Photo: Stephen Handler

A temperate forest in winter, with branches and trunks covered in snow.

HOW DO TREES SURVIVE OUTSIDE ALL WINTER?

By Rebecca Rooney

As winter comes to temperate regions, forests change dramatically. Songbirds migrate south, while other animals, ranging from black bears to tree frogs, prepare to hibernate for the winter. These organisms have adapted to the snow-laden cold of temperate forests, but what about the trees making up the forest?

Trees can't migrate like birds; however, they can enter a state similar to hibernation called dormancy. During this period trees are in a state of suspended growth, conserving resources for the following year and adjusting their physiology to acclimate to the oncoming cold.

Dormancy is vital as winter brings many unique stresses that can damage tissue, increasing susceptibility to pests and pathogens. Ice presents a threat at multiple levels. External ice buildup can result in damaged and broken branches, while internal ice formation can lead to frost cracks, a process where a stem splits from repeated ice expansion. Water stress can be another concern because frozen soils reduce water availability. Many tree species turn to dormancy to reduce their vulnerability to these factors.

As trees wind down their growth in the autumn, they recover important nutrients from their leaves – a process known as senescence. The environmental cues triggering this process are complex, but changes in day length and temperatures play a significant role. Once given the "go" signal, leaves break down chloroplasts, the organelle (any of a number of organized or specialized structures within a living cell) responsible for photosynthesis, to recover nitrogen and other nutrients to store in their roots and stem for the following year. Retaining nutrients is important as they can be difficult for plants to obtain and are essential for future growth. After nutrient recovery, leaves fall to the forest floor and the leaf scars become sealed off to prevent water loss.

Trees that don't drop their leaves, like most conifers, must ensure that their leaf tissue doesn't freeze. This is accomplished by increasing sugar content in their leaves, creating a sort of sugary antifreeze. Creating antifreeze properties doesn't just happen in conifer leaves. Trees also boost sugars in their living tissues, such as buds and phloem, to prevent cells from rupturing. Amazingly, trees can increase the permeability of their cell membranes, allowing water to freeze outside the membrane, while the interior remains liquid due to the higher sugar content. Additionally, a tree's living cells can enter a state of deep supercooling, where cellular contents become so viscous that ice cannot form.

Assuming a tree can use these mechanisms to survive the winter, then its final challenge is to break dormancy and successfully "wake up" for spring. For some species, one hazard is the loss of functioning xylem, a tissue composed of many conduits responsible for water transport. To function properly, xylem must maintain an unbroken chain of water molecules to move water throughout the plant. If that chain is broken, then that conduit fails to function. In the spring, as xylem sap unfreezes, air bubbles form, blocking conduits and preventing water transport. Some tree species have adapted to repair these broken pathways by pressurizing their xylem to remove bubbles. This form of xylem repair expends extra energy; however, it increases the capacity for water transport to tissues, which becomes important in spring as leaves and flowers emerge.

Leaf emergence is essential as it allows for photosynthesis to begin; however, it is important to get the timing right. Leafing out too early can be dangerous for leaves as late spring frosts can damage tissue. That said, the cold isn't all bad, spending a certain amount of time at chilling temperatures (i.e., just above freezing) in the late winter and early spring is required for many species to break dormancy. Trees sense temperatures and use the amount of chilling time to estimate spring onset and hopefully leaf out when conditions are right. It's important for trees to get the timing right to optimize the tradeoff between time for growth relative to the risk of frost damage. Environmental cues like daylength and temperature have allowed trees to successfully live in cold climates; however, winters have been changing in temperate regions causing researchers to question if these cold adaptations will still be beneficial in the future.

Winters have been becoming shorter and milder across Wisconsin for several decades, and this trend is expected to continue. This may sound like a relief for overwintering trees; however, these changes may present new challenges. For example, warmer winters are predicted to result in a reduced snowpack, which serves an important role in insulating the forest floor from freezing air temperatures. This insulation protects seedlings and generally reduces the amount of soil freezing, which has been shown to negatively impact trees by increasing fine root mortality and creating conditions that cause soil nutrient loss. Shorter winters can also impact the amount of chilling time, causing some trees to leaf out later or less effectively. Couple this with unexpected late spring freezes and it's possible for new leaves and flowers to become damaged. While there is uncertainty around how climate change will impact forests, it is certain that trees will face various challenges and opportunities as winters continue to change. Understanding how trees have adapted to survive allows us to better understand how they may be vulnerable in the future and helps us to steward our forests with the future in mind.

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