Stress in a Changing Climate: Drought, Decline, and New Pest Threats

INVIGORATEU CONFERENCE 2026

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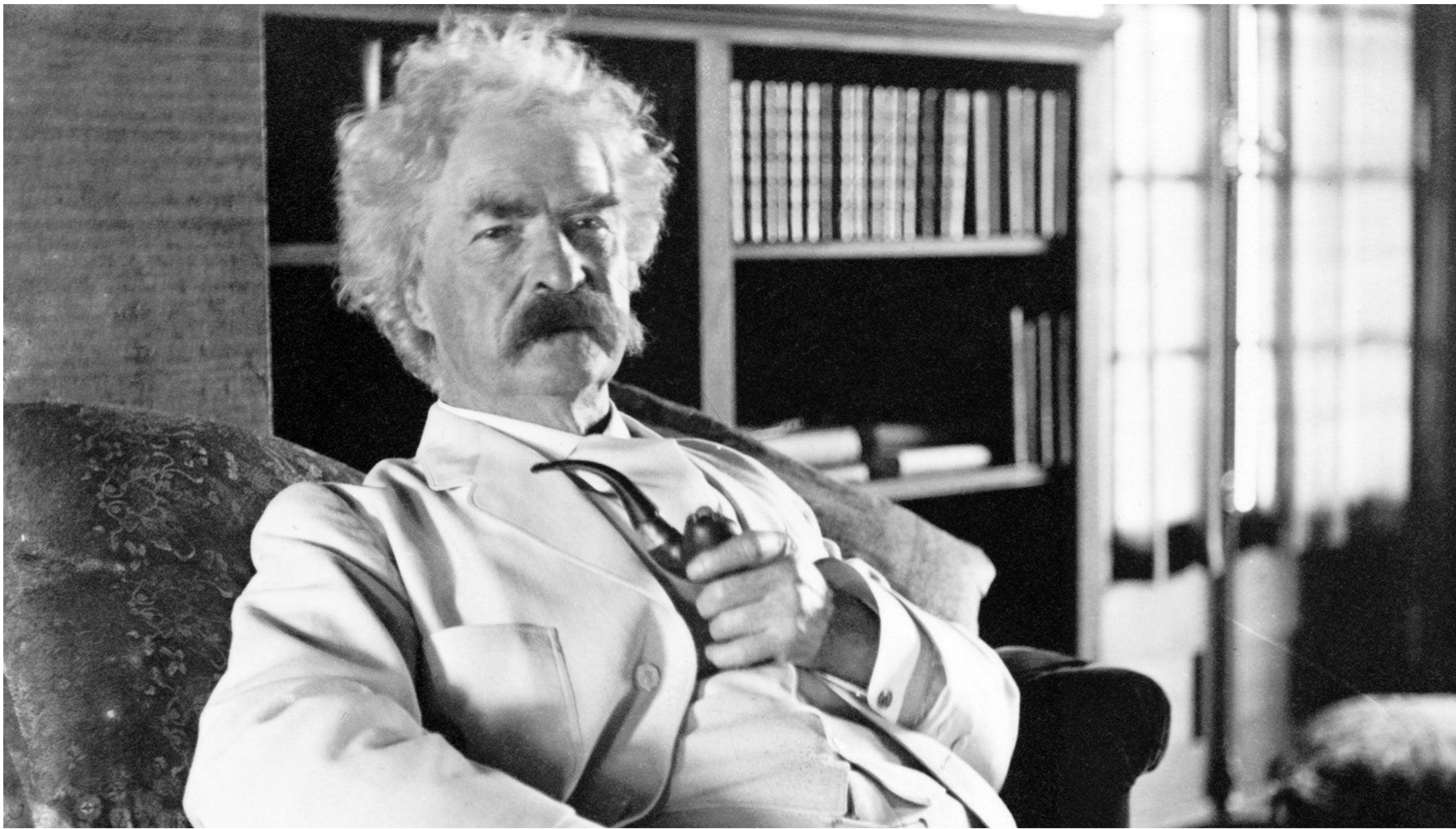
Presentation Outline

- **Historical and Future Climate Trends**
  - Weather versus Climate
  - Climate in the Last Century
  - Future Climate Predictions
- **Drought, Tree Physiology and The "Big Three"**
  - Transpiration (Water Potential, Cavitation, Embolism)
  - Photosynthesis and Growth
  - Respiration
  - Role of Hormones and Microbes in Drought Mitigation
  - Water Relations, Pests, and Diseases
- **PHC Practices to Help Mitigate Drought Effects**
- **Quick Pest Update**
  - SLF, Elm Zigzag Sawfly, New Disease of *Carpinus* spp.

“***Everyone Talks About the Weather, but They Never Do Anything About It***”

Mark Twain



Weather versus Climate (NOAA Definition)

- ***Weather and climate describe the same thing—the state of the atmosphere—but at different time scales***

- **Weather -** what you experience when you step outside on any given day or the state of the atmosphere at a particular location over the short-term

- **Climate -** average of the weather patterns in a location over a longer period of time, usually 30 years or more

Historical Climatic Patterns: 1911-1940 vs. 1971-2000

McEwan et al., 2011

- **Most important factors in drought stress**
  - Maximum spring-summer precipitation
  - Maximum summer temperatures
- Droughts less severe and less frequent
- Continued years with abundant moisture
  - More frequent and intense

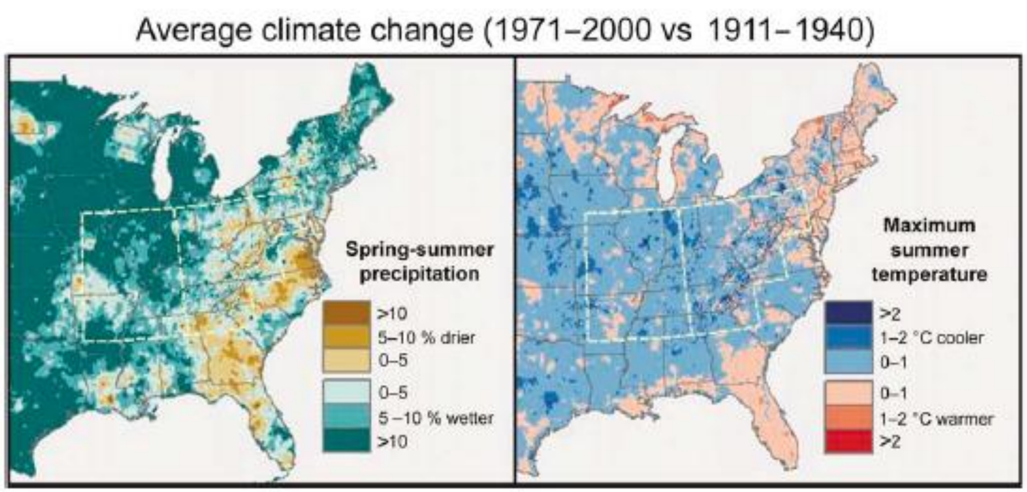
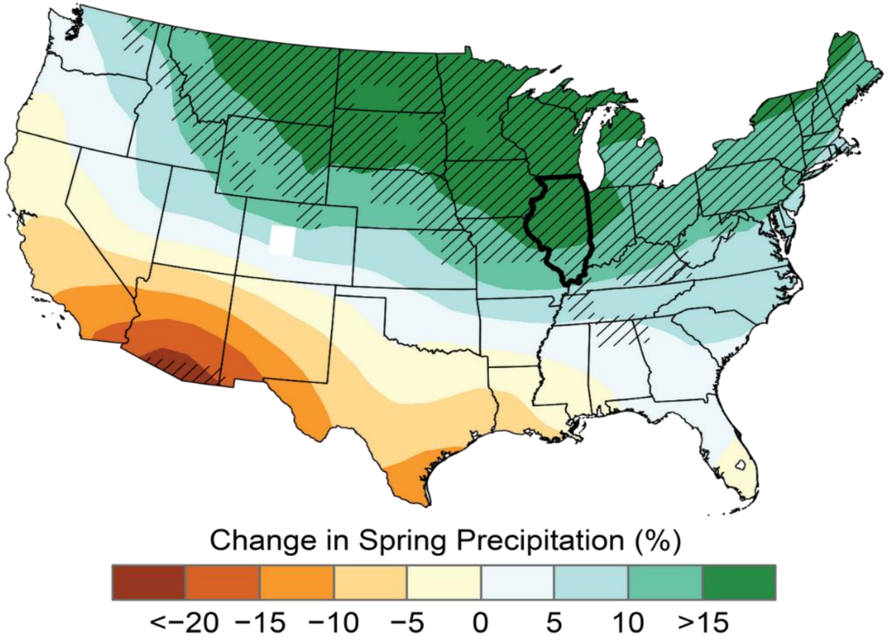
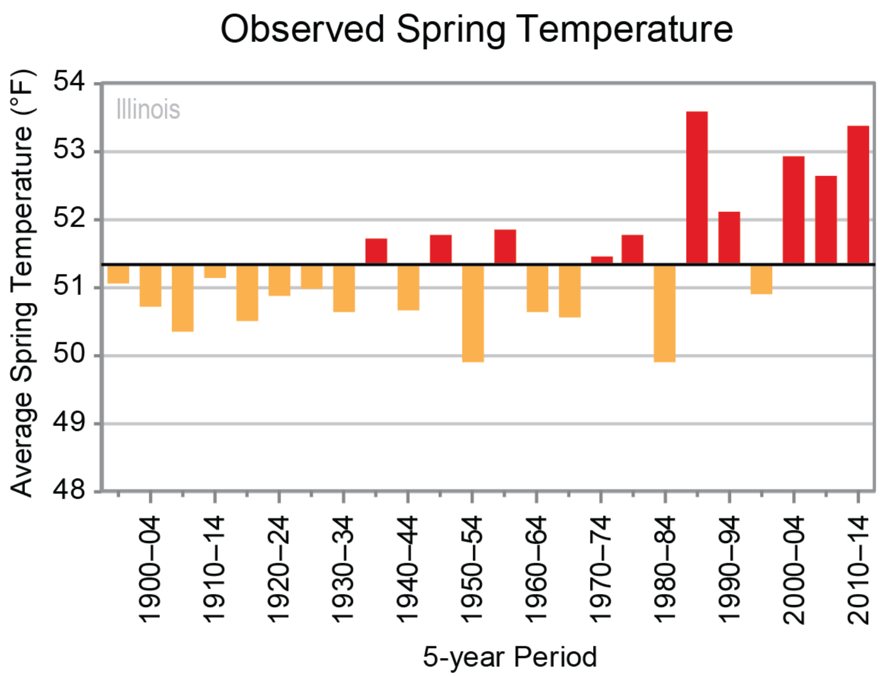


Figure 3. Climate change in the eastern U.S. derived from annual (1911–1940) and normal (1971–2000) climate data (PRISM Group 2008). In the left panel, green areas experienced wetter spring-summer conditions 1971–2000 compared to 1911–1940; in the right panel, blue areas experienced cooler summer temperatures over these same periods. Spring is defined here as March–May, and summer as June–August. Yellow lines define the western and eastern areas of the central oak region used for the PDSI reconstructions in Fig. 2.

Projected changes in Spring (March–May) Precipitation (%) and Temperatures for Middle of 21st Century versus Late 20th Century

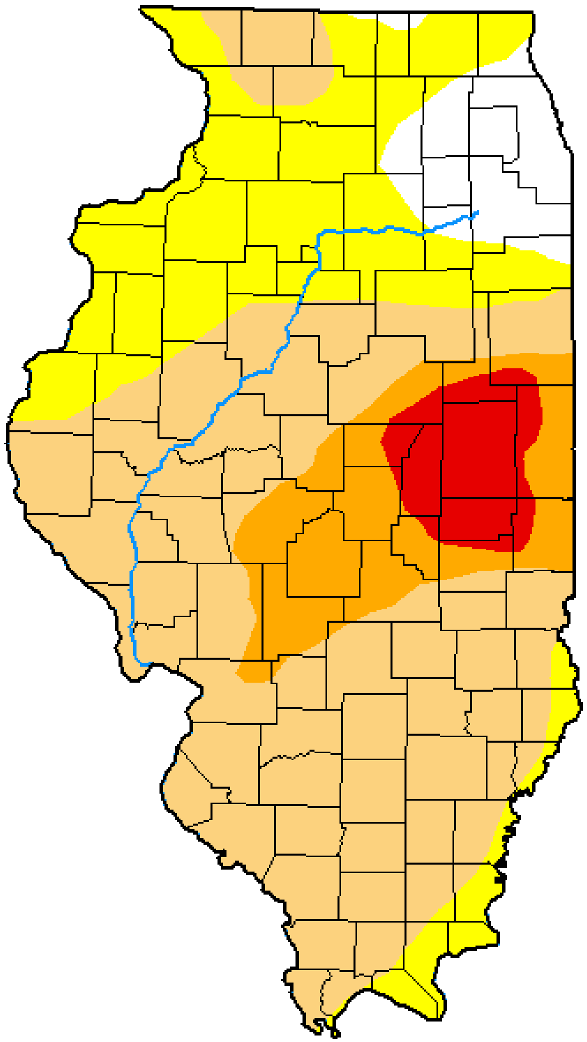




- Increased spring temperatures
- Increased night time humidity
- Pathogens likely to persist

U.S. Drought Monitor
Illinois

January 20, 2026
(Released Thursday, Jan. 22, 2026)
Valid 7 a.m. EST



Intensity:

- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to https://droughtmonitor.unl.edu/About.aspx

Author:
Brad Rippey
U.S. Department of Agriculture

droughtmonitor.unl.edu

Tree Physiology: "The Big Three"

- **Transpiration** – movement of water through the plant
  - Transports water and nutrients and cools plant
- **Photosynthesis** – converts CO_2 and H_2O into sugar (carbohydrates) and gives off O_2
  - Food used for chemical compounds and metabolism
  - Transported as sugar, stored as starch
- **Respiration –** used carbohydrates produced via photosynthesis to convert into energy using oxygen
  - **Respiration complements photosynthesis!**
  - Photosynthesis results in food production, respiration breaks down the food and converts it into energy

Transpiration—Cohesion Hypothesis

Evaporation (the driving force)

The lower water potential of air causes evaporation from cell walls.

This lowers the water potential in cell walls and in cytoplasm.

Cohesion (in xylem)

Cohesion holds water columns together in capillary-sized xylem elements.

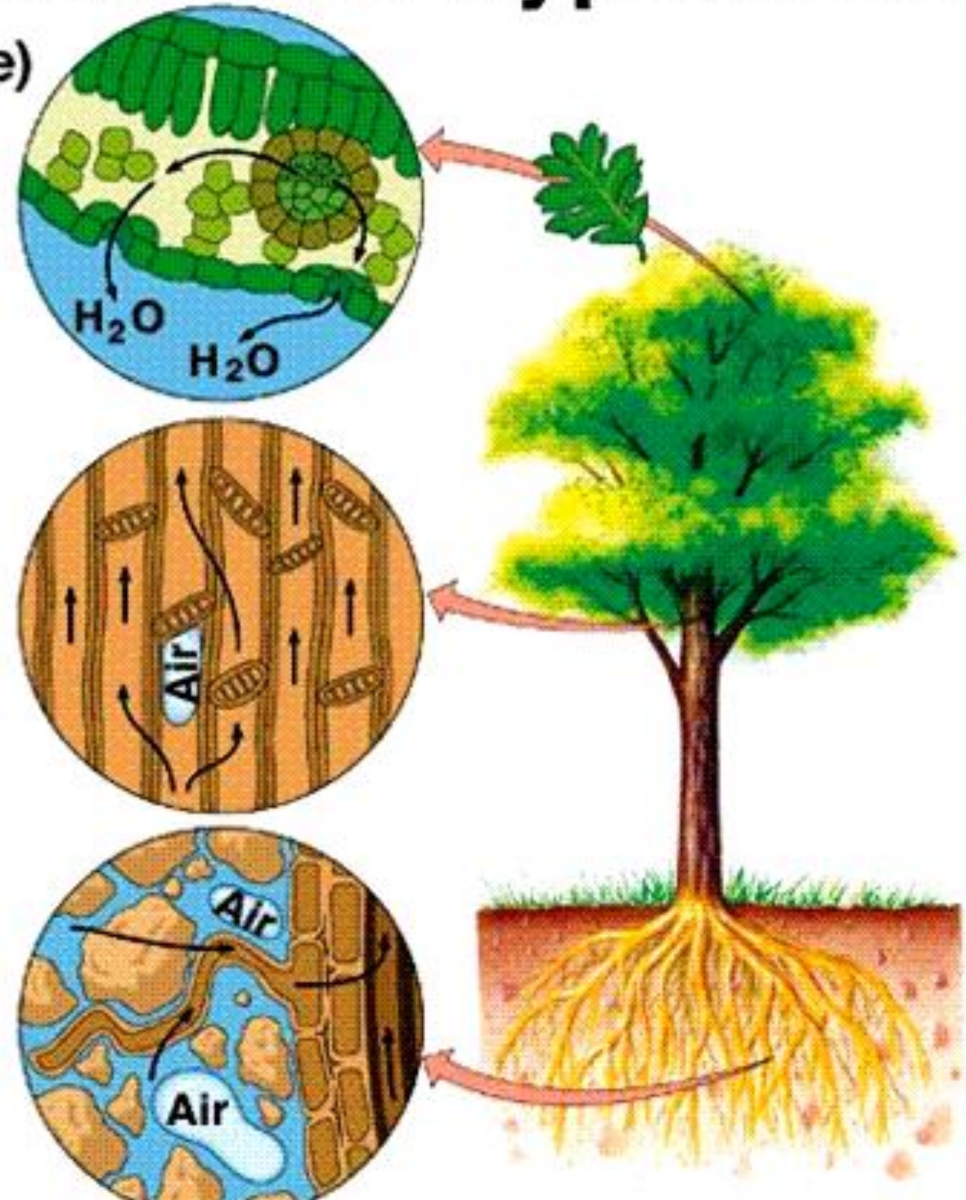
Air bubbles block movement of water to next element.

Water uptake (from soil)

Lower water potential in root cells draws water from soil.

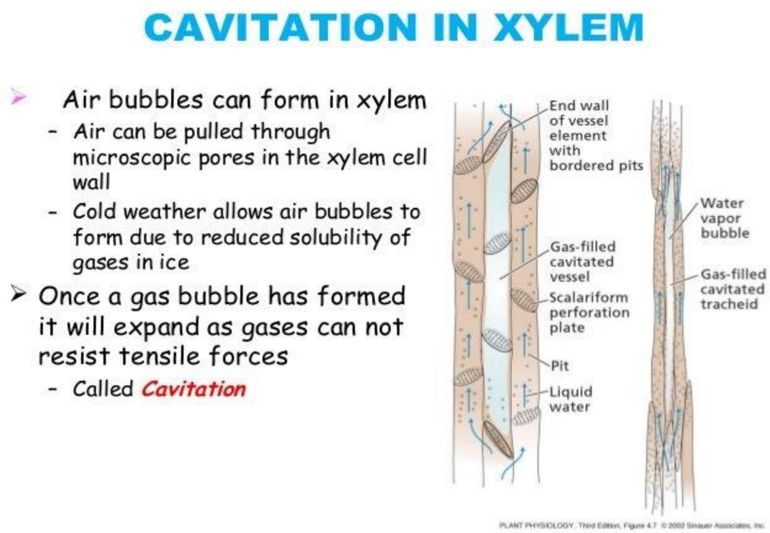
The absorptive surface increases with the production of more root hairs.

Water moves through endodermis by osmosis.

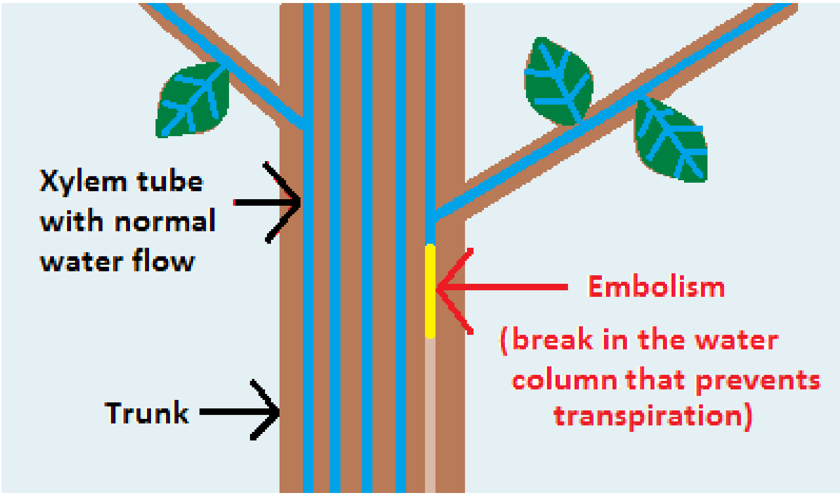


Cavitation and Embolism in Xylem Vessels

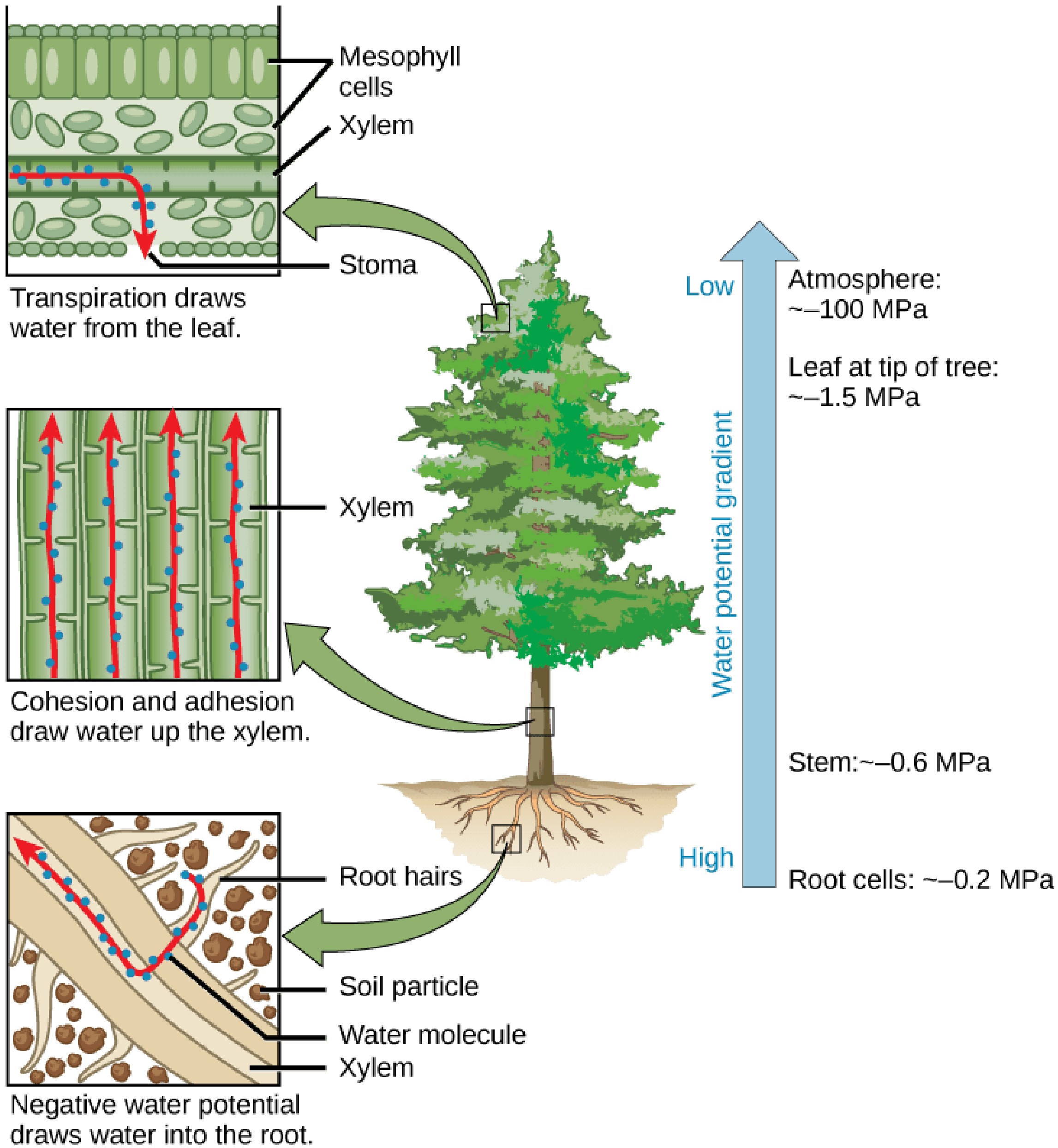
- **Cavitation -** occurs when tension of water within xylem becomes so high that dissolved air within water expands to fill the vessels



- **Embolism -** process where air bubbles block the water-conducting elements of plant due to decrease in soil water availability or increased atmospheric demand

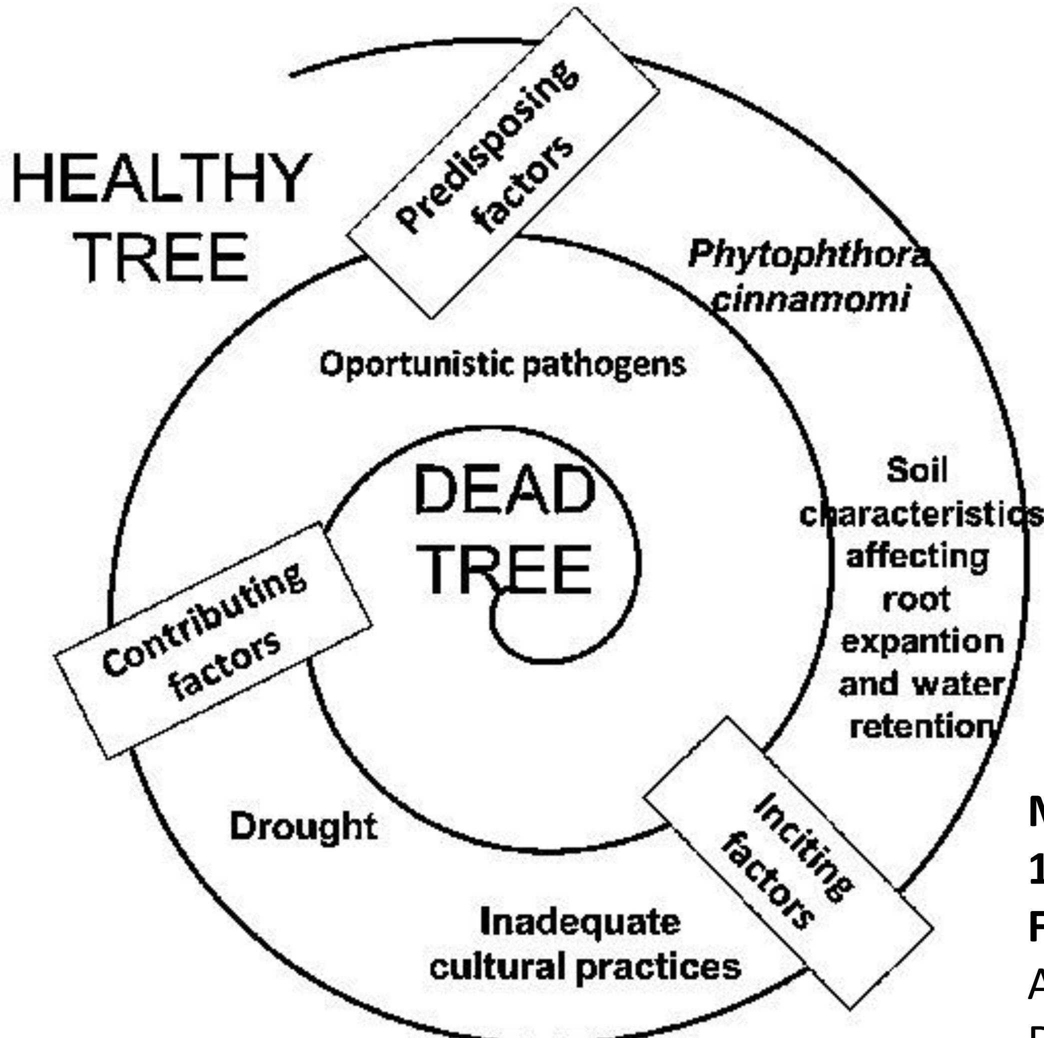


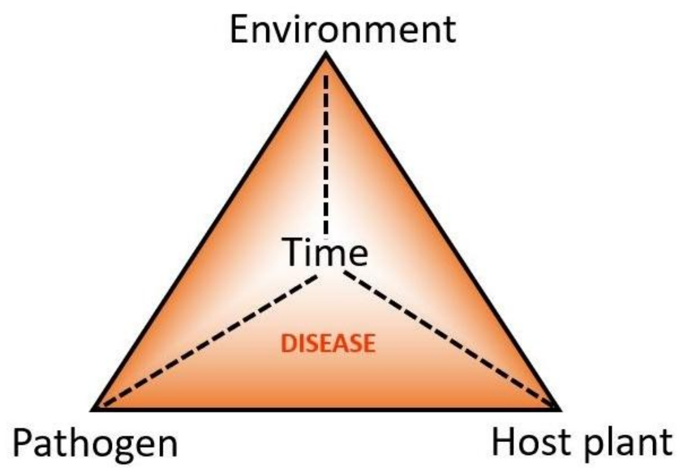
Water Potential and Transpiration in Trees



Climate Change and Woody Plant Health

Manion's Spiral of Tree Decline (1991)

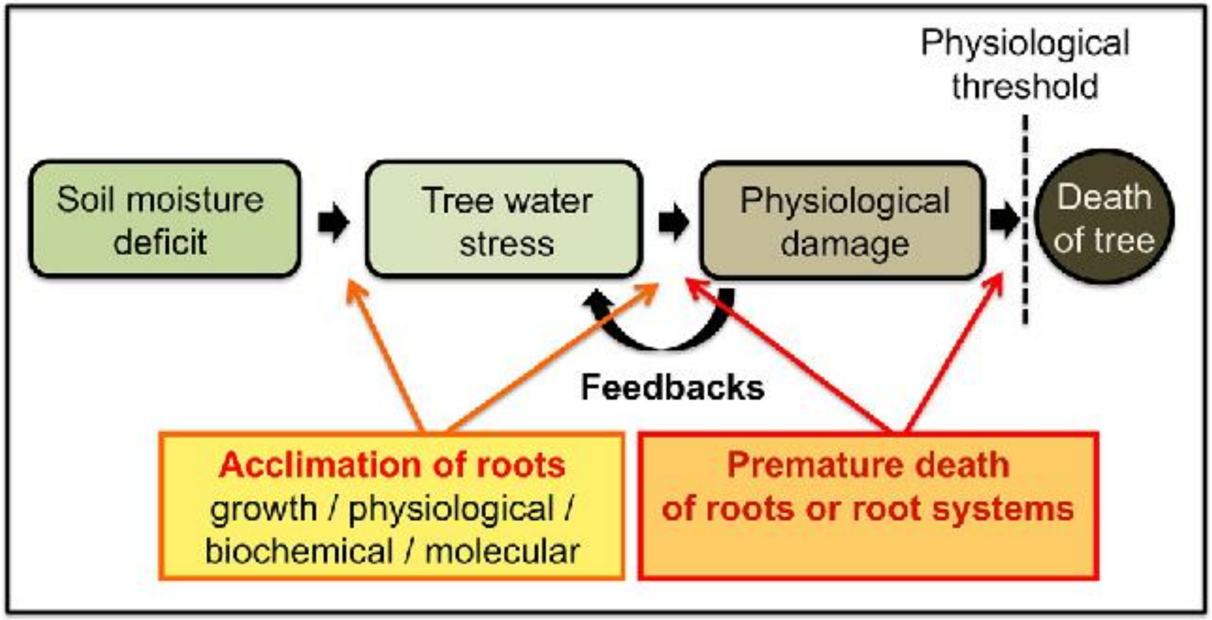




Manion PD, LaChance D. 1992.
Forest decline concepts: An overview. In: Forest Decline Concepts, eds Manion PD, LaChance D,

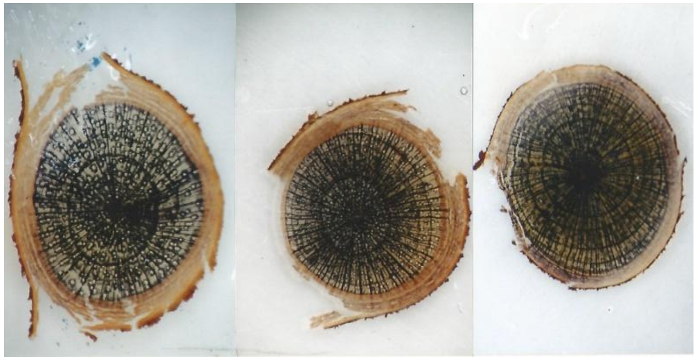
Drought Induced Tree Response

Using the White Oak Model



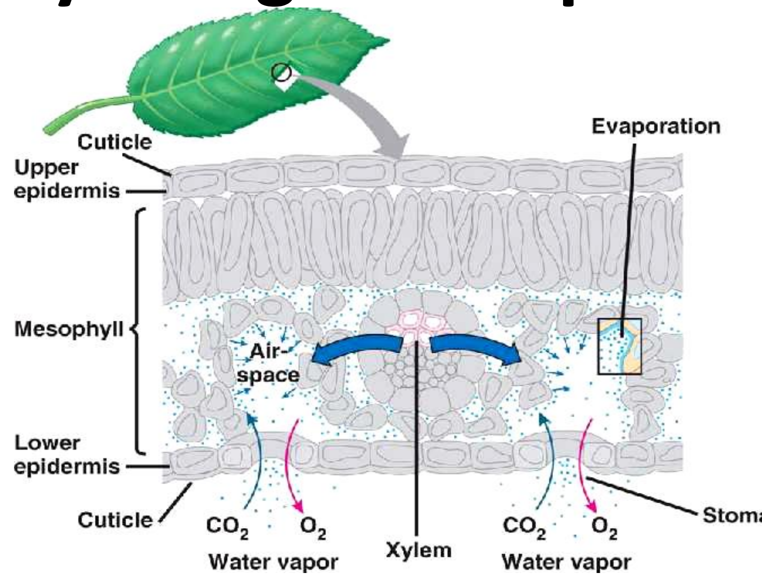
Drought and Oak Tree Response

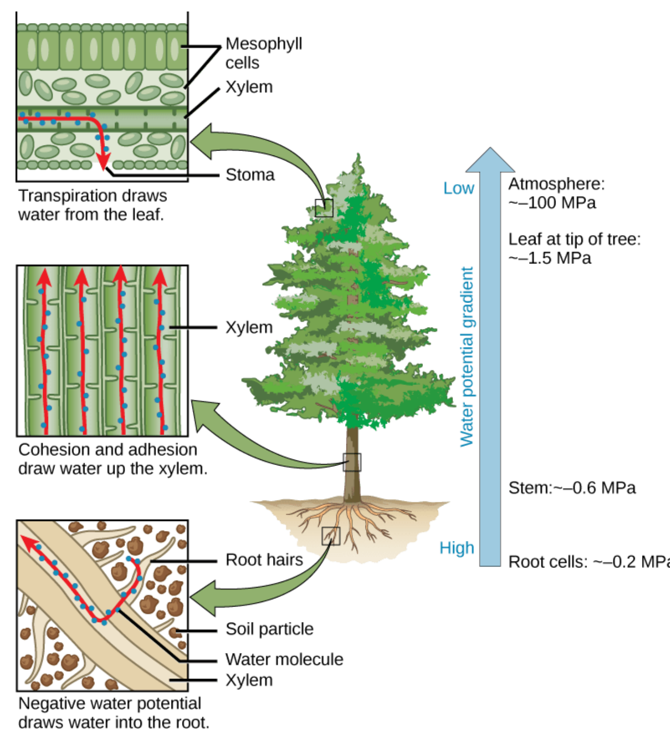
- **Duration and intensity of drought is important**
- Both photosynthesis, and respiration decrease
- **Growth of all plant organs decrease with drought**
  - **Crown transparency, branch dieback, reduction in height and diameter/caliper**
  - Root length and number of root tips increase with increasing drought conditions
  - **Reduction in leaf area and subsequent leaf shedding**
- **Premature fall color occurs**
  - Decreasing chlorophyll and increasing carotenoid levels



Drought Stress and Tree Physiological Response

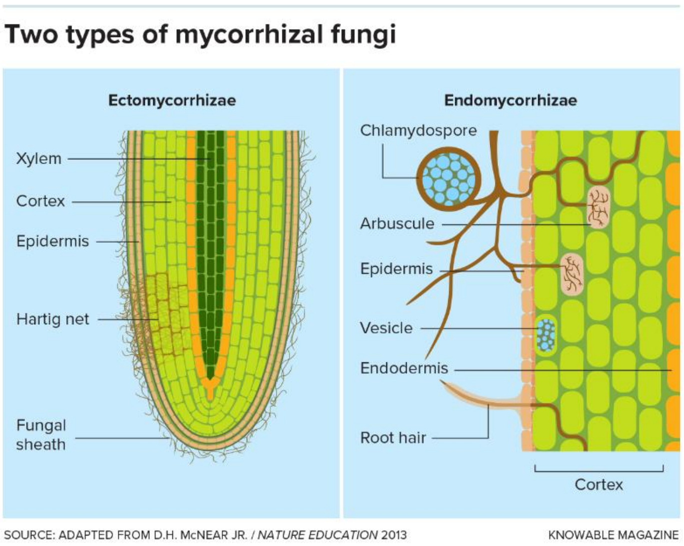
- Rapid response is stomatal closure
- Regulation of transpiration
- Low xylem pressures and air embolism disrupts water transport, hydraulic failure, desiccation, whole tree death
- Smaller vessel diameters, increase pit membrane thickness

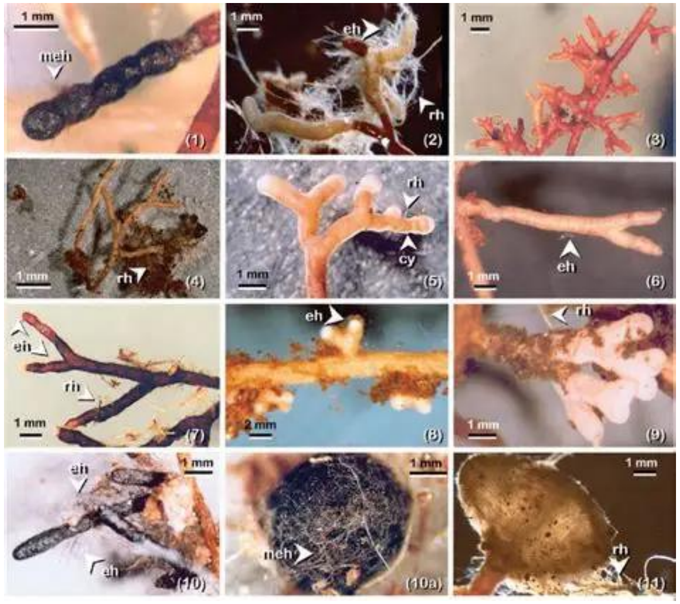




Drought Stress, Plant Hormones, and Soil Microbes

- **Hormones help control drought physiology**
  - ABA plays role in drought sensing, alters root development, regulates root-shoot ratio and leaf shedding
- **Soil microbes improve leaf water potential and photosynthetic rates**
- **Microbes react strongly to drought stress impacting drought stressed plants**
  - Shifts density and behaviour of mutualistic fungi and/or pathogens
  - ECM alters tree response to drought along with ABA and other hormones





Plant Hormones and Drought Response

HORMONE	ROLE IN DROUGHT RESPONSE
Abscisic acid (ABA)	Stomatal regulation
Auxin (IAA and IBA)	Lateral root formation, root branching, leaf senescence, abscission
Brassinosteroids (BR)	Root development and architecture
Cytokinens (CK)	Root to shoot ratio
Ethylene (ET)	Root development, leaf senescence
Gibberellins (GA), Jasmonates (JA)	Root growth, stomatal closure, root physiology
Salicylic acid (SA)	Osmotic stress and ROS response
Strigolactones (SL)	Root branching and architecture

Temperature Extremes and Oak Tree Stress

- Spring and summer seasons key
- Extreme temperature changes and low winter and spring temperatures damage buds, flowers, young tissues, lead to winter desiccation
  - **Chilling** – sudden drop in temperature during active plant growth or development
  - **Freezing** – caused by sub-freezing temperatures resulting in intracellular or intercellular ice formation
- High summer temperatures affect flowering and fruiting

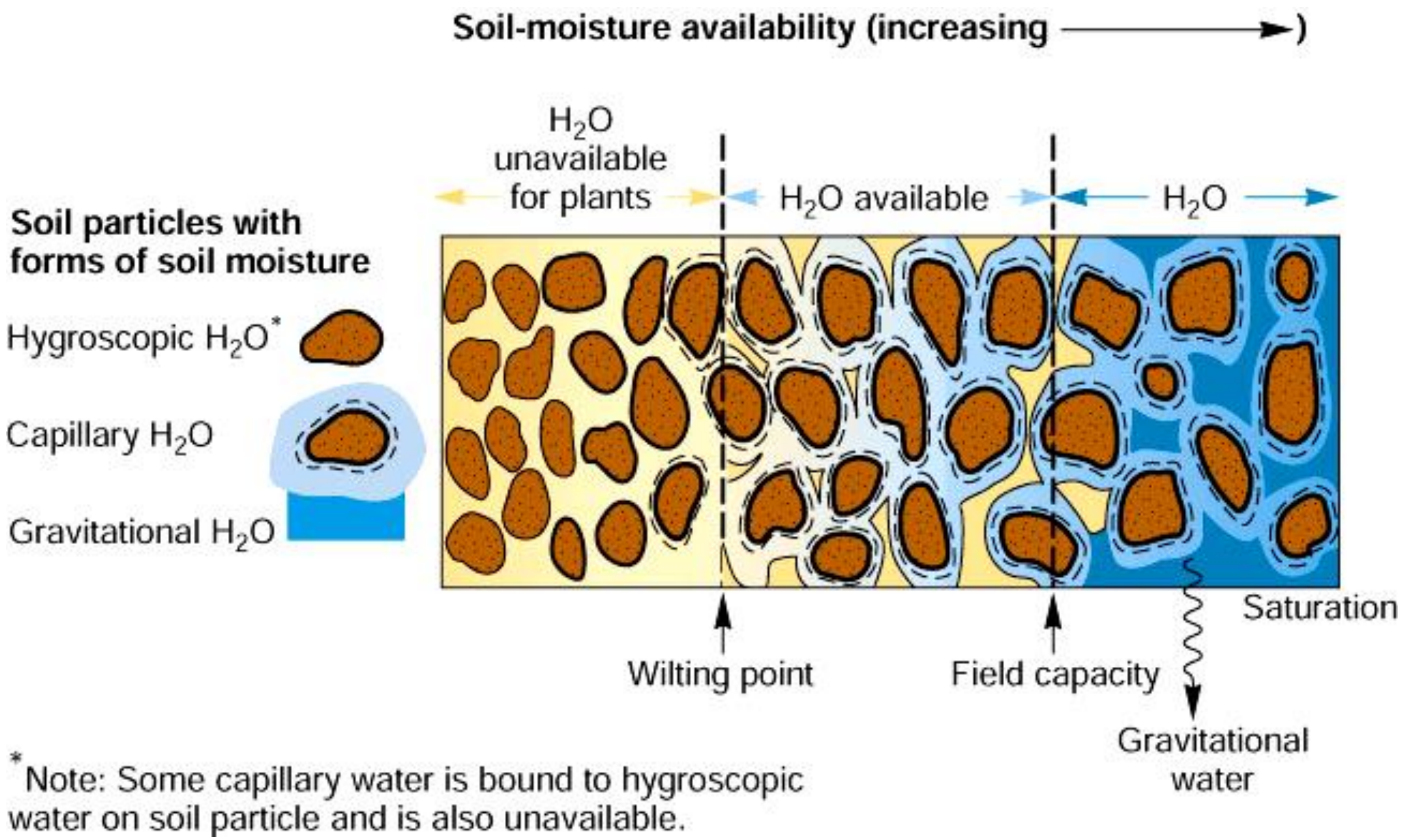


Seasonal Precipitation and Oak Tree Stress

- Spring and early summer precipitation critical for soil moisture retention, nutrient uptake, plant health
  - Lack of soil moisture disrupts physiological processes leading to stress and can limit root growth
- Excessive summer precipitation may lead to increase in oak decline
  - Flooding, increase in foliar diseases and other pathogens (BOB)

Soils, Water Relations and Tree Roots

- Clay soils slower to drain, sandy soils prone to drought
- Well-drained soils are critical (i.e. **field capacity**)
- Be aware of **soil interface** issues



What are Optimum Growing Conditions for White Oaks

- Optimal summer temperatures: 21 to 29^{O}C
- Optimal spring precipitation: 150-300 mm
- Optimal summer precipitation: 200-400 mm
- Annual optimal precipitation: 760-1,270 mm

Recurrent Drought and Oak Decline

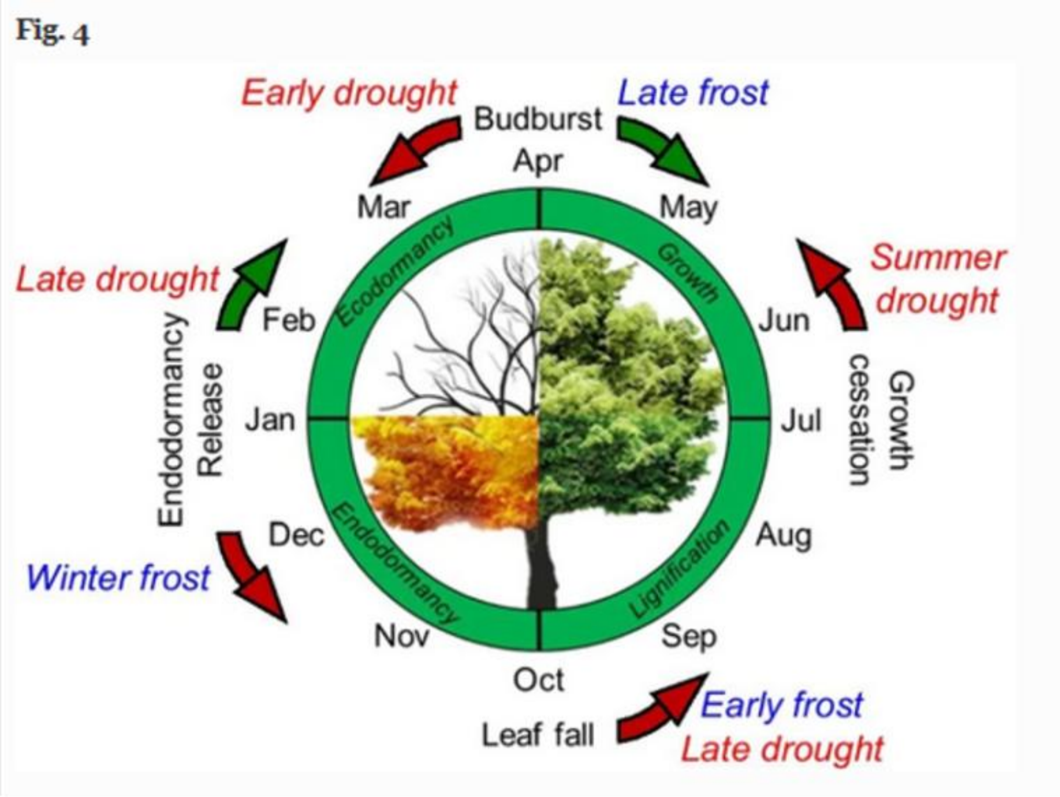
- **Decline conditions rarely revert back to normal**
  - Impacts fine root growth and mycorrhizal associations limiting water and nutrient uptake
  - Impacts disease and insect resistance
- **Pathogens are considered major culprit in tree decline**
- **Older trees less able to adapt or adjust to stress**

Trees, Flooding, and Saturated Soils

- **Just as damaging as drought**
- Will vary with species
- Roots must have O_2 to respire
- Symptoms similar to water stress
- **Premature fall color is "red flag"**

Problems Confronting Woody Landscape Plants

- **Biotic factors**
  - Insect pests and Diseases
  - Animal damage
- **Abiotic factors**
  - **Drought**
  - **Flooding**
  - **Frosts and Freezes**



Charrier G. et al (2021) Annals of Forest Science

Acute versus Chronic Oak Decline

Acute Oak Decline

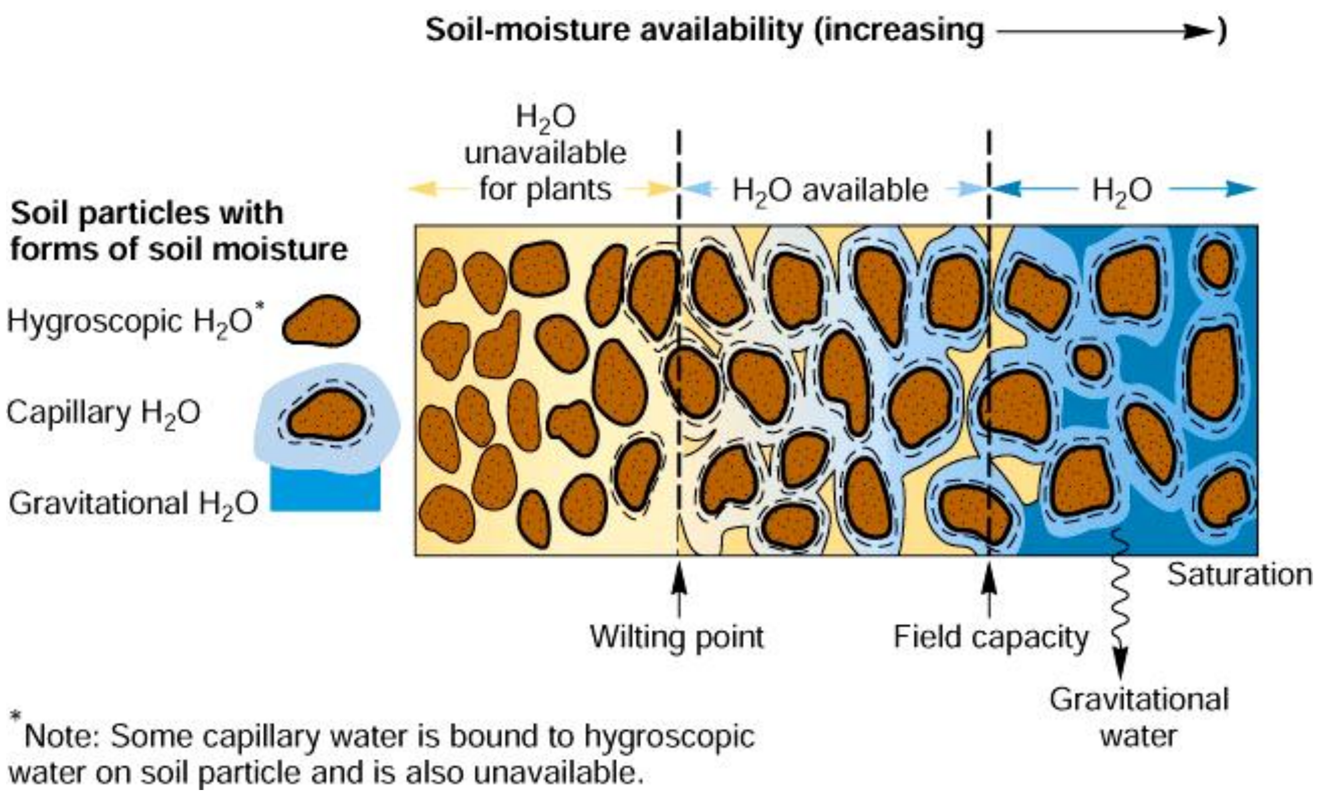
- Specific set of symptoms
- **Rapid decline and death within 3-5 years**
- **Symptoms include:**
  - Bacterial and/or fungal caused cankers
  - Wood-boring insects (borers and bark beetles)
  - Bark cracking and splitting
  - Sparse crowns and undersized leaves
  - Short internode growth

Chronic Oak Decline

- Decline across tree populations
- Cyclic episodes of rapid mortality in local but widespread locations
- Followed by decreasing or slower mortality
- Individual trees exhibit deteriorating crown condition
- Varies with tree species
- Usually irreversible without intervention
- Multiple causal agents involved

Root Rots and Soil Moisture Levels

- **Flooded or saturated soils** favor the fungus, and pre-dispose tree roots to infection
- **Roots stressed by reduced soil O_2** exude more amino acids and other chemicals that attract fungal zoospores and root resistance is reduced



Stressed Related Root and Crown Rots

- **Phytophthora Root Rot** common on sweet gum, horse-chestnut, maple, oak, tulip-tree
  - Soil borne and prevalent in cool, wet, poorly-drained soils and enter through wounds or small roots and root hairs
- **Armillaria Root Rot** common on oaks
  - Mushroom cluster at tree base, black shoe string mycelium (**rhizomorphs**) under bark

Stress Related Cankers

- **Nectria canker** common on birch, elm, linden, maples, and *Prunus* spp.
- **Thyronectria canker** common on maple and oak
- **Botrysphaeria Canker** common on apple, ash, crabapple, elm, honeylocust, linden, maple, oak, pine, redbud, and sycamore

Sap-Feeding Insects and Plant Water Stress

- **Perform poorly on water-stressed plants**

- Survivorship was adversely affected resulting in lower pest density

- No effect on ovipositional preference and fecundity

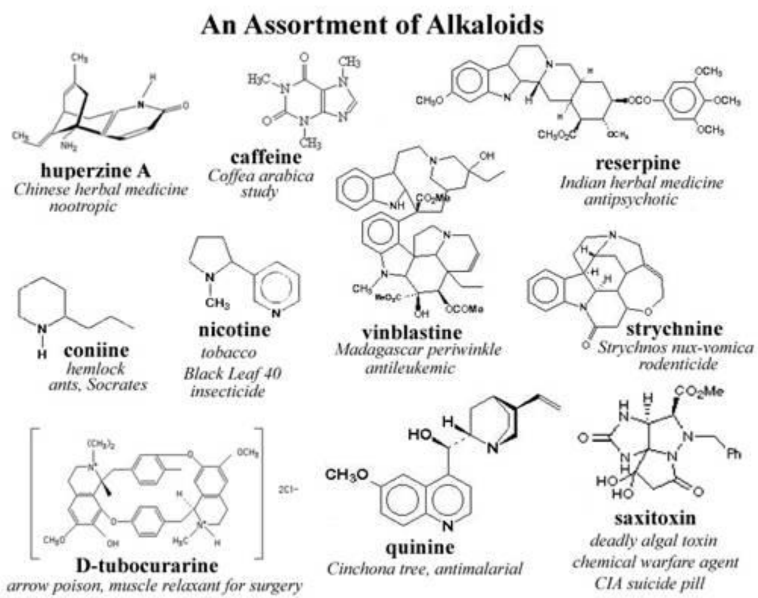
Plant Water Relations and Chewing Insect Pests

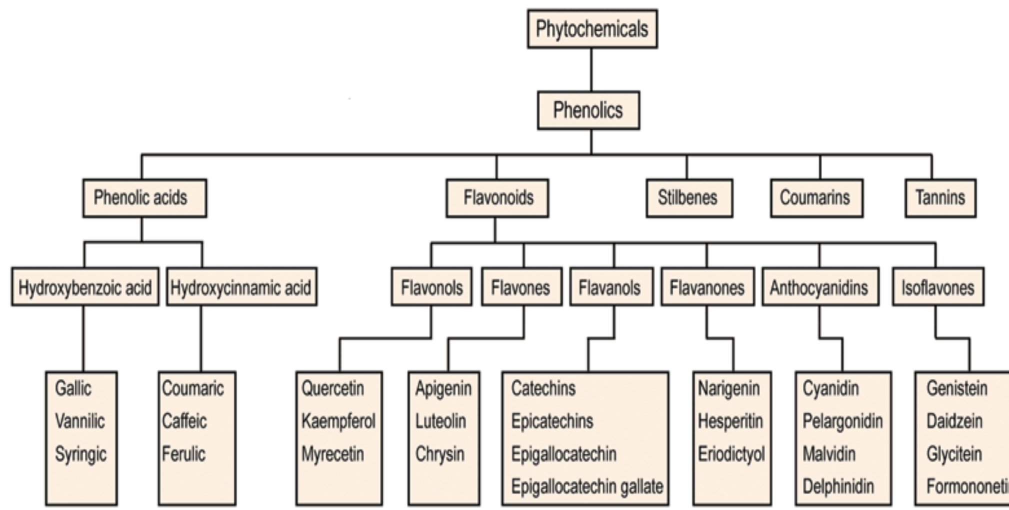
- **Survival, density, and overall performance were adversely affected on chronically water stressed plants**
  - Moths, sawflies, beetles
- Tougher foliage results from water stress and reduces N availability
- **Leafminers** benefit due to elevated leaf N and avoidance of **allelochemicals with no effect for Lepidopteran and Dipteran leafminers**



Plant Water Relations and Chewing Insects

- Intermittent stress may not benefit chewing insects due to **allelochemical production** which are avoided by sap-feeders which feed in the vascular system
- Reduced water content and elevated allelochemicals (**phenols**) resulted in poor caterpillar performance on stressed plants





Plant Water Relations and Wood-Boring Insects

- **Bark beetles benefit from water stress due to decreases in oleoresin pressure**
  - Implicated for bark beetles in pines
  - Reduced bark moisture and lower incidence of drowning in saturated bark tissue for longhorned beetle larvae on Eucalyptus

Illinois Oak Decline Study

Potential Factors Contributing to Oak Decline and Death

Oak Decline Stages

Oak Decline, Stage 1

Oak Decline, Stage 2

Oak decline, Stage 3

Oak decline, Stage 4

Oomycete Species Associated with Oak Roots

Illinois Rural Oak Forests and Urban Oaks

Oak Species	Oomycetes Sequenced
White Oak, Northern Red Oak Urban Oak Studies	***Phytophthora chlamydospora*** *Pythium sp.* Isolate Pyt726 ***Pythium torulosum*** **(oaks growing with turf)** *Pythium vanterpoolii* ***Phytopythium vexans*** **(rural and urban oak trees)**
Bur, Black, Shingle Oaks	***Phytopythium vexans*** **(rural and urban oak trees)** ***Pythium aff. diclinum***
White, Swamp White, English, and N. Red Oaks **Urban Oak Studies by** Adams and Watson (2024), Remsen et al. (2025), and Miller et al., 2025)	***Phytophthora pini*** **(WO)** ***Phytophthora gonapodyides*** **(WO/SWO),** ***Phytopythium plurivora*** **(WO)** *Pythium littorale* (WO) *P.ythium latarium* (NRO) ***Globisporangium heterothallicum*** **(WO)** ***Globisporangium (Pythium) macrosporum*** **(NRO)** ***Elongisporangium anandrum*** **(NRO)**

Root Sampling Sites with Low (L) to Very Low (VL) Soil Nutrient Levels

(2023-2024)

Soils Nutrients (VL-L)	% of All Oak Root Sampling Sites
Phosphorus (P)	**60%**
Potassium (K)	< 2%
Magnesium (Mg)	18%
Calcium (Ca)	**51%**
Sulfur (S)	**33%**
Zinc (Zn)	**40%**
Manganese (Mn)	0%
Iron (Fe)	0%

% Root Infection by Site, Hydrology, Soil Texture, pH, and Soil Nutrient Levels

Site	% Inf.	Slope, Hydrology, Texture	pH <6.0	Low P	Low Ca	Low S	Low Zn
Miami Woods FP	100	Flat-Poor-SCL	X	X	X	X	
Willow Springs FP	100	Flat-Poor-SCL	X	X	X	X	X
Matth. SP	70	Flat-WD-SL	7.0	M	H	M	VH
Wash. County SP [1,2]	100	Flat-Poor-SCL	X	X	X		X
Randolph County SP [2]	100	Flat-Poor-SCL	X	X	X		X
GVFP [1,2]	100	Flat-Poor-SCL	X	X	X		
Blackhawk SHS	83	Upper-Flat-WD-SL	7.1	H	VH	M	H
Carlock	20	Upper-WD-SL-SCL	X	X	M	M	X
Blackwell FP [1]	100	Flat-Poor-SCL	X	X	X		
Means			78%	78%	67%	22%	44%
[1]Perched or Seasonal HWT, [2]Clayey, Clay Pan		SCL=Silt-Clay-Loam WD=Well-Drained					

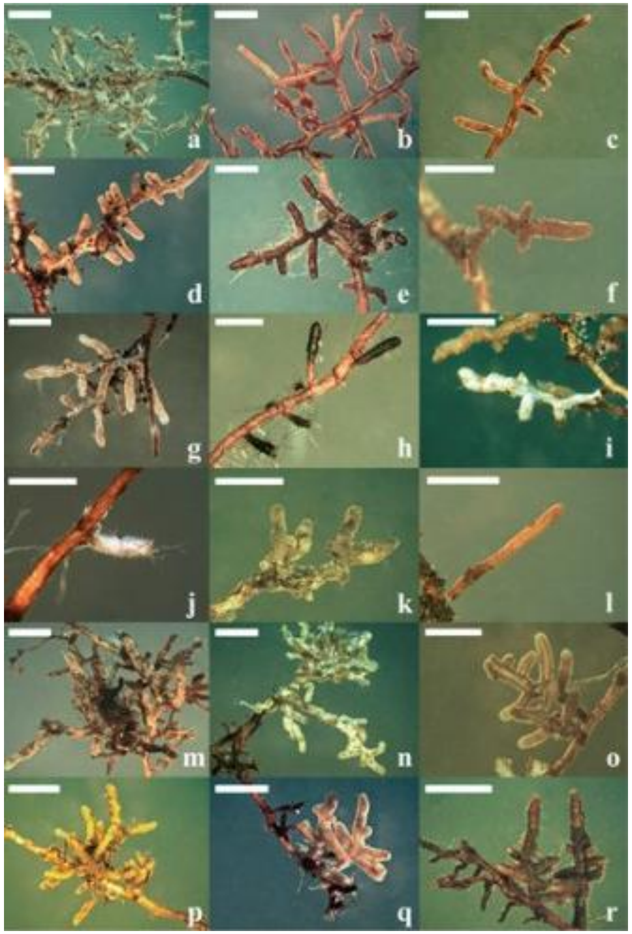
Summary: What Have We Learned So Far?

- **Visual tree assessments do not reflect root infection**
  - **Oomycete infection rates >80%**
- Number of known oak pathogens have been identified
- **White oaks tend to have higher infection rates**
- Higher infection on flat slopes (slope <5%)
- Higher infection on poorly drained sites with clayey subsoils, and high or perched water tables
- Low or no infection on sandy to sandy-silt soils
- Rooting depth does not appear to affect root infection
- **Higher infection on soils with low levels of Ca, S, or Zn**
- **High levels of Fe may affect overall nutrient balance**

Fungicide Trials for Urban Oaks

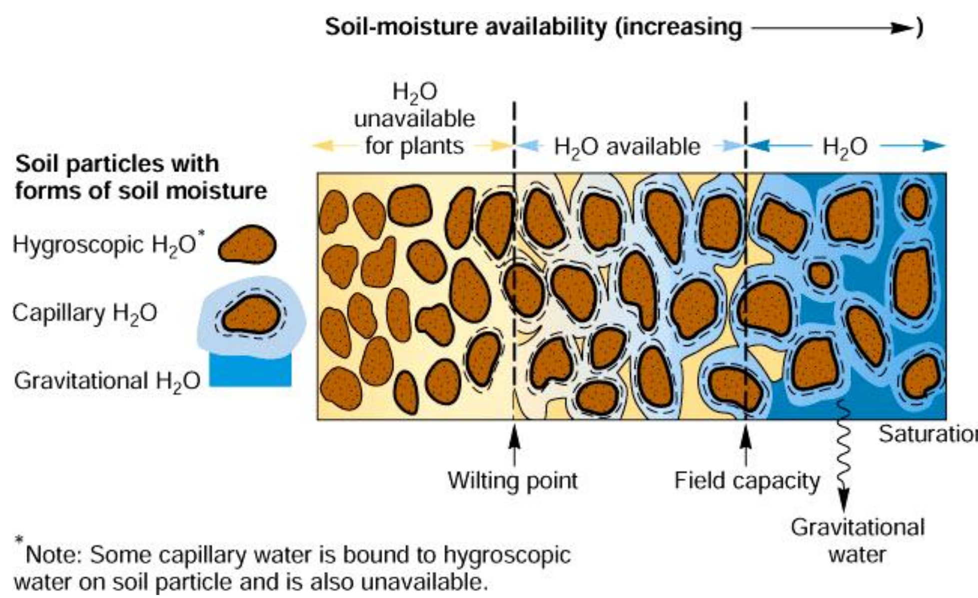
- Fungicide Treatments
- Root Core Samples for Root Density
- Colonization by mycorrhizae
- Annual Visual Canopy Assessments

Soil cores for measuring root density



Factors Associated with Decline Diseases of Urban and Landscape Trees

Factors	Maple	Oak	Birch	Linden	Honeylocust
Predisposing	Salt, compacted, poor soil aeration, **restricted root space**, girdling roots	Age, drought, high soil pH, fill, **poor or excessive drainage**	Age, **excessive drainage,** outside natural range and natural habitat	Salt, **restricted root space**	Outside natural range and habitat, **restricted root space**



Factors Associated with Decline Diseases of Urban and Landscape Trees

Factors	Maple	Oak	Birch	Linden	Honeylocust
Inciting	Construction, **drought,** temperature extremes, defoliation	Construction, **drought,** defoliation, frost damage	Sudden exposure, **drought,** defoliation, frost damage	Construction, **drought,** temperature extremes, sun scald	Construction, **drought**
Contributing	Sugar maple **borer**, cankers, root rots	**TLCB**, cankers, root rots	Bronze birch **borer**, sap rots, root rots	**Linden borer**, sap rots	Cankers, root rots



Mitigation and Management of Tree Stressors

- **"Right plant, Right place"**

- **Know what is below the surface, take a soil sample**
  - Helps determine soil nutrient availability and aides in leaf tissue analysis to determine nutrient deficiencies

- **Improve soil-water drainage and soil structure**
  - Manage drainage away from tree roots
  - Don't allow water to pool around the collar or root system
  - Apply mulch to conserve soil moisture, moderate soil temperatures, and lessen compaction
  - Where feasible, use radial trenching or air-spading to reduce compaction and improve soil structure

Mitigation and Management of Tree Stressors

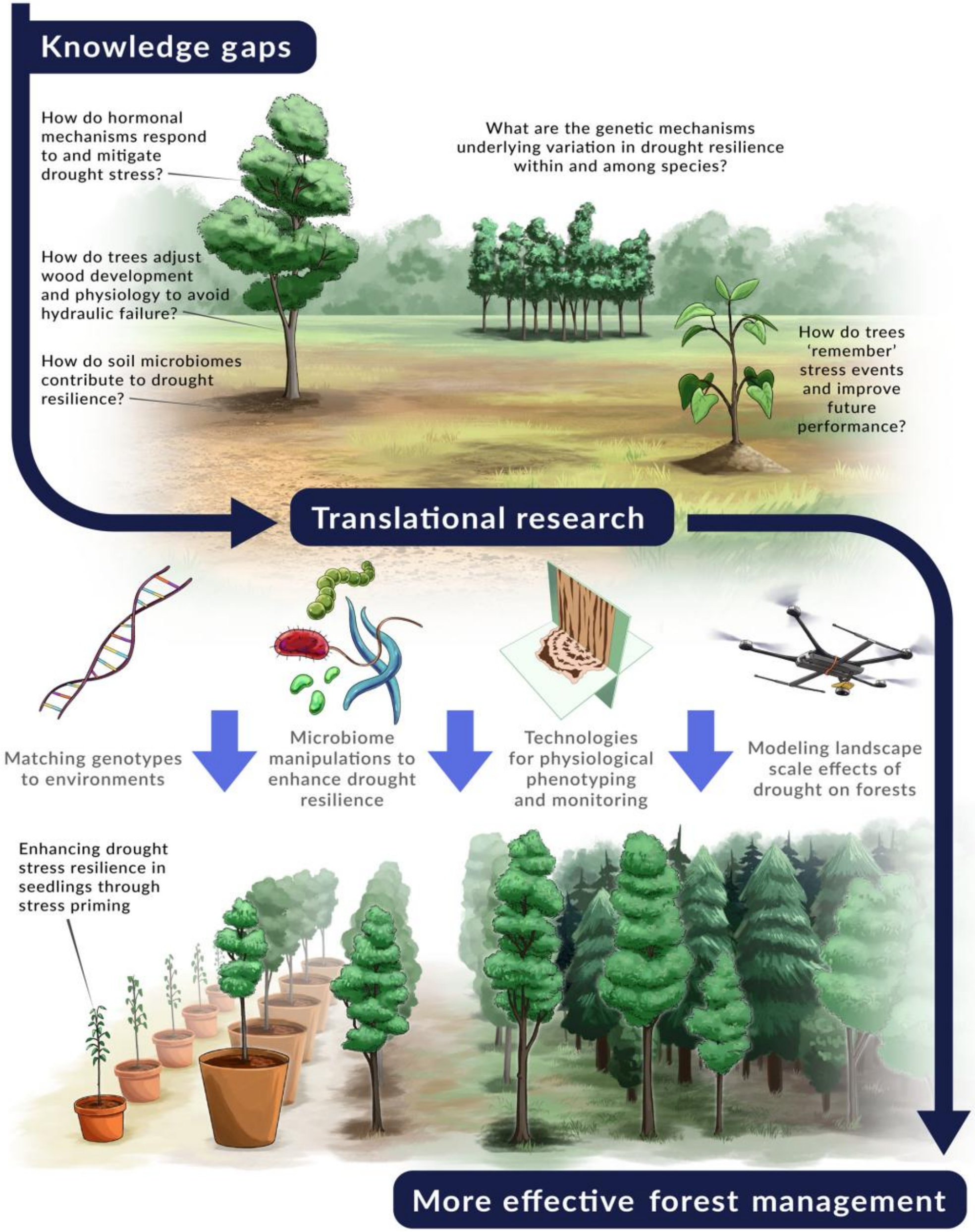
- **Water during hot dry weather**
  - 1” of irrigation per week for actively growing trees
    - Optimal spring precipitation: 6 to 12”: (150-300 mm) for oaks
    - Optimal summer precipitation: 8 to 16” (200-400 mm) for oaks
    - Annual optimal precipitation: 30 to 50” (760-1,270) mm for oaks
- **Maintain proper soil nutrition and fertilization**
  - Water newly planted B&B trees to facilitate root regeneration
  - Fertilize established trees
    - Annually 1-2 lbs. N per 1,000 ft^2
  - Limit fertilization of mature-overmature trees
    - 1 lb. N at 1-2 year-intervals
- **Apply chemical pesticides as needed**
  - Use least toxic products
  - Conserve natural enemies and pollinators

Challenges Related to a Better Understanding of Climate Change Research

- Woody plant research is expensive and take decades due to long rotation times
- Ability to predict tree responses to drought and future climatic conditions
- Understand that long-term drought results in long-term legacy effects
  - Differences in responses between Angiosperms and Gymnosperms
- Pursue "***assisted migration***" of tree species within and/or movement beyond their current range
- Integration of technology and remote sensing into woody plant management

Questions Still to Be Answered

- Better understanding of interactions with mature trees
- Do trees select and/or recruit microbes suitable for drought conditions
- Relationship between tree phenotypic variation and associated microbes
- Genetics and Drought Resilience



REMEMBER, IT WILL BE COMPLICATED!!!

Elm Zigzag Sawfly

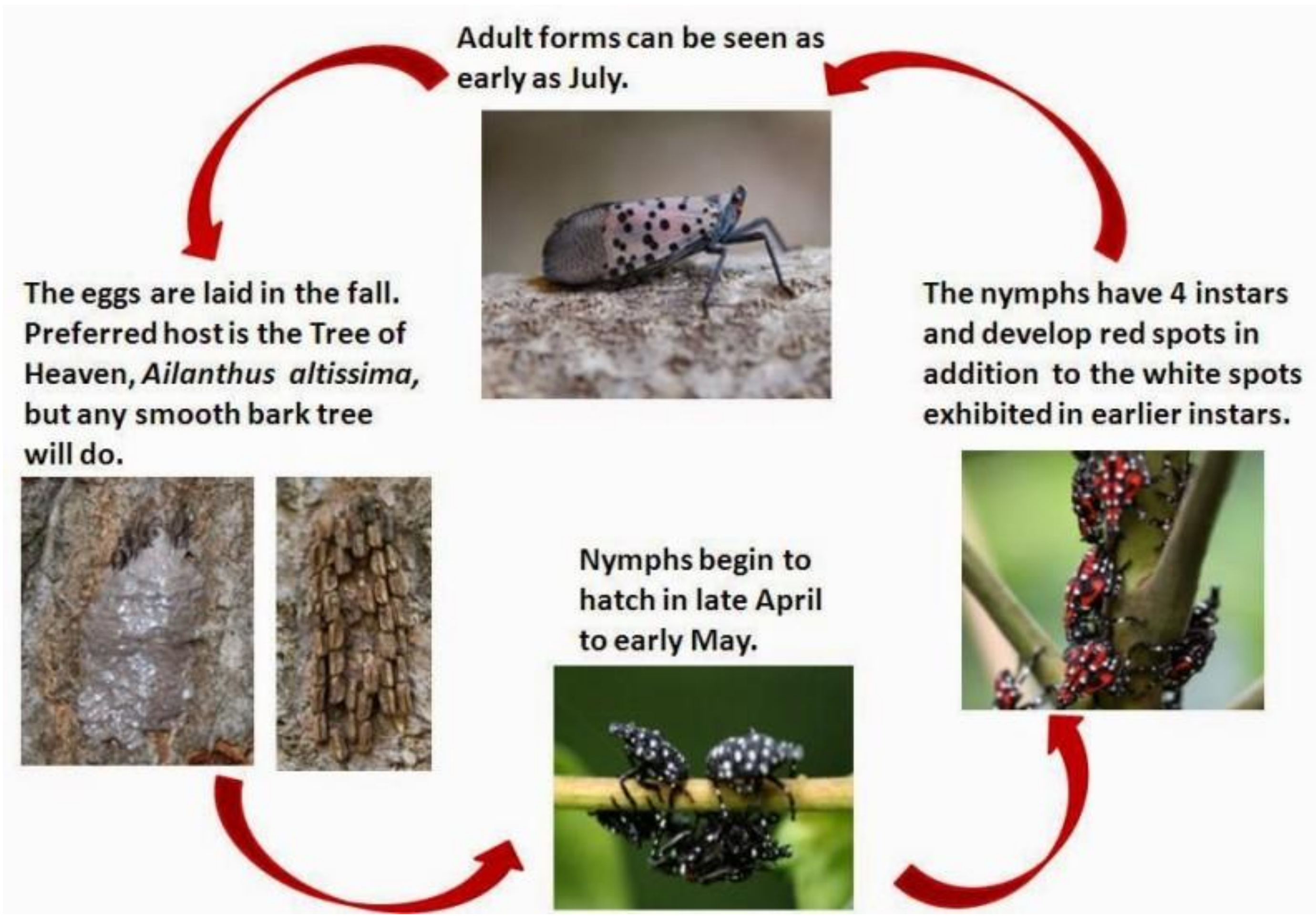
- Native to China, Japan, Russian Far East, first discovered in MI, WI, and **IL in 2024 (Cook County)**
- **Reported elm hosts include** *U. americana, U. alata, U. parvifolia, U procera, U. pumila, U. rubra*, ‘Cathedral’, ‘Frontier’
- **4 to 6 generations per year**
- **Strong flyer** (can disperse 30-50 miles/year)
- Feeds from the edge of leaf in a zigzag pattern
- Very rapid adult emergence
- Forms summer and winter cocoons
- **Management includes**
  - Early detection (EDRR programs)
  - Chemical management

Spotted Lanternfly (SLF)

- Native to China, India, South Korea, and Vietnam
- Present MI, OH, IA, IN, **IL (Cook County)**
- **Major pest of vineyards and tree fruits**
- **Preferred hosts include Tree of heaven,** walnut, and willow
- Eggs laid in late fall
- Remove unwanted grape, brush, TOH
- Mature trees do not require protection
- Young, plants may need protection




Spotted Lanternfly Life Cycle



New “Disease” of *Carpinus* spp.

Common Symptoms:

- Size reduction of leaf
- Puckered texture
- Cupped leaves
- Marginal chlorosis
- Darker coloration (near midvein)
- Thick/leathery leaves
- Entire leaf chlorosis
- Red pigmentation in leaves
- Cankers on stem/ branches
- Twigs/terminal leaves wilted, brown, curled
- Fungal fruiting bodies on early leaves

Thank You for Your Attention!