands of pure *P. menziesii*

→ When these 3 key conditions are present, SNC disease will develop and infect Douglas-fir trees

What is disease resistance?

- Broadly, in an ecological community, resistance is a measure of how much a community is affected by a disturbance (e.g. fire, pest, pathogen, human interference)
    - More resistant individuals or communities are less affected it is by disturbances
- Specifically, the ability of an individual and/or population to resist or tolerate pathogenic infection based on genetic variation within the genome that conveys resistance or tolerance traits (traits can be physiological or morphological)
    - i.e. the ability of a species to defend itself against disease due to its genetic composition and diversity

How is disease resistance found?

- In the field, researchers can identify individual trees from infected populations that exhibit specific phenotypes which appear to convey resistance
- From there, researchers can take tissue samples from those apparently resistant trees and also from trees that appear to succumb to infection
- In the lab, researchers can genotype those samples and compare the genomes of the resistant and non-resistant trees to see if there are consistent genetic differences, i.e. do the resistant trees have different genes? Different gene expression? SNPs? Etc.

→ Ideally, if genetic resistance can be found, then resistant lineages can be bred

Disease resistance in other tree species

- Disease resistance has been found in some tree species, such as:
  - Asian and Chinese chestnut trees have been found to be resistant to Chestnut Blight disease, so researchers are trying to incorporate and hybridize those resistant genes into American chestnut trees
  - Western white pine trees have been the subject of many past and present studies looking to find resistance to White Pine Blister Rust disease—major gene resistance has been found in select populations, but research continues as more virulent strains of the disease emerge

→ Importantly, it is not possible to make tree species immune to disease, but selecting and breeding for resistance can improve tree species survival in conditions when disease is amplified

Potential for resistance to SNC

- Studies are ongoing, but there have been observations of Douglas-fir that appear to be resistant or tolerant to SNC in natural populations and experimental groups
- It is important to asses for resistance when Douglas-fir are young seedlings to be able to increase the chance of survival and improve the chances of establishing more resistant populations in the wild
- It is impossible to eliminate pathogens from forests, but establishing some level of resistance in natural populations is important for maintaining ecosystem health

Host resistance to SNC – Summary

- Forest diseases caused by pathogens, such as SNC, are a natural part of forest ecosystems; but, they can become harmful when the pathogen is either 1) non-native or 2) amplified by environmental conditions
- Genomics technology makes it possible for researchers to identify the genetic basis for host resistance or tolerance to diseases and thereby selectively breed trees that can overcome infections in their natural environment
- Disease resistance has been discovered in other tree species, and it is possible that it is present in Douglas-fir given the results of current research