# Tracheid diameter is the key trait determining the extent of freezing induced embolism in conifers

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## Introduction

**Question:** Are conifers more resistant to freezing and loss of water conductivity than angiosperms?

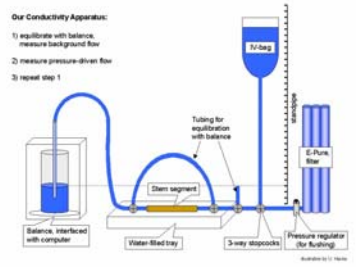
**Hypothesis:** Freezing induced embolism is related to conduit diameter, and conifers and angiosperms with conduits of equivalent diameter will exhibit similar losses of hydraulic conductivity in response to freezing.

## Terms

- **Embolism**- obstruction of water movement due to air bubbles caused by freezing and thawing.
- **Cavitation**- the formation of partial vacuums in a liquid by a swiftly moving solid body.
- **Hydraulic conductivity**- ability to conduct and transport water
- **Percent Loss of Conductivity due to freeze-thaw (PLCft)**

## *Hydraulic conductivity measurements*

Hydraulic conductivity was measured in the laboratory with the apparatus described by Sperry (1993) and calculated as the flow rate of water for a given pressure gradient (4 to 5 kPa) through a segment of known length.




## *Centrifuge experiments*

This experiment induced freeze-thaw conditions on samples of branches and roots by putting them in a Centrifuge machine which applied mild tension (–0.5 MPa) and a temperature-controlled bath. This experiment induced embolism.

## *Air saturation experiments*

They pressurized the stems of *Abies lasiocarpa* with air to test the hypothesis that PLCft is a function of dissolved air content in xylem sap. This method simulated the effect of increased conduit size because the degree of supersaturation (applied air pressure relative to ambient) is proportional to a conduit volume holding an equivalent amount of dissolved air at ambient pressure.

Layman's terms: they used Abies lasiocarpa to test how PLCft is because of a change in the size of the conduits. The change in conduit size was simulated by presure applied to the stems.

## Tree structure and function

Tracheid diameters

Adapting to climate

increase in warmer climates

decrease in freezing climates

Changes within vascular system

roots

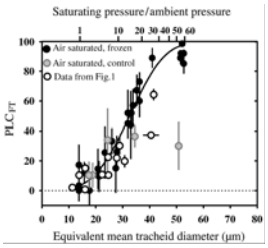
trunks

branches

| Species/family | Organ | Mean tracheid | Maximum tracheid |
|---|---|---|---|
| *Abies concolor* | Root | 30 ± 1.2 | 55 ± 2.1 |
| *Abies lasiocarpa* | Root | 25 ± 1.2 | 48 ± 1.9 |
| *Gingko biloba* | Root | 26 ± 1.8 | 46 ± 3.8 |
| | Branch | 16 ± 2.7 | 28 ± 2.1 |
| *Juniperus scopulorum* | Root | 22 ± 0.8 | 38 ± 0.9 |
| | Branch | 11 ± 0.3 | 19 ± 0.3 |
| *Pinus contorta Dougl.* | | | |
| | Root | 29 ± 0.8 | 54 ± 1.2 |
| | Branch | 14 ± 0.6 | 23 ± 1.4 |
| | Trunk | 27 ± 0.4 | 52 ± 0.8 |
| *Sequoia sempervirens* | Branch (large) | 26 ± 1.2 | 48 ± 2.8 |
| | Branch (small) | 20 ± 0.8 | 42 ± 2.5 |
| *Taxodium distichum* | Branch | 40 ± 2.7 | 76 ± 7.6 |
| | Root | 41 ± 1.3 | 70 ± 1.9 |

## Freezing Climates

- Freezing enduces embolism
  - Function of conduit air content
    - *Increase in PLC when ambient pressure increased*
    - *Increase in mean diameter above 30microm*
- *Gymnos vs. Angios*
  - *Are There Any Differences?*




## Results

- Great increase in PLCft for tracheid dia. over 30 um.
- 100PLCft for dia. Over 40 um. (Taxodium distichum) not suitable for cold climate

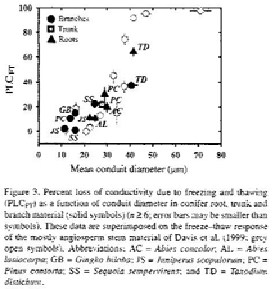



Figure 3. Percent loss of conductivity due to freezing and thawing ($PLC_{FT}$) as a function of conduit diameter in conifer root, trunk, and branch material (solid symbols) ($n \geq 6$; error bars may be smaller than symbols). These data are superimposed on the freeze–thaw response of the mostly angiosperm stem material of Davis et al. (1999; grey open symbols). Abbreviations: AC = *Abies concolor*; AL = *Abies lasiocarpa*; GB = *Gingko biloba*; JS = *Juniperus scopulorum*; PC = *Pinus contorta*; SS = *Sequoia sempervirens*; and TD = *Taxodium distichum*.

## Discussion and Conclusions

- Conduit diameter is chief variable in PLCft
- In regards to freeze-thaw, tracheids are no better than angiosperms containing same dia. of conduit
- Tracheids w/dia. Larger than 43 um will embolize at -0.5MPa
- Davis (1999)- Angiosperms 44um embolize at -0.5MPa
- Pinus, Picea, Larix, and Abies (13um-18um)

**The question remains:**

Why did gymnosperms evolve tracheids rather than simply reduce diameter of vessels?