Growth Capacities of COAST REDWOOD

Photo Essays by Connie Barlow

1. Lignotubers
2. Basal Sprouts from Lignotubers
3. Fallen Branches Sprout by Layering
4. Trunk Reiteration
5. Propagation from Cuttings
6. Bark Beetle Evidence

*All photos by **Connie Barlow**, unless source specified*

LEFT: Connie Barlow, 2020, Prairie Creek Redwoods State Park

Current Events and Key Conclusions

• 2019 - **BARK BEETLE evidence** on a fallen branch, which Barlow **documented at Prairie Creek Redwoods State Park**). At the time of her discovery, common knowledge was that Coast Redwood was impervious to bark beetles. This remains true for the thick-barked trunk, but the canopy branches (evolved when natural fires did not reach the canopy) grow rather thin bark, and are thus susceptible to beetle entry especially during droughts.

• 2022 - **CANADIAN FORESTRY REPORT:** **"Potential for Assisted Migration of Coast**

Redwood (Sequoia sempervirens) to Vancouver Island: Problems and Prospects", by Richard S. Winder, Anais Valance, Ian Eddy, Vince Waring, and Alessandra Jones, October 2022, Report BC-X-459, Natural Resources Canada. Note: **Direct DOWNLOAD for Researchgate members**.

> EXCERPT: Climate change threatens coast redwood (Sequoia sempervirens) within the extent of its current range along the western coast of North America, from southern California to southern Oregon. **We examined the potential for assisted migration of coast redwood to the western coast of Vancouver Island as an adaptation strategy to counter climate threats.** While **many coast redwood trees have been planted successfully throughout the Pacific Northwest**, a question remains concerning the ability of the species to establish successive generations of seedlings in this region. We first plotted potential **optimal habitat** for self-sustaining populations of coast redwood on Vancouver Island using several key factors, including optimal annual **fog frequency** (> 200 h), optimal elevation above sea level (20-300 m), aspects not facing and adjacent to the ocean, optimal mean spring temperature (>6C) and optimal biogeoclimatic zone. Within this optimal habitat, we also plotted the variation in three relevant parameters: mean annual precipitation, mean summer humidity, and cumulative annual frost-free days. This resulted in **a prediction of narrow strips of optimal habitat along the central west coast of Vancouver Island**, wherein the best environmental trade-offs were located midway along coastal inlets....
>
> PREVIOUS papers suggesting ASSISTED MIGRATION (as a future possibility):
>
> • 2011 - **"Lineage Divergence in Coast Redwood (Sequoia sempervirens), Detected by a New Set of Nuclear Microsatellite Loci"**, by V. Douhovnikoff and R. Dodd, 2011, *American Midland Naturalist*.
>
>> EXCERPT: ... Stands are composed of **a high proportion of clonal members** (Douhovnikoff et al., 2004; Rogers, 2000) that may have persisted over many generations. **This persistence mode of reproduction can be advantageous in the face of disturbance events and also may have been of great benefit to redwoods during the cold periods of the Pleistocene** [as seedlings are more vulnerable to below-freezing temperatures than are mature stems and stumps]. However, two major disadvantages to this mode of growth are (1) lack of recombination that would otherwise allow new adaptive gene combinations to be expressed, and (2) **low vagility of the species**. These two consequences of vegetative reproduction in long-lived organisms such as redwood are likely to mean that it will be unable to adapt to the new conditions or migrate into the displaced habitat. **Assisted migration may be necessary to allow populations to match the new climates.**
>
> • 2013 - **"Potential Late-Holocene Disjunction of Sequoia sempervirens on the Central Oregon Coast"**, by Daniel G. Gavin et al., 2013, *Northwest Science*.
>
>> EXCERPTS: ... A recent extinction of redwood on the Oregon coast raises important questions about the conservation of this species under climate change.... Ongoing climate change within the range of redwood may eventually affect its growth, jeopardize southern populations, and invoke a need to assist its migration northward (Douhovnikoff and Dodd 2010, Johnstone and Dawson 2010).

Evidence of a recent natural disjunction, as presented here, provides a precedent for redwood as a component of central Oregon coastal ecosystems. This precedent could be used in the future to help justify a plan for assisted migration and extension of the northern limit of redwood.

- **"Regeneration Dynamics of Coast Redwood, a Sprouting Conifer Species: A Review with Implications for Management and Restoration"**, April 2017, by Kevin L. O'Hara et al., *Forests*.

  EXCERPT: ... **Restoration strategies in a changing climate** should include a broad set of tools, as it is not clear yet how species will adapt to the increase in the temperature. Multiple scenarios need to be considered. The already difficult process of migration of trees to new habitats, restricted to maximum distances of seed dispersal, is further complicated in redwood because the species is reliant on a sprouting reproduction strategy. The data from common garden trials might be used to **evaluate the potential for the assisted migration in redwood**. It may be possible to **shift the range of the species further north, along the coastline of Oregon, where moisture conditions will be suitable for species survival and reproduction**. Another strategy may be enrichment planting of drier and warmer provenances to diversify the gene pool of existing redwood stands and increase their resilience to climate change. However, with either assisted dispersal or blending of provenances, **active management of redwood forests will be necessary**.

• 2022 - **SEATTLE CITIZEN GROUP PLANTS REDWOODS IN PAC NW:** Initially formed as **"Moving the Giants"** (2016), the citizens refocus their redwood plantings for "climate adaptation" and "carbon sequestration": **PropagationNation.us**. Barlow aims for the set of photo-essays on this webpage to support the group in:

(1) **Encouraging citizens in the recipient ecosystems to rejoice at the opportunity to host Coast Redwood** — not only for its carbon-sequestration ability and its magnificence above ground, but also for **the wonders of its below-ground lignotuber, interconnected root system, and wondrous ability to regrow great trunks from basal sprouts**. As Harvard botanist Peter Del Tredici concluded,

> "The *Sequoia* **lignotuber can produce physiologically juvenile shoots continually throughout most of its long life**. This ability endows the tree with a kind of ecological immortality — by which I mean that **as long as environmental conditions remain constant, the tree can live forever**, or at least until it's uprooted."
>
> — Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

(2) **Enhancing their scientific understanding of Coast Redwood in the Pacific NW** — including management choices in **nurturing the group's initial plantings of rooted branchlets** toward ultimate tree-form growth.

(3) **Resting assured that the initial "plagiotropic" (shrubby) plantings are nevertheless destined to become giant trees.** Online research has led Barlow to offer **11 CONCLUSIONS**, the last two of which confirm that:

- **The existing PLAGIOTROPIC (shrub-like) plantings of**

redwood clones in Seattle will almost surely manifest the tree-form (although perhaps requiring a decade or two).

• Staking the little plants may be helpful, but **Coast Redwood is capable of manifesting vertical growth entirely on its own**, later followed by radial branching symmetry along a leader stem of its choice.

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1. Redwood Lignotubers

January 2023
photo-essay by **Connie Barlow**

NOTE: **Coast Redwood is the common name of *Sequoia sempervirens***, yet Giant Sequoia is the common name of *Sequoiadendron giganteum*. Excerpts of technical papers by **Peter Del Tredici** used in this section (and the next) sometimes refer to **Coast Redwood by its genus name, italicized: *Sequoia***. The two papers are:

- Peter Del Tredici, 1998, **"Lignotubers in *Sequoia sempervirens*: Development and Ecological Significance"**, *Madrono* 45:3, pp 255-260.

- Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

• PRAIRIE CREEK REDWOODS STATE PARK (1 photo)

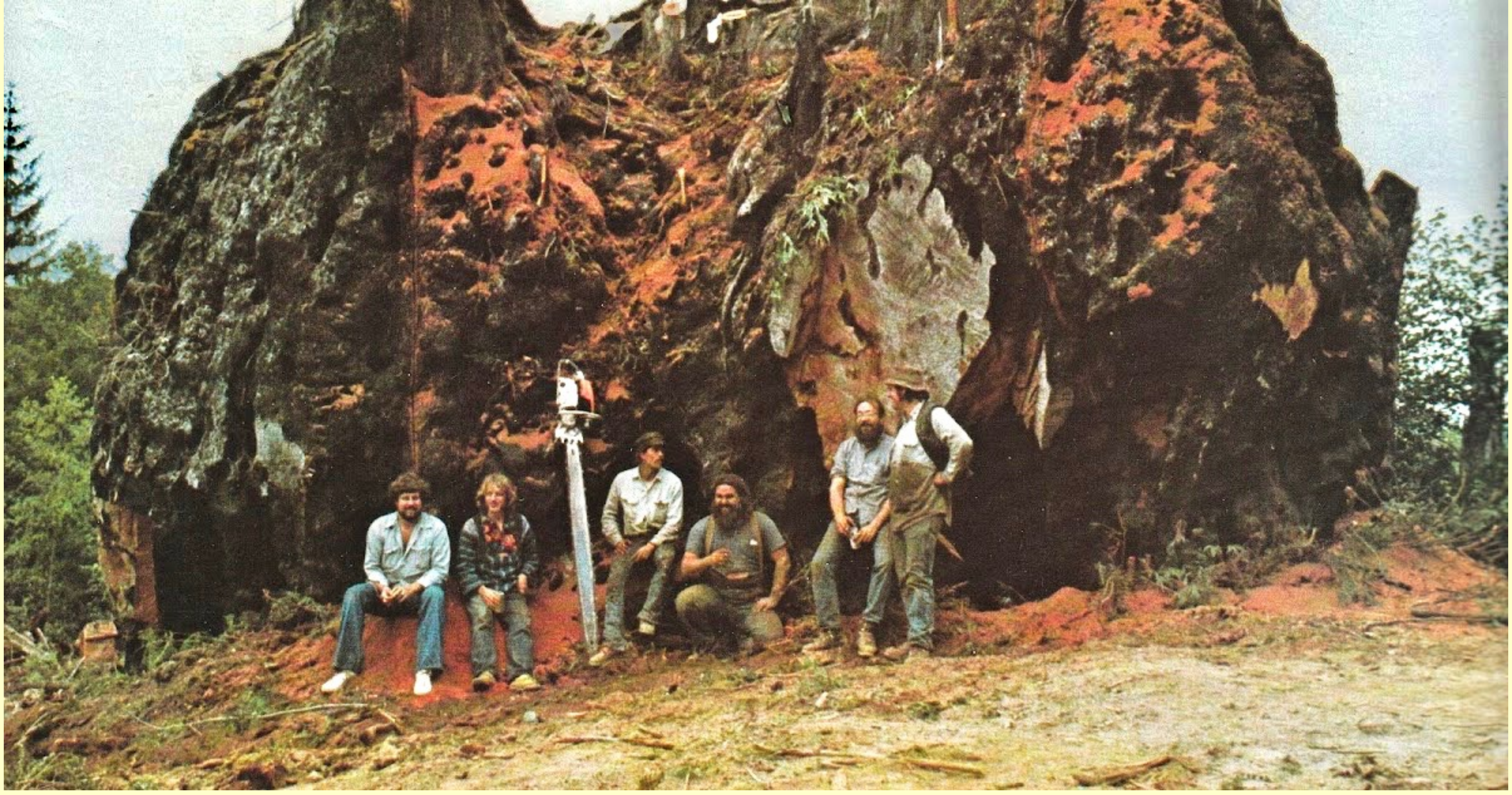
ABOVE: Many species of trees will grow **"epicormic "burls"** along their trunks, as in this redwood grove in **Prairie Creek Redwoods State Park**. Burls usually develop as **a result of injury** to the bark. **Fewer species will grow lignotubers at their root crown, and these structures develop as an inherent and natural feature** (no environmental injury is required). Continuing to expand over many centuries, the lignotuber of a Coast Redwood becomes the largest of all.

• STOUT GROVE of JEDEDIAH SMITH REDWOODS STATE PARK (1 photo)

ABOVE: The lignotuber of a very large stem is **extending a long distance laterally**, with this section visible above the soil line.

> "**The lignotuber is a specialized organ of regeneration and carbohydrate storage that contributes to the long-term survival of the tree** by producing buds that can develop into shoots following traumatic injury to the primary trunk and by generating new roots that increase the stability and the vigor of both young and old trees.... Over time, lignotubers can become quite large and contribute to the survival of plants in three ways:
>
> > (1) They are a site for the production and storage of **suppressed shoot buds** that can sprout following injury to the primary stem.
> >
> > (2) They are a site for the **storage of carbohydrates and mineral nutrients**, which may allow for **rapid growth of these suppressed buds following stress or damage**.
> >
> > (3) For plants growing on steep slopes, they can function as a kind of **clasping organ that anchors the tree** to the rocky substrate.
> >
> > — Peter Del Tredici, 1998, **"Lignotubers in *Sequoia sempervirens*: Development and Ecological Significance"**, *Madrono* 45:3, pp 255-260.

• ARCHIVAL PHOTO NEAR SANTA CRUZ:



ABOVE: **Famous photo of a lignotuber** "mined" on the timber claim of George Hartman, along King Creek. Decades after logging had stripped forests of the valuable trunks of the giant redwoods, new markets were discovered for the unusual patterns in the massive lignotubers that lurked beneath the surface of the stumps.

• PRAIRIE CREEK REDWOODS STATE PARK (next 3 photos)

ABOVE: At the center of this photo is an actively budding section of lignotuber at Prairie Creek Redwoods State Park. It is at eye-level on the base of an old growth redwood. (Notice the blueish large redwood trunk in the distance at left.)

BELOW: Close-up of the same active lignotuber section, as above.

ABOVE: Another active lignotuber at Prairie Creek Redwoods State Park.

• FRESHWATER CREEK tributary called Graham Gulch, east of Eureka (next 3 photos)

ABOVE: At low flow, one can walk upstream the tributary creek of Graham Gulch, which flows under Pacific Lumber Camp Rd. into Freshwater Creek (east of Eureka). A mature redwood trunk strangely leans only a dozen feet upslope of the creek. This is unusual because **mature redwood stems do not lean**. Notice the brown color and unusual structures on the "underside" of the leaning trunk. It evidences a seeming desire to extend its growing lignotuber into the downhill soil — perhaps seeking reinforcement for stability. Hence, **the suppressed buds in this case have awakened into root shapes**.

ABOVE: Closeup of the active lignotuber section of the above leaning redwood stem. Environmental conditions can induce **"adventitious roots"** attempting to find soil.

BELOW: An even closer view of the above lignotuber.

> "Under field conditions, most redwood seedlings do not form visible bud swellings at the cotyledonary nodes until they are between three and six years old. Interestingly, these tiny lignotubers often produce **adventitious roots** as well as leafy shoots in response to the partial burial that they experience following the heavy rains and erosion characteristic of the region."
>
> — Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

• HUTT PARK in EDMONDS, WASHINGTON (north of Seattle; 1 photo)

ABOVE: Horticultural plantings of Coast Redwood within forest settings far north of its native range will produce viable seeds that can become seedlings — if deer are absent. An old planting of 2 redwoods in **Hutt Park in Seattle WA** has generated quite a few seedlings and saplings. The sapling in this photo appears to have **already grown a small lignotuber**, from which basal sprouts have risen on the sunny side. As well, **the lowest 4 buds on the stem have taken the form of suppressed buds**, from which new leader sprouts or new roots can emerge if circumstances provoke their release. (This photo was extracted from the 55-minute site visit **VIDEO of the Hutt Park Redwoods** by Connie Barlow in 2017.)

> "Lignotubers originate in buds located in the axils of the seed leaves (cotyledons) and a few of the leaves immediately above them.... After a few years of cultivation in the greenhouse, nearly all of the young lignotubers were producing leafy shoots and **the swelling of the stem associated with lignotuber formation had spread upward to engulf several nodes above the cotyledons**.
>
> — Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

LEFT: A seedling of Coast Redwood emerges above the ground with **a pair of cotyledons, longer than the leaves**.

As the stem continues upward growth, true leaves emerge.

The **lignotuber will begin to develop** at the spot (the "axil") where each cotyledon emerged from the stem.

"Seedlings of *Sequoia sempervirens* develop lignotubers as part of their normal ontogeny from **detached meristems located in the axils of the two cotyledons**.... Lignotubers continue to expand throughout the life of a *Sequoia*, eventually forming massive, basal swellings that are covered with leafy shoots and/or suppressed shoot buds."

— Peter Del Tredici, 1998, **"Lignotubers in *Sequoia sempervirens*: Development and Ecological Significance"**, *Madrono* 45:3, pp 255-260.

"The few conifer species, excluding *Pinus* species, that resprout after 100% leaf scorch are mainly from crown-fire ecosystems, although some species (e.g., *Wollemia nobilis,* ***Sequoia sempervirens****,* *Taxodium distichum*) occur in moist environments."

— Geoffrey E. Burrows, 2021, **"Gymnosperm Resprouting: A Review"**, *Plants*.

CONCLUSION 1: Redwood's capacity to grow an **enormous lignotuber** at or below its root crown is just as wondrous and unique as the capacity for great height and longevity.

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2. Redwood Basals Sprout from Lignotubers

January 2023
photo-essay by **Connie Barlow**

QUESTION 1: Understanding **the latent ability of Coast Redwood to self-thin its initial profusion of basal sprouts** following death of the main stem, while considering the likelihood that **root fusions with neighboring redwoods are likely**, can affect "management" decisions for fire-damaged redwood groves. Fundamentally, **should the basal sprouts be left to grow and senesce naturally, or should active management eliminate some of the sprouts?**

ABOVE: **Two years after the 2020 CZU Fire** in the Santa Cruz Mountains, **basal sprouts are supporting the living root systems** beneath the devastation of the above-ground redwood kill at **San Vicente Redwoods**. *Source:* ***Save the Redwoods League****.*

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ABOVE: Archived photos of basal regrowth after old growth logging can be instructive in **urging today's forest managers to go light on pruning back the basal sprouts. Instead, there may well be advantages in letting the redwood root systems themselves determine when the first flush of basals have sufficiently done their job**. When that time arrives, a reduced number of basal stems naturally begin to race, together, toward the sky. So long as sunlight continues to reach the base, the remaining basals will continue to serve the system's needs for photosynthates.

Source: **"Timber Growing and Logging Practice in the Coast Redwood Region of California"**, 1932, S.B. Show and R.Y. Stuart, Technical Bulletin No. 283, U.S. Department of Agriculture. EXCERPT:

"As logging has progressed and the area of virgin forests diminished, redwood operators, like operators in other regions, have recognized that they were becming to an ever-increasing extent holders of cut-over land, and engaged in what might be called "the cut-over-land business" ... They found, however, that, except in instances of unusual abuse, **their cut-over land would renew its growth of redwood to an appreciable extent and in a remarkably short period of time without any assistance from them**.

"... Another study showed that **on south slopes** the percentage survival of thrifty redwood trees planted in the open was from 0 to 22 percent of the total set out; the corresponding figures, where the trees were set so that they received some shade from the south, east, and west, wer 70 to 90 percent.... The same study showed that on **north slopes** the survival without individual shade was 63 percent; with shade from three sides, 90 percent."

"... It has been found that several years must elapse after planting before trees become thoroughly established and begin rapid height growth. **Sprouts, of course, grow rapidly from the start.** In all probability the yields from stands containing a high percentage of planted stock will be lower at a given age than where the trees originated from sprouts. At 50 years of age, the volume per acre of stands from seedlings is 74 percent that of sprouts."

ABOVE: **A set of basals rise from the stump of a very large redwood** that was logged in the first decade of the 20th Century. Location: **Private forest near Swanton, north of Santa Cruz**, 2005.

• FRESHWATER CREEK (dirt logging road, upstream of the paved Pacific Lumber Camp Road; 6 photos)

ABOVE: The **private, old logging road that parallels Freshwater Creek, east of Eureka** (beyond the paved section of Pacific Lumber Camp Road), cuts into the slope of the first bench above the floodplain. Here one can see a portion of the **lignotuber trending down the slope** of the old roadcut.

> "When second-generation trees are found growing on **a steep slope near a stream or a road cut**, the woody lignotuber is readily observable as a massive 'plate' of **downward-growing tissue that follows the contours of the ground and extends two 2 to 3 meters out from the nearest trunk**. As well as giving rise to new shoots, such exposed lignotubers are also the source of roots that help to **anchor trees to eroding slopes**. On rocky sites, the lignotuber has a tendency to form a kind of clasping organ that envelops the adjacent substrate, further stabilizing the tree."
>
> — Peter Del Tredici, 1998, **"Lignotubers in *Sequoia sempervirens*: Development and Ecological Significance"**, *Madrono* 45:3, pp 255-260.
>
> "The *Sequoia* **lignotuber can produce physiologically juvenile shoots continually throughout most of its long life**. This ability endows the tree with a kind of ecological immortality — by which I mean that **as long as environmental conditions remain constant, the tree can live forever**, or at least until it's uprooted."
>
> — Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

ABOVE & BELOW: Walking along the upstream dirt section of the **Freshwater Creek** logging road, a marvelous set of 4 basal trunks comes into view, rising from a logged stump downslope toward the creek, and thus out of view.

ABOVE: Farther upstream **Freshwater Creek**, along the logging road, basals rise from an old stump (barely visible) on the steep slope leading down to the floodplain.

BELOW: Photo taken while lying on top of the old stump in the photo above, looking upward.

"Preliminary observations suggest that **all of the roots that support a second-generation *Sequoia* sprout, regardless of its size, are generated by the lignotuber**."

— Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

ABOVE: Upstream **Freshwater Creek**, where the logging road crosses via a bridge.

> "Early thinning or precommercial thinning is common to reduce overall stand density and to reduce the number of sprouts in redwood sprout clumps. **Sprout clumps are typically thinned to two or three sprouts per clump**, but repeated generations of stumps can form complex patterns of stumps that may extend over several meters. In these cases, more sprouts may be left. Thinning redwood sprout clumps reduces aggregated spatial patterns, promoting a more random arrangement of stems found in even - aged or complex, multi-aged stands and **may not always increase sprout growth**. Age of sprouts affects sprout size, which affects equipment options for thinning clumps.... **It is possible to thin too early in stands of sprouting species like redwood**.
>
> "... Challenges to management include **the social scrutiny that accompanies managing of such an iconic species**, and the difficulties in obtaining full stocking of desirable species. For this latter challenge, **interplanting of redwoods and aggressive control of shrubs and competing plants are standard operating procedures**. Redwood sprouts can also be persistent in their aggregated spatial patterns, thereby **necessitating thinning to increase growth and form more random spatial patterns**.... Simply stated, **an active management approach is generally viewed as the best way to restore old redwood forests and the ecological values they provide**."
>
> — Kevin L. O'Hara et al., 2017, **"Regeneration Dynamics of Coast Redwood, a Sprouting Conifer Species: A Review with Implications for Management and Restoration"**, *Forests*.

*Editor's note of DISAGREEMENT with the above: **Root fusions that connect neighboring trunks prior to logging (or stem destruction by fire) are unseen and therefore can neither be measured nor***

even documented as to presence or absence.

Therefore, it is not surprising that technical papers advising on "restoration" of fire-damaged groves tend to ignore ***possible advantages of the natural process of abundant basal sprouting followed by self-thinning for maximizing retention of the original root systems*** *(including fusions).*

Fused roots may be especially important for ***distributing water*** *during the post-fire time of intense sunlight (and hence heat and evaporation), especially in this warming climate.*

PHOTOS LEFT: **Fused roots of two *Liquidambar* trees** along an ephemeral creek in northeast Alabama. (Close-up of the left-side trunk at bottom. (Photos by Connie Barow, 2010.)

Below is an excerpt of a 2004 paper that suggests **the importance of maintaining maximal retention of root systems** — and thus the benefits of **permitting abundant basal sprouting to grow and persist without human intervention of early pruning**.

> "**If the ramets in a clone remain integrated, resources can be shared across the genet.** As a result, large redwood clones not only have a proportionately larger footprint in terms of resource use, but they may also be taking advantage of economies of scale and greater access to resources. Future work on the integration of redwood clones and the extent and dynamics of **resource sharing** is necessary to determine the larger scale physiological importance of cloning in redwood.
>
> "... **Clones have access to an already established root system**, grow much faster than seedlings, and are not susceptible to damping off.... Without a biological limit to the number of ramet generations over time that can be produced vegetatively, **a successful redwood genotype is locally persistent and potentially immortal**."
>
> — Vladimir Douhovnikoff, Adelaide M. Cheng, and Richard S. Dodd, 2004, **"Incidence, Size, and Spatial Structure of Clones in Second-Growth Stands of Coast Redwood, *Sequoia sempervirens* (Cupressaceae)"**, *American Journal of Botany*.

ABOVE: Upstream **Freshwater Creek**, visible only while walking in the creek itself. Notice how **the number of basal sprouts have already self-thinned naturally, suggesting eventual merger into a new "single" tree trunk** somewhat bigger than the original that was cut down by logging (and still visible, in part, in this photo).

> "**The ability to produce new shoots and roots from undifferentiated tissue is not only a disturbance survival mechanism, but also the primary reproductive strategy for *S. sempervirens*** (Barbour et al., 2001; Douhovnikoff et al., 2004). The majority of reproduction takes place asexually resulting in a landscape populated by clonal groups.
>
> When a mature redwood is felled, due to natural or human causes, shoots are produced from the remaining stump. **The shoots compete, but not in the traditional sense. Because *S. sempervirens* is a coppicing species, with shoots connected to a shared root system, individual shoots compete for apical dominance rather than for the survival of the organism** (Kauppi et al., 1987; Burrows, 1990; Laureysens et al., 2003). As one shoot achieves dominance, other shoots begin to senesce (Sach et al., 1993) **thinning the stand naturally**. While *S. sempervirens* **self-thins with facility**, other coniferous forests face issues of over-crowding due to competition, which can lead to etiolation for individual trees and significant stand-level mortality due to reduced crown to height ratio and pre-disposition to insect and fungal attack (Floyd et al., 2009; Lutz & Halpern, 2006). **Coast redwood forests are less susceptible to these dangers because regenerating tissue is connected to well established root systems, *S. sempervirens* is highly shade tolerant, and suppressed trees can increase their crown to height ratio when released through epicormic sprouting** (Sawyer et al., 2000).
>
> **The regenerative properties of *S. sempervirens* have allowed foresters to manage second growth stands with minimal effort for decades** (Fritz, 1945). These same properties suggest that a natural regenerative approach to restoration could be successful. However, though much work has been done on the effects of forest thinning in coast redwood forests (Cole, 1983; Chittick & Keyes, 2007; O'Hara et al., 2010), very little is

known about the natural processes of recovery in the absence of continued human disturbance.

CONCLUSION & DISCUSSION: **"The results of this study indicate that natural recovery is an effective technique for the restoration of coast redwood forests.…** Active management tools such as stand thinning are counter-indicated as they are generally employed as a restoration technique to reduce tree density in overstocked stands and to promote the dominance of desired species. Additionally, the added disturbance of mechanical thinning is likely to impact sensitive understory herbaceous species that are dependent on the moist shady environment provided by a mature forest canopy.… **Overall, the arboreal features of the forest appeared to be quite resilient to human disturbance, while shade-loving herbaceous species were not. With this in mind, implementation of mechanical restoration techniques, such as stand thinning, are counter-indicated.**

— Will Russell, Jeff Sinclair, and Kristin Hageseth Michels, 2014, **"Restoration of Coast Redwood (*Sequoia sempervirens*) Forests through Natural Recovery"**, *Open Journal of Forestry*.

• FRESHWATER CREEK, along the paved section of Pacific Lumber Camp Rd.

"On trees damaged by logging or erosion, **lignotubers give rise to large secondary trunks that equal or exceed the primary trunk**. Mature trees that had been logged 90 to 100 years ago have now developed lignotuber sprouts well over a meter in diameter."

— Peter Del Tredici, 1998, **"Lignotubers in *Sequoia sempervirens*: Development and Ecological Significance"**, *Madrono* 45:3, pp 255-260.

ABOVE: The forest along the paved road is so close to Freshwater Creek that, for environmental and road stability reasons, it cannot be harvested again. **Regrowth is now more than a century old**, yet the wood is so resistant to rot that the **old cuts for inserting the board platforms** of the cross-cut sawyers are still often visible (as in the old stump far right).

• YELLOW-GATE TRAIL (Freshwater Creek, 2 photos)

ABOVE and BELOW: Visible immediately on the uphill side along Yellowgate Trail, which is the old logging road up the **Graham Gulch tributary of Freshwater Creek**, is an old stump whose basals are multi-aged and numerous.

"As spectacular as these old-growth forests are, with their trunks disappearing into the fog that enshrouds the forest much of the year, they do not present a complete picture of the species. For that, **one must visit redwood stands that were logged fifty to one hundred and fifty years ago**. It is here that one finds the multi-trunked specimens that have sprouted from around the stumps of the original trees.

"In some redwood forests, the second generation of trunks have also been cut, leading to **a third generation of sprout growth**. Among conifers, the redwood is unique in its remarkable power of basal regeneration. To my mind **it is the redwood's ability to resprout — its great vitality — that makes the tree worthy of admiration and study**.

Quasi-religious feelings are expressed by nearly everyone who visits and old-growth redwood forest, but **few people think about or are even aware of the tree's extraordinary powers of survival**."

— Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

• PRAIRIE CREEK REDWOODS STATE PARK (next 4 photos)

ABOVE: Basals arising from lignotuber along nature trail at Elk Creek campground.

"**Clones were not limited to fairy-ring structures**, but consisted of a wide range of shapes including concentric rings, ring chains, disjunct, and linear structures. Between-ramet distances of up to 40 meters were measured, indicating that **clonal reproduction is not limited to basal stump resprouting**.

— Vladimir Douhovnikoff, Adelaide M. Cheng, and Richard S. Dodd, 2004, **"Incidence, Size, and Spatial Structure of Clones in Second-Growth Stands of Coast Redwood, *Sequoia sempervirens* (Cupressaceae)"**, *American Journal of Botany*.

ABOVE: Roots of fallen giant at **Prairie Creek Redwoods State Park**.

ABOVE: The "Corkscrew Tree" at **Prairie Creek Redwood State Park** clearly is a set of basals that bend around one another.

• ROCKEFELLER GROVE of the Redwood National Park system (next 3 photos)

ABOVE: **Rockefeller Grove** is a special environment that contributes to forest stability. It is located on **a wide flat "bench" that rises steeply above the current channel of the Elk River**. Extensive downward cutting of the river channel, likely in recent times owing to clearcut logging practices that fostered powerful erosional currents, now ensures added stability to this grove — which **will likely persist until the warming climate** can no longer be tolerated by this species.

ABOVE and BELOW: **Rockefeller Grove** ground-level burl.

• SIMPSON GROVE of the Redwood National Park system (2 photos)

ABOVE: **Simpson Grove**. This massive "tree" clearly is a set of merging basals.

CONCLUSION 2: Redwood's capacity to **initiate, self-prune, and eventually merge basal sprout regrowth** following death of the current main stem is just as wondrous and unique as the capacity for great height and longevity.

CONCLUSION 3: Managers of redwood plantings should **err on the side of non-interference when wondering if basal sprouts should ever be pruned or cut back**. The only exception is to allow propagators to remove the tips of basal sprouts for cloning that particular genotype.

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3. Fallen Branches Sprout by Layering

January 2023
photo-essay by **Connie Barlow**

INTRODUCTION: This "layering" section and the next on "trunk reiteration" explore the degree to which Coast Redwood has **the capacity to restore a tree-like vertical growth pattern, with radial branching, from the horizontal growth pattern intrinsic in an intact or severed lateral branch or branchlet**.

PRACTICAL IMPORTANCE: Knowledge of redwood capacities for **layering** and **trunk reiteration** may be useful for improving methodologies in rooting cuttings toward the goal of **achieving tree-form growth** patterns despite plagiotropic tendencies.

3A. Redwood Layering of Ground-Lying Branches

producing vertical (orthotropic) growth from lateral branches (plagiotropic)

ABOVE: Connie Barlow (2019) at **Seabeck Conference Center**'s Douglas-fir working forest, into which Coast Redwoods were introduced in the mid 1980s. **The lichen-spotted trunk apparently fell onto a redwood branch.**

ABOVE: **Sprouts emerging in abundance, with some apparently upright leaders**. (Notice at left the same lichen-covered fallen trunk that may have initiated this process of new growth by **vegetative "layering"**.

ABOVE: Connie found that this end of the moss-covered fallen branch **had been sawed**. She also found it had become **too well-rooted to be lifted upward**.

CONCLUSION 4: There is strong **evidence that Coast Redwood is capable of producing new upward stems when a laterally growing branch** is bent to the ground (and possibly also when broken off by windfall). As with other "layering" species of conifers (some spruce and fir), this ability ultimately results in a clonal patch of stems that continue to grow upward as fully formed trees, including **a radial growth pattern of each new stem's branches.**

• *Visit Barlow's HOUR-LONG VIDEO of her within-forest redwood inventory:* **VIDEO: Pt. 9F - Coast Redwoods Thrive and Multiply at Seabeck, WA 2019**. The above 3 photos of the branch sprouts were copied as stills from the video, beginning at timecode 11:50.

> "Little is known about how redwood clonal spread occurs beyond local basal sprouting. While fairy-rings, concentric circles, and figure eights or longer chains can be explained by repeated basal sprouting of new ramets, it is still unclear how disjunct structures come about. **It is possible that falling trees bury branches that then sprout** (Rogers 2000), or that soil disturbance, such as in the use of harvesting equipment, **may expose and promote sprouting in roots** (Weber 1990, Lavertu and others 1994). An example of this may be the disjunct and somewhat chaotic pattern found on site J1 (fig. 2c). **This is an important area for further research.**"
>
> — Vladimir Douhovnikoff and Richard S. Dodd, 2004, "Clonal Spread in Second-Growth Stands of Coast Redwood, *Sequoia sempervirens*, *American Journal of Botany*.

EDITOR'S NOTE: In the introduction section of the above paper, the authors wrote: **"This is the first major study of clonal spread in redwoods using molecular genetic techniques.** In this research our goals were to evaluate the importance of clonal spread in **second-growth redwood stands**, and to explore the local spatial structure of redwood clones."

"There are also physiological problems involved in the phenomena of **layering** in this group of plants, which cannot at present be satisfactorily settled. These problems relate to **the theories of orthotropism and plagiotropism and their mutual relations**. The whole subject is at the theoretical stage, without adequate evidence in support of any of the various hypotheses. In the process of layering, the rooting (when it occurs) is simple enough as a response to moisture and absence of light. **The change from dorsiventral to radial symmetry is to be expected as a result of the tip becoming erect, being an adjustment to changed light relations. The change in direction of growth from horizontal to erect is the part that is difficult to explain.** It is bound up with the **agencies which cause lateral shoots, ordinarily plagiotropic, to become orthotropic when the terminal shoot is removed or damaged**. In the process of **layering**, it should be noted, **this change takes place without antecedent removal of the main shoot**. The case is thus somewhat different, but the same factors doubtless govern it. In the present state of knowledge relating to orthotropism, plagiotropism, and correlation, it will be useless to continue the discussion at length.

— William S. Cooper, 1911, "Reproduction by Layering Among Conifers", *Botanical Gazette*

- 1999 REPORTED EVIDENCE OF "LAYERING":

"Induced Lignotubers on Layered Branches": Only once have I observed "layering" in Sequoia. Rudolf Becking, a retired ecologist from Humboldt State University, had taken me to see what he assumed was a group of "seedlings" that had germinated following a particularly severe flood in the 1960s. **Closer examination showed that they were not seedlings at all. Rather, they were lateral branches of very weak, spindly saplings that had been bent over by limbs falling from the nearby canopy trees and had taken root and reestablished a vertical orientation.**

"Typically, **a single, downward-growing lignotuber had developed along the side of the branch in contact with the soil**, although in a few cases several lignotubers had formed along the length of the buried stem. On such layered branches, **the original connection to its parent trunk had mostly withered away, leaving only the bowed shape of the stem and the off-center lignotuber as evidence of its origin in a branch**.

"As is the case with lignotubers derived from the cotyledonary node, those formed by layered branches possess the ability to generate both buds and roots. How long it takes for a branch to develop a lignotuber after it has been pinned to the ground is not known, but it is probably at least a year or two. From the ecological perspective, the layering ability of redwood seedlings appears to give them some **flexibility in responding to environmental conditions by migrating from areas of shade into areas with better light**."

— Peter Del Tredici, 1998, **"Redwood Burls: Immortality Underground"**, *Arnoldia*.

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3B. Examples of Ground-Lying Branches of Genus Torreya

The experience of **Torreya Guardians**, founded in 2005 by Connie Barlow, may be useful for redwood planters in the Pacific Northwest:

In three locations where *Torreya taxifolia* (a member of the yew family, Taxaceae) was planted horticulturally many decades ago, partial shading by canopy trees inclined this species to put forth into the sunlight at least one ground-laying branch, up to 30 feet long. Fortunately, the private landowners at these three sites have not pruned those branches back. Photo-essays by Connie Barlow follow for these three sites:

• HARBISON HOUSE, Highlands NC (April 2015)

ABOVE: **Jack Johnston, northeastern GA**, is measuring the circumferences of the half-dozen, nearly century-old, Torreya trees planted by botanist **Thomas Grant Harbison**, at his home near Highlands, NC. Planted so close to one another, it was not surprising that **several of the trees had extended a lower branch more than a dozen feet outward in quest of sunlight**. Notice the long branch extending to the right from the dark trunk just to the right of Jack. This was the biggest torreya, circumference 55 inches, and you will see that long, low branch again in the next two photos.

ABOVE: Jack is pointing to the **longest low branch extending outward**.

BELOW: Jack estimates this branch as **20 feet long**. Here he is lifting the branch, and thereby determined that **it had not rooted into the ground**.

Neither Jack nor Connie examined the branch to determine whether any radially symmetrical, vertical shoots were rising up from it. These 3 photos were extracted from a video that Connie posted on youtube of this site visit. The final picture is at approx 16:15 timecode:
VIDEO: "FL Torreya in Highlands, NC: 90 yrs de facto rewilding (2015)"

• BILTMORE GARDENS, Asheville NC (October 2018)

ABOVE and BELOW: **This double-stemmed Torreya tree is overtopped** by an evergreen Norway Spruce and a deciduous *Liriodendron* to its left. Not surprisingly, a low branch on the sunny side **extends 30 feet outward toward a mowed lawn**. (Below is a close-up of the origin of the branch.)

ABOVE and BELOW: The distant end of the ground-laying branch, estimated 30 feet long.

The video sequence that Connie documented in 2018 has not yet been edited and posted on youtube. One photo of this branch is posted on the information-rich **Biltmore Gardens** webpage on the Torreya Guardians website.

• BRIARWOOD PRESERVE, Saline Louisiana (November 2018)

Here you will find **the best documentation (including close-up photos of radially symmetric, vertical stems) of a long, ground-laying branch of Florida Torreya.** All photos were captured as stills from the VIDEO that Connie posted on youtube. Clint Bancroft, Connie Barlow, and Michael Dowd were the Torreya Guardians visiting the historic plantings of *Torreya taxifolia* at this site, which is also known as **Caroline Dormon Nature Preserve**.

The VIDEO is in two parts. The photos below were extracted from the second video: **"Florida Torreya in Louisiana (Pt 2) - Mature Grove with Seedlings**. Timecode 04:45 is where the ground-branch sequence begins.

ABOVE: Low branch reaching toward the road, approximately 30 feet.

ABOVE: The ground branch had many offshoots, covering a large area in green torreya leaves. Here you can see a several-inch-tall upward sprout emerging from the top of the thickest branch, lower left.

BELOW: A close-up of that same vertical sprout.

ABOVE: Two more examples of radially symmetric, upward sprouts.

ABOVE: Base of trunk with basal sprouts, directly below the extending low branch.

ABOVE: The outward, splaying sections of the ground-laying branch **beautifully intermingle with evergreen Christmas ferns** — which associate with **the same mychorrizal fungal partners** as does Torreya.

DISCOVERY: This is **the first laying-branch example where we can be sure that portions of it actually rooted.** (Connie tried to lift up several segments; some lifted while others did not.)

HIGHLY RECOMMENDED: **Watch the 18-minute section of the VIDEO that explores the**

ground-laying branch, with commentary. Begin at timecode 04:45 of **"Florida Torreya in Louisiana (Pt 2) - Mature Grove with Seedlings**. This sequence includes some photos Connie had taken in 2005 of CALIFORNIA TORREYA growing in acrobatic ways for accessing sunlight.

CONCLUSION 5: **The ability of genus Torreya to expand photosynthesis via ground-laying branching is likely not applicable to Coast Redwood** for the simple reason that Coast Redwood is capable of racing to the top of the canopy, whereas slow-growing Torreya usually cannot. As well, Torreya Guardians have not yet tested whether cutting a radially symmetric upward growth visible on a ground-lying stem is capable of naturally rooting into a tree-form growth pattern.

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4. Trunk Reiteration in Redwood Canopy

producing vertical (orthotropic) growth from lateral branches (plagiotropic)

Trunk reiteration in old growth of Prairie Creek Redwoods State Park

INTRODUCTION: Old growth redwood trees have, by definition, existed for centuries — even a millenium or more. During this time storms have often **"topped"** the main stem, while other accidents may have **"tipped"** the ends of the lateral growing branches — which thereby may **induce the formation of secondary trunks growing upward** from one or more lateral branches. In turn, **those lateral branches thicken as the new verticals grow**. Veteran tree climbers, led by **Steve Sillett**, noticed that few second growth redwoods had experienced top-destroying events, and thus **"trunk reiteration" was scarce and under-developed**. In 2018, he and six colleagues published the results of their own **experiments in "topping" and "tipping" tall second-growth redwoods** that had undamaged crowns. The results were impressive:

> "... Like many conifers, the genetically determined architectural model of redwood consists of an **orthotropic (i.e., vertical) trunk bearing numerous plagiotropic (i.e., horizontal) branches** (Tomlinson, 1983). Wind-induced crown breakage appears to promote structural complexity by creating gaps in otherwise dense, model-conforming crowns. **Trunk reiterations eventually arise from the damaged main trunk and limbs**, giving each tree an individualized and more complex structure. The vast majority of crown-mapped redwoods

in old-growth forests possess broken tops with internal decay, and **nearly every limb measured in these trees has a broken branch axis beyond the reiteration** (Sillett et al., 2015a).

"... In old-growth *Sequoia sempervirens* forests, **reiterated trunks and limbs** provide habitat elements for specialized arboreal species, including an endangered seabird, *Brachyramphus marmoratus*. The oldest second-growth redwood forests that established after 19th century logging lack species dependent on complex structure, presumably because redwoods maintain simple, model-conforming crowns for centuries unless damaged by wind or fire.... Trunk reiterations and limbs develop as redwoods age, but **undamaged trees can retain a simple crown form for centuries**. In young forests without remnant trees, redwoods almost always lack reiterations and possess dense, conical crowns with small branches, explaining why old-growth associated species are now virtually restricted to parks and reserves (Sawyer et al., 2000, Cooperrider et al., 2000)."

METHODS: "We imposed a factorial experiment on 24 redwoods 59 to 75meters tall in six second-growth forests to **determine if trunk reiteration and limb formation can be induced by removing treetops (topping) and branch tips (tipping) to disrupt apical control**.

RESULTS: "**Topping stimulated trunk reiteration** from the cut, and reiterated tops gained height more rapidly than controls. **Tipping also stimulated trunk reiteration** from branches, especially when combined with topping, **resulting in formation of limbs (i.e., branches giving rise to reiterated trunks)**."

— Stephen C. Sillett et al., 2018, **"Manipulating tree crown structure to promote old-growth characteristics in second-growth redwood forest canopies"**, *Forest Ecology and Management*.

CONCLUSION 6: **Trunk reiteration is another ability of Coast Redwood that extends our human sense of wonder.** As well, this ability is regarded as an important habitat feature for **successful nesting of the endangered Marbled Murrelet**. Redwood's ability to restart vertical stem growth from an old horizontal branch offers **support that when humans attempt to root branchlet tips cut from canopy branches, those rooted cuttings will eventually produce bona fide trees**.

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5. Propagation from Cuttings

(rooting and then obtaining vertical orientation)

March 2023

photo-essay by **Connie Barlow**

5A. Introduction

ABOVE: Radial branching pattern of a wild redwood seedling near **Eureka, California**.

BELOW: Radial branching pattern of a wild seedling generated by mature redwoods, **35 years after redwoods were introduced to the Seabeck Forest northwest of Seattle**.

BACKGROUND: REDWOODS born from SEEDS naturally grow in the standard, **"orthotropic" pattern of a single stem, rising vertically, with a radial branching pattern**. Cuttings rooted from BASAL SPROUTS will also grow in a standard way — and with no staking. However, cuttings taken from BRANCHES in the canopy will not automatically grow in the standard way: The **cells retain the directional memory of horizontal branch growth, called "plagiotropic"**.

PROBLEM: The reason that I have researched and am contributing this photo-essay on propagating Coast Redwood from cuttings (rather than from seeds) is that the **the citizen group based in Seattle** that began distributing Coast Redwood in 2016 initially acquired their nursery stock from **Archangel Ancient Tree Archive**. At the time, Archangel had not yet learned that **taking cuttings from basal sprouts or from epicormic tissues on trunk burls** are the only ways to produce plants that naturally grow into a tree form with radial branching. **In their early years, Archangel clipped branchlet tips from far up in the canopy** — and those cuttings rooted into a **plagiotropic** growth pattern. Attainment of the standard tree form is now a primary goal of both groups. ***But what about the initial plantings of rooted branchlet tips onto lands in the Seattle area?***

TWO QUESTIONS:

Q1: Once a plagiotropic potted redwood is planted, **are there any methods to nurture its growth toward the tree form?** Possibilities may include **staking** a main stem into the upright position and/or periodic **pruning back the tip** of the stem. But will these actually work?

Q2: **How many years might need to pass before the plant will settle into a fully upright growth pattern, and with radial branch symmetry?**

Redwood Grove Planted in Laurelhurst Park

The ten saplings are only about 18 inches high now, yet they are genetically identical to some of the largest and oldest coast redwoods on earth. They were planted in Laurelhurst Park as part of an effort to expand the presence of coast redwoods in the Seattle area. Laurelhurst Elementary School students from three kindergartens and three third grade classes planted the trees on Nov 17, 2017.

ABOVE: In 2017, **citizens in Seattle were planting clones** of redwood trees derived from rooted branchlets.

These plagiotropic redwoods were all tied to a stake.

LEFT: Now, of course, **Archangel is using micropropagation techniques** to ensure that all their plants adopt an orthotropic growth form right from the beginning. *Source: Video posted in 2019.*

____

Prior to 2023, I had only **one experience of an original REDWOOD BRANCHLET CUTTING being staked and then finally continuing to grow upward without staking** — *but not yet with a single leader nor complete radial symmetry (with flat-lying leaf structure) of the highest branches*.

Fortunately, I VIDEO-DOCUMENTED that experience in 2017, which took place near Upper Lake, California. Go to **TIMECODE 28:06** of:

- **VIDEO CTL 9E - California Sequoias to Inland Pacific NW: Is it too dry?**

ABOVE: In 2017, DENISE RUSHING talked about how she has been nurturing this **redwood rooted cutting** toward vertical growth. In this **7-minute VIDEO segment**, you can see the **strange branching and leafing pattern**.

RIGHT: **Five years later (March 2023) a tree form has almost fully manifested.** A big vertical growth spurt has moved the top of this redwood to directly right of the squirrel nest in this photo.

In an email to Connie Barlow, 5 March 2023, Rushing wrote:

> "Here is a photo of that squirrely redwood tree after our latest snow. It seems to be **growing tall and the top is straight. The branches are a bit more normal now.** As you

can see here, we needed to trim the lower branches away from the path."

• DON THOMAS CONFIRMS REDWOOD'S ABILITY TO ACHIEVE A TREE-FORM:

Don Thomas is a Torreya Guardian (in Los Gatos, California) who particpated in 2022 in the first intentional "assisted migration" of the California Torreya tree (*Torreya californica*) into the Pacific Northwest (Vancouver, BC). In 2023 he told Connie Barlow:

> "Regarding cutting propagation of coast redwoods, my very first job after college in the mid-1970s was at a non-profit nursery called the Saratoga Horticultural Foundation.... This institution was set up to introduce into horticulture new varieties of plants better adapted to California. I remember that among the trees we grew were cutting-grown cultivars of Sequoia sempervirens, including Sequioa 'Santa Cruz', Sequoia 'Los Altos' and **Sequoia 'Aptos Blue'**. The different varieties had different colors of foliage and different growth forms and allowed uniform-looking plantings of redwoods. As I recall, **it was possible to train all of these clonal cutivars into upright symmetrical trees**. But I think they were slower growing than seedling trees and did not grow as tall. I discovered that these varieties are still being propagated and sold by **a nursery in North Carolina**.
>
> "I could not contact the Saratoga Horticultural Research Foundation because it disbanded in 2006 and **donated all of its assets to UC Davis**. But I was able to locate a planting of one of the selected varieties, **Filoli Blue, on the Stanford campus**. I've also attached a photo I took recently of one of the trees." SEE PHOTOS BELOW:

ABOVE LEFT: 2007 photo of the **Filoli Blue cultivar of Coast Redwood on the Stanford campus**. Source: Trees of Stanford (photo by John Rawlings).

ABOVE RIGHT: 2023 photo by Don Thomas of a **Filoli Blue cultivar of Coast Redwood on Stanford campus**. If this tree actually began as a rooted branchlet, then the basal sprouts are welcome evidence that branchlet cuttings carry the redwood's evolved capacity to maintain a root system and thereby regrow a new stem when the original stem is injured beyond repair.

ABOVE: March 2023 DON THOMAS wrote, "For **further evidence that upright, tree-form redwood trees can be grown from cuttings**, at Home Depot (Cupertino, California) this week I discovered that they are selling a cutting-grown redwood cutivar, 'Aptos Blue', in 15 gallon containers for $59.98. I've attached a couple of photos."

———————

CONCLUSION 7: There is strong evidence that this canopy giant is not willing to just turn into a shrub. Eventually, **a rooted redwood branch cutting will assume single-stem vertical growth.** The only remaining question is *when* the standard radial pattern of branch growth will develop at the top and thereby produce horizontal branches with flat-lying leafy branchlets.

Thus, **the existing PLAGIOTROPIC (shrub-like) plantings of redwood clones in Seattle will almost surely manifest the tree-form** (although perhaps requiring a decade or two). Staking the little plants may be helpful, but **Coast Redwood seems to be capable of manifesting vertical growth entirely on its own**, later followed by radial branching symmetry along a leader stem of its choice.

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5B. Papers on Nurturing Tree Forms from Cuttings

February 2023
Conclusions and Excerpts
by **Connie Barlow**

BACKGROUND ON CUTTINGS TYPES:

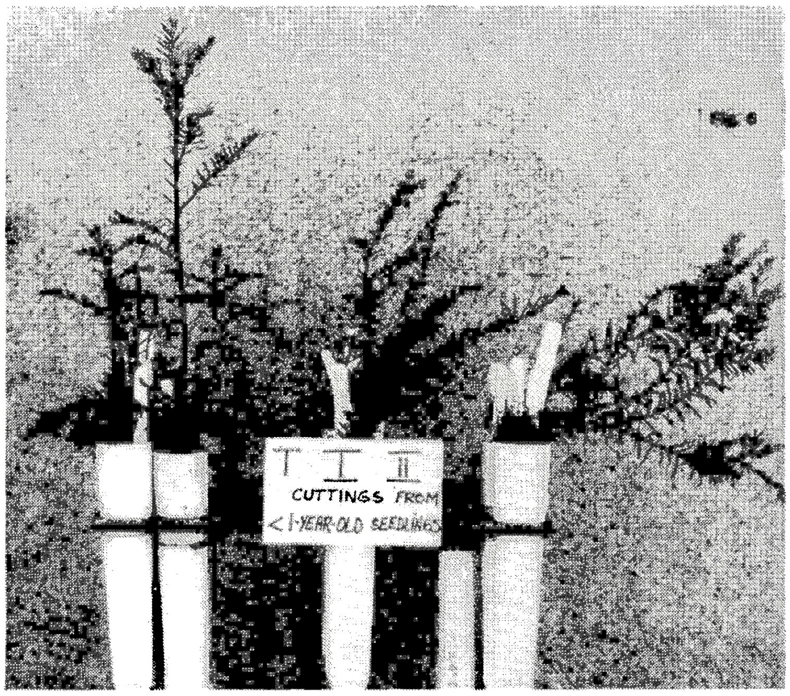

Fig. 6. — Characteristic stem angle classes of stecklings of terminal (left), primary (center) and secondary (right) branch orders.

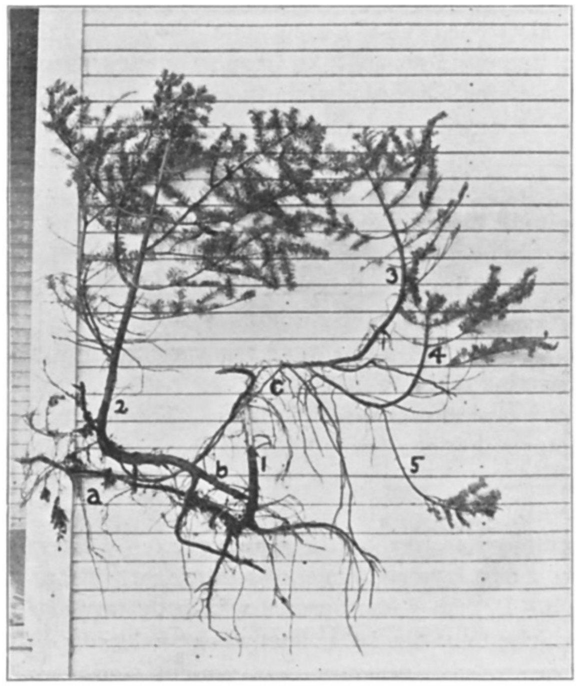

FIG. 1.—An example of layering as it commonly occurs on Isle Royale, Lake Superior; *Abies balsamea*.

ABOVE LEFT: Natural growth forms of rooted REDWOOD cuttings from different locations (L to R): tip of apical sprout, tip of horizontal branch, and tip of branchlet of a branch. *Source:* **"Cyclophysis and Topophysis in Coast Redwood Stecklings"**, 1988, by A.B. Power, R.S. Dodd, and W.J. Libby, *Silvae Genetica*.

ABOVE RIGHT: Extracted rootings of the natural layering process in Balsam Fir. *Source:* **"Reproduction by Layering Among Conifers"**, 1911, by William S. Cooper, *Botanical Gazette*.

BELOW: **"Influence of shoot origin and certain pre- and post- severance treatments on the rooting and growth characteristics of Douglas-fir (Pseudotsuga menziesii) stem cuttings"** (PhD thesis), 1973, by Darvil Kim Black, Oregon State University.

EXCERPT:

"... Wareing (152) cites the classical set of experiments conducted by Vochting in 1904 with *Araucaria excelsa*. These show the importance of shoot position when selecting cuttings.

When apical shoots or an axillary bud from the main stem are selected for vegetative propagation, normal radially symmetrical plants were obtained. Rooted cuttings from FIRST ORDER side shoots grew **horizontally** as they would on the intact plant. Cuttings from SECOND ORDER shoots grew **horizontally also, but only as string-like structures, without branching**." (pp. 17-18)

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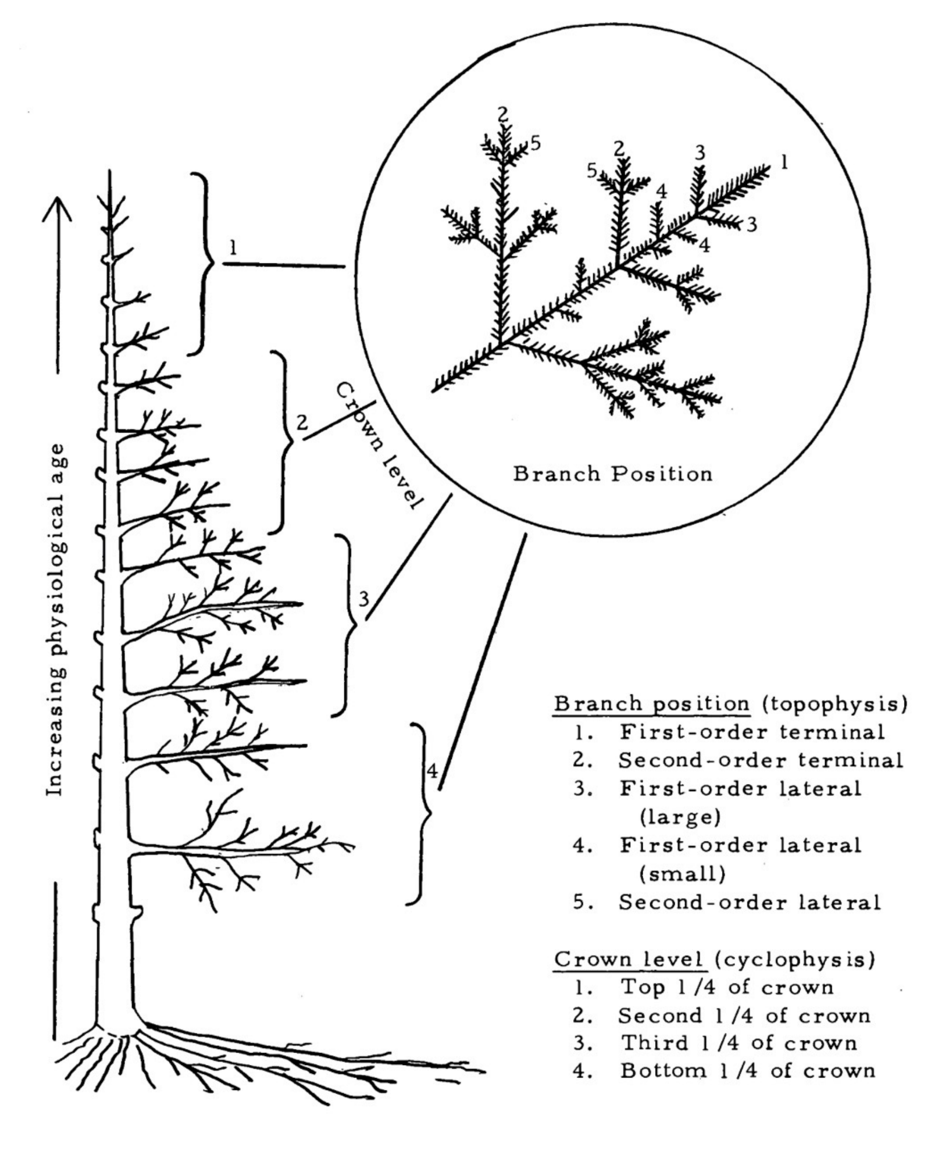

Figure 1. Topophysis and cyclophysis. Diagram showing the physiological age levels and branch order positions used in this study.

CONCLUSION 8: **Rooting potential is always best when cuttings are taken from the tip of a vertically growing stem.** For REDWOODS, this means harvesting cuttings from the tips of basal sprouts. **Next best for rooting is the tip of a branch** (labeled 1), with diminishing capacities in branchlet tips labeled 2 through 5.

The same sequence likely applies to branch cuttings shifting from their initial plagiotropic to the desired orthotropic (tree-like) orientation. Thus, branch cuttings from the same tree that were rooted and then planted out in Seattle might range widely in when (and whether) the tree form is fully recovered. As shown in the above figure, "First-order branch terminal" cuttings offer the best prospects. "Second order lateral" cuttings would be the worst.

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WHY PUBLISHED PAPERS ARE INCONCLUSIVE:

The images and cuttings preferences above apply generally to conifers. **Plagiotropic growth is thus the expected initial outcome when rooting a cutting from anywhere other than the apical tip of a main stem or basal sprout** (and not all conifers have basal sprouts).

I have not, however, encountered any papers that offer practical advice for nurturing a planting that exhibits "plagiotropic growth" into a fully "orthotropic" orientation.

It seems that very early on, propagators learned not to take cuttings from branches. And soon after that, they began to explore **"micro-propagation" techniques** whereby the tiny, undifferentiated "axillary meristems" could be extracted and then reliably prompted into "orthotropic growth". This, of course, is not possible outside of a lab — and it has **no practical application** for nurturing the plagiotropic clones that have already been planted in the Seattle area.

The papers most useful toward the task of **nurturing large, outplanted redwood clones that still exhibit "plagiotropic" growth use the keyword REJUVENATION**. But even these apply mostly to micro-propagation techniques applied to lateral cuttings.

• 1993, **"Micropropagation and Rejuvenation of *Sequoia sempervirens*: A Review**, Y. Arnaud, A. Franclet, H. Tranvan, and M. Jacques, *Ann Sci For*.

> "... Attempts at vegetative propagation by cuttings in California (Becking and Belleto, 1968; Libby and Mc Cutchan, 1978; Libby, 1982) as well as in France (Franclet, 1981), have shown that **for cuttings of old sequoias, rooting is difficult, later growth is slow and plagiotropic**. For the propagation of such trees, **sprouts or suckers must be used** (Lindquist, 1974; Franclet, 1981; Poissonnier et al, 1981). Such shoots are rarely available in great numbers under natural conditions, but certain techniques, such as cutting back of the main trunk or root-heating via industrial water (Cormary et al, 1980) can increase their production. These difficulties have stimulated further research work (Festa and Gambi, 1978; de la Goublaye, 1981; Vershoore-Martouzet, 1985), encouraged by the demonstration that the species can be cultured in vitro (Ball, 1950; Restool, 1956). **In reviewing the in vitro micropropagation of *Sequoia sempervirens*, it is necessary to separate micropropagation from other regeneration strategies.**

> "... The ability of the explants to develop axillary buds depends on the chrono- logical age of the mother plant and the original shoot, and on the original position of the material on both the ortet and ramet (Boulay, 1978; de la Goublaye, 1981; Verschoore-Martouzet, 1985). Thus, **explants originating from a sucker are more reactive than explants derived from the crown, and for the same sucker the most apical regions (most recently formed) show the best response**.

> "... Fouret (1987) reported that, at the end of the elongation phase, when the initial material was young, the leaves were long, soft and light in color. Furthermore, **the phyllotaxy was of axial type in a clone from a 1-yr-old tree, whereas it was either of axial or crosswise-opposite type in a clone from a 50-yr-old tree, and of crosswise-opposite type or more often distichous type in a clone from a 500-yr-old tree**.

> "... REJUVENATION is a necessary prerequisite for mass propagation, and can be defined as the recovery by old plant material of at least some of the properties of younger material (see Pierik, 1990). Walker (1985) preferred the expression 'rejuvenilization, reserving the expression **'rejuvenation' for the rapid and total recovery of juvenile character**, for example in apomictic or zygotic em- bryo formation (Franclet and Boulay, 1989). In situ pruning, cutting back or grafting can induce a rejuvenating process (Vershoore-Martouzet, 1985), improving in vitro performance (Franclet, 1981; Franclet et al, 1987). The effect of these techniques is to bring the root system closer to the above ground shoot system (Doorenbos, 1965; Chaperon, 1979; Franclet et al, 1980; Favre, 1980).

> "... With **repeated subcultures of meristems issued from a very old tree** (ARC 154: 500 yr), the shoots progressively recovered a young physiological state, evaluated by a better rooting ability (realized ex vitro), by the acquisition of the ability for adventitious budding

on isolated leaves and by a better reactivity of the isolated apical meristems (Walker, 1986). **But the plants still maintained plagiotropic growth in the greenhouse. Total (according to the praticians) or ontogenetic (see Schaffalitzky de Muckadell, 1959) rejuvenation of material from a very old tree has thus achieved.**"

Editor's note: The above paper limited its observations to micro-propagation results in the lab. A previous Sequoia publication (below) likewise did not present long-term data on whether out-plantings could naturally self-correct to a fully tree-form — perhaps over the course of decades. But as you will see, it is suggestive.

• 1988, **"Cyclophysis and Topophysis in Coast Redwood Stecklings"**, by A.B Power, R.S. Dodd, and W.J. Libby, *Silvae Genetica*.

"Two studies were conducted with vegetative propagules of *Sequoia sempervirens* to improve our understanding of the effects of branch order (topophysis) on the rooting of cuttings and growth performance of the resulting stecklings.... The results indicate that **both maturation stage and branch order have significant effects on the rooting of cuttings and on the growth characteristics of the resulting stecklings**.

"... During a decade's observations with various kinds of coast redwood propagules, we have noted that recently rooted young stecklings exhibit a wide spectrum of stem angles; some vertical, but most non-vertical to varying degrees. It was clear that **the persistence of plagiotropic growth of stecklings was longer for cuttings taken from older plants, or for cuttings from higher in the crown of a tree**.

"... Stecklings from the terminals and two branch orders developed marked differences in growth form by eight weeks after rooting. **Stecklings from terminals generally maintained an orthotropic growth habit. The degree of plagiotropic growth was more marked for stecklings from secondary branch order than for stecklings from primaries.**

"... Stecklings that **commenced plagiotropically began to recover from this in three ways:**

1. The apex of plagiotropic shoots gradually turned upwards. **Later, the stem moved towards the vertical presumably as a result of compression wood formation.**
2. Buds from the lower third of the shoot flushed and grew orthotropically.
3. Orthotropic shoots arose de novo from the basal callus.

There were no consistent differences between stecklings of primary and secondary branch orders as to the mode of recovery from plagiotropic growth.

"... **The change from plagiotropic to orthotropic growth was associated with a change from bilateral to radial symmetry.** ... In contrast to stecklings of hedge origin, primary and secondary branch positions of seedling origin did not produce any orthotropic shoots from the stem but only from the callus...."

CONCLUSION 9: Redwood's ability to be nudged into a "phase change" so that plagiotropic rooted cuttings from lateral branch materials might shift into tree-form have been explored from the standpoint of commercial forestry interests. Accordingly, quick solutions are what matter. **The above 1988 paper nonetheless is suggestive that COAST REDWOOD can self-correct on its own, but over a time-scale that precludes commercial interest.** (The next paper seems to concur.)

• 1973, **"Influence of shoot origin and certain pre- and post- severance treatments on the rooting and growth characteristics of Douglas-fir (Pseudotsuga menziesii) stem cuttings"** (PhD thesis), by Darvil Kim Black, Oregon State University. *Editor's note:* Even though this is a PhD thesis, it was often cited in later papers. Because of its 1973 publication date, this was before "micro-propagation" techniques fundamentally changed how cloning was practiced.

> ... In general, the results reported here for Douglas-fir resemble those for other conifers. **The rooting potential remains high in young trees up to nine years of age, and then drops off rapidly, reaching a very low level between 14 and 25 years**.... Root quality, as well as rootability, declines with increasing age of the parent tree.... Rooting potential decreased with increasing age of the seedling trees. This **response to aging is common to most, if not all, trees and shrubs**.
>
> **... The natural transition of cutting ramets from the plagiotropic to the orthotropic growth habit was slow and was not hastened by staking, pruning, repotting, or unidirectional lighting. This transition occurs in some juvenile clones in three years, while others take seven or eight years or even longer for old clones**. Preliminary observations of cutting ramets from different origins suggest that cuttings from young clones, terminal branch positions, top crown sections, and **orthotropic shoots** in sheared trees [trees pruned back under a power line] produce orthotropic trees more rapidly than cuttings from other sources.
>
> ... Another horticultural example of topophysis is *Taxus cuspidata*. In order to obtain the desired upright habit, cuttings must be taken only from erect terminals or upright-growing laterals rather than horizontal side shoots (55). This phenomena is also seen in *Taxus baccata* (100) and *Coffea arabica* cuttings (55).
>
> ... Frohlich (44) showed that the time required for orthotropic growth habit to develop in *Picea* cuttings was related to their original branch order position on the tree, taking longer with higher order branches. Within each branch order, **material from younger trees made the transition faster than materials from older trees**. ... To summarize, there appears no serious problem with plagiotropism in cuttings of the genera Pinus, Taxus and Larix, although there are differences in cutting survival and vigor of growth. In contrast, **there are marked differences reported for cuttings of various species of the genera *Picea, Pseudotsuga, Abies, Araucaria* and *Cunninghamia*, which all have similar formal growth habits.** A partial solution to the problem of plagiotropic growth appears to be the proper selection of cutting material.
>
> ... Several characteristics distinguish the plagiotropic from the orthotropic plant. Obvious morphological differences include **needle orientation and bud and branch arrangement, which are bilateral in plagiotropic shoots, but radially symmetrical in orthotropic ones**. The most noticeable and easily measured difference, however, is **the growth angle of the main stem**.
>
> ... **Staking was difficult to maintain since the reaction wood formed in the old portions of the stem created considerable pressure on the stakes.** The bamboo stakes were bent with such force that some were broken. When bending was prevented, the extension growth was at the same angle as before staking (Figure 2). These and other observations indicate that **pruning and staking treatments used were not effective in hastening the transition of Douglas-fir from the plagiotropic to orthotropic growth habit**.
>
> ... The transition occurs gradually and at a somewhat predictable rate over several years. During the transition, the stem becomes more upright and the arrangement of the needles, buds, and branches becomes more radially symmetrical. This study, and observations on another 20 clones, indicated that **orthotropic plants from cuttings can be expected after three years with some clones, but requires longer, even up to six to ten years with others**.

> … McCullock (95) reported that cutting ramet plants were still plagiotropic after three years in the field. **Thirty years later the trees that McCullock reported as plagiotropic are now symmetrical, orthotropic, uniform trees, which would compare favorably with seedling trees of the same age.** The ortet from which these ramets were propagated was an old tree. It thus appears that **given enough time, cutting ramets from even old clones will become orthotropic.** … It seems that the ramets in this species will eventually become orthotropic regardless of their source.

CONCLUSION 10: Even though the above 1973 paper is about Douglas-fir, it very much **elevates confidence in the ability of Coast Redwood to gradually reorient from plagiotropic plantings to a fully orthotropic tree form**. This is terrific news for the recipients of plagiotropic redwood plants in the Seattle area.

CONCLUSION 11: The above 1973 paper concluded that "pruning and staking treatments used were not effective in hastening the transition of Douglas-fir from the plagiotropic to orthotropic growth habit." **This is actually good news for recipients of plagiotropic potted redwoods because it means that even with no further attention and assistance, these plantings will indeed adopt the tree form, albeit at their own slow pace.**

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5C. Learning about genus Sequoia from genus Torreya

February 2023
photo-essay by **Connie Barlow**
(founder of **Torreya Guardians** in 2005)

BACKGROUND: While I have no personal experience with propagating cuttings of any conifer, as webmaster of **Torreya Guardians**, I document online the photos and experiences of volunteers who do engage in collecting cuttings and/or attempting to root and ultimately establish this **critically endangered species**.

Therefore, **this subsection will feature photos and reports that highlight similarities and differences between genus Sequoia and genus Torreya.** Included will be information on and our experience of **propagating FLORIDA TORREYA, *Torreya taxifolia* from cuttings.**

As well, a new branch of Torreya Guardians formed in 2022 based on the West Coast. **Volunteers in California** photo-document the largest wild specimens of **CALIFORNIA TORREYA, *Torreya californica***. They also access seeds and assist their migration northward. Thus far, there has been **one long-distance transfer: from the Santa Cruz Mountains to Vancouver, British Columbia**.

Growth similarities between
Genus *Torreya* and Genus *Sequoia*

One way in which Torreya species are similar to the Coast Redwood is that both develop a **lignotuber**.

Both therefore also have tremendous capabilities to send forth **basal sprouts** for replacing an injured main stem or simply for increasing photosynthesis whenever light becomes available near the base.

ABOVE: This young stem of CALIFORNIA TORREYA originated from an older root system on **a steep slope within a wild Coast Range section of forest northwest of Napa Valley**. A tree likely fell onto the already leaning stem and thus forced a portion of its **lignotuber** to emerge into view.

• SIMILARITIES between CALIFORNIA and FLORIDA SPECIES OF GENUS *TORREYA*

Florida Torreya, ***Torreya taxifolia***, is sibling species to California's own endemic, ***Torreya californica*** — whose common name is California Torreya or California Nutmeg.

ABOVE LEFT: **California Torreya**. Connie Barlow stands between two regrowth basals on a very **steep slope in Sequoia National Park, 2005**. In the foreground are several saplings of this species.

ABOVE RIGHT: **Florida Torreya**. Jack Johnston (a Torreya Guardian) with a century-old horticultural planting of a grove of torreya at **Harbison House in Highlands, North Carolina**, April 2015. (Photo by Connie Barlow)

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• BASAL SPROUTING of HEALTHY FLORIDA TORREYA

 

ABOVE LEFT: Basal sprouts on the south side of the **Florida Torreya** horticultural grove at **Harbison House, Highlands NC**, 2006. Note: Torreya is usually a subcanopy tree, and in this photo the deciduous canopy that overtops this planted grove is so dense that the camera automatically used a flash on this drizzly afternoon in August.

ABOVE RIGHT: Basal sprouts of various ages emerge from a seed-producing **Florida torreya** in the front yard of a home in **Clinton, North Carolina**.

• TOPPED TORREYA TREES ARE RESCUED BY BASAL SPROUTS

 

ABOVE LEFT: In **May of 2004** Connie Barlow first visited the Florida torreya grove at **Biltmore Gardens (NC)**. All 11 trees from the original 1939 planting were then still alive. Here is one of those trees, sporting a basal sprout.

ABOVE RIGHT: In **August 2006**, Connie returned to the Biltmore just **2 years after a hurricane had destroyed the white pine overstory and injured several of the original torreyas beyond repair**. Staff removed the casualties. Only three of the original 6 torreyas that were on the highest slope level remained — and even these had been top-injured.

ABOVE LEFT: In **2018**, Barlow documented that many of the **post-storm basals were still supporting one of the top-pruned trees**. There was no reason for the tree itself to senesce all the basals, as significant sunlight was still available near the base.

ABOVE RIGHT: In **2018** the canopy had gained leafiness — but not any height. **Past an early age, topping of the main stem of Torreya will not evoke a new leader from the stem itself**. Instead, one or more of the basals will continue their upward growth, if unpruned by humans. **Torreya species thus lack Coast Redwood's remarkable ability of "trunk reiteration".** Nevertheless, similarities in lignotuber development and post-injury basal profusion reveal that both generally will do whatever they can above ground in order to maintain as much of the old growth root systems as possible. Their mantra: ***Stems come and go, but roots are forever.***

Below is a paper that confirms that some conifers will not replace a top-injured main stem with a new leader emerging from anywhere except the base of the tree:

• 2004, **"A review on the effects of donor maturation on rooting and field performance of conifer cuttings"**, by R.G Mitchell et al., *Southern African Forestry Journal*

> … As donor plants, whether in hedge or tree form, reach ontogenetic maturation, however, cuttings harvested from them produce malformed stems (Roulund, 1975; Peer and Greenwood, 2001). Trees, whilst still in a juvenile state, will continue to produce new leaders that will replace the main leader if it is removed from the tree during its stage of growth. However, **once the tree reaches the point of ontogenetic maturation, removal of the main leader will not stimulate its replacement by a branch**. The tree will continue to grow without any change in orientation. This effect, observed by the horizontal growth form of the lateral branches, is referred to plagiotropism and cuttings harvested from parent material that have reached an irreversibly mature state may express plagiotropic growth in the field (Roulund, 1975; Dekker-Robertson and Kleinschmit, 1991; Peer and Greenwood, 2001).
>
> In many cases, cuttings harvested from recently matured donors continue to display plagiotropic characteristics during the early stages of field growth but display vertical growth habits, otherwise known as orthotropic growth, after a few years. It is believed that **the change in growth habit from plagiotropic to orthotropic could be as a result of the production of compression wood** (Frampton et al., 2000). Compression wood is a response to gravity and stress and is known to have a lower cellulose and higher lignin content (Butterfield and Meylan, 1980). It is viewed as a serious defect in timber due to its weaker structure. **Cuttings harvested from donors in the advanced stages of ontogenetic maturation, however, do not regain orthotropic growth patterns.**
>
> … **The factor that has the greatest influence on cutting production is the age at which the donor plant reaches reproductive maturity and is most commonly termed, the point of "ontogenetic maturation". Once a donor plant had attained this state, manipulation of the donor to regain juvenile characteristics once more is very difficult,**

although through repeated serial propagation, some authors achieved a degree of juvenility. Once this state has been reached, cuttings harvested from ontogenetically mature donors, display plagiotropic (malformed) and reduced growth habits.

Unlike REDWOOD, TORREYA cannot restore a top-injured canopy by trunk reiteration. But TORREYA vastly outperforms REDWOOD in its youthful ability to recover from early herbivory:

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• TORREYA SEEDLINGS EASILY RECOVER from HERBIVORY

Young seedlings of Florida torreya readily **resprout leaders from their main stem** whenever the apical tip is nipped off by a browser. As a slow-growing subcanopy tree that rarely can expect to achieve canopy status, **Torreya is likely a more adept re-sprouter from its then-current main stem than Redwood**.

ABOVE: Sometime in 2016 a seedling that had emerged from a seed planted directly into the ground in November 2013 had all its leaves devoured and its top nipped off. By May of 2017 (photo left), recovery was underway. By November 2017 (photo right), **two possible new leaders and one basal** had flushed. *Notice that the mid-height leader had already had its tip nipped off again.* Visit the **Greensboro NC torreya page** for ongoing results.

____

 

ABOVE LEFT: Summer of 2019, Paul Camire in **Capac, Michigan** discovered that a number of the seeds he had planted directly into his forest during the spring of 2016 had established seedlings. However, this one's apex and leaves had already been browsed off when he noticed it in July 2019.

ABOVE LEFT: **Seven weeks later, that same seedling had remarkably recovered**, adding substantial height in new, **radially symmetrical leader growth**.

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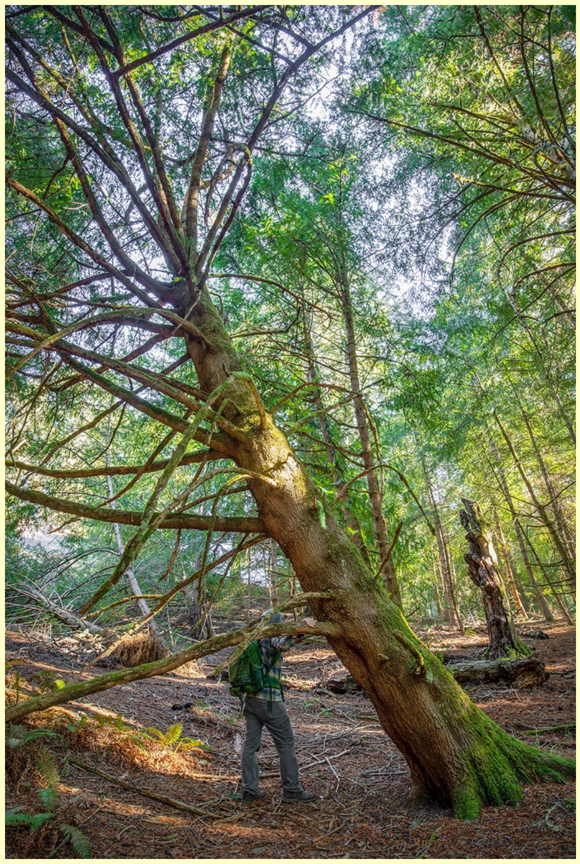
• REDWOOD SEEDS are TOO SMALL to MATCH TORREYA'S SEEDLING RECOVERY CAPACITIES

ABOVE: A comparison of **Torreya v. Redwood seed sizes** suggests that Redwood likely cannot recover from apical herbivory when a very young seedling. Therefore, the experience of Torreya Guardians in observing young seedling recovery likely has little application to redwood propagation from seed. However, **recovery from early herbivory of rooted cuttings is likely equally bad for both**.

• TORREYAS CAN LEAN; REDWOODS CANNOT

A clue that torreyas are strong contenders at a young age in **subcanopy shade** is the number of **tall trees that are leaning** — including the current national champion (as of 2014) and the slowly dying champion that I (Connie Barlow) visited in 2005.



ABOVE LEFT: Seen from particular camera positions, **the late-champion north of Santa Cruz** (along Scotts Creek) reveals that it began its life journey for many years leaning outward from Coast Redwood canopy shading, which was logged out for building materials soon after the great San Francisco fire of 1906. (Photo by Connie Barlow, 2005)

ABOVE RIGHT: In 2022, Eric Hongisto photographed this leaning Torreya within the **San Andreas Fault**, east of the creek at Fort Ross State Historic Park. On both sides of the fault are old growth redwoods.

ABOVE LEFT: Another view of **the same late-champion Torreya in the Santa Cruz Mountains**, as portrayed in the photo in the row above it. In 2005 Connie Barlow took this photo of Lee Klinger, founder of **Sudden Oak Life** in California.

ABOVE RIGHT: The mid-section of the late champion **branched into 3 main stems**. Take another look at the top of the above left photo: Do you see signs of multiple stems beginning there — and perhaps all the way to the base? *And does this suggest that* ***the tree may actually be the result of several merged basal regrowths?***

ABOVE: This California Torreya in the Coast Range northwest of Napa Valley evidences **extreme capabilities to (a) lean, (b) produce upright stems from the horizontally oriented main stem, and (c) launch a fast-growing upright basal sprout**, while the horizontal older stem grows so slowly it is covered in moss. (Notice in the background of both photos the same upright and stump redwoods.)

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• TREE-FORM v. SHRUBBY GROWTH of FLORIDA TORREYA in CLEVELAND, OHIO

A good way to begin the **TORREYA example of tree-form seedlings v. cuttings from lateral branchlets** that, after rooted, will turn only into shrubs is to visit one of the principal volunteers in Torreya Guardians: **FRED BESS of Cleveland, Ohio**.

ABOVE: Fred has **3 Florida Torreya trees planted in his front yard**. All are getting pretty much full sun — and fierce winter cold. The two on the left are males. The one on the right is female, which began producing seeds in 2018. All began as seeds, not rooted cuttings.

ABOVE: Fred has **one Florida Torreya grown from a rooted branchlet**, which he planted in his backyard. Although it is shrubby, it is a very valuable female and now also produces seeds. (Connie Barlow is in the picture, as she visited Fred October 2018 just before he harvested the seeds.)

WATCH THE 16-MINUTE VIDEO Connie posted of her visit: **"Seeds of Florida Torreya Produced in Ohio**.

ABOVE: Fred has a lot of experiments ongoing in his greenhouse. Here are several very young torreya seedlings, nurtured from seeds. (Ginkgo leaves on the right.)

ABOVE: After 1.5 years in his greenhouse, Torreya Guardian **Fred Bess (Cleveland, OH)** achieved successful **rooting of 3 of 5 branchlet cuttings** he had collected from the shrubby Florida Torreya in **Spring Grove Cemetery, Cincinnati** during his visit there in December 2019. (See photos from that visit directly below.)

Fred has learned that rooting branchlet cuttings of Florida Torreya **will not automatically grow into trees**. One advantage, however, is that successful rootings of such cuttings will produce male and female cones several years earlier than will trees grown from seed.

LESSON: For certainty in establishing trees from cuttings, the upright BASAL SPROUTS should be the cutting source — not cuttings from branches on the tree, nor from any of the small lateral branches that may have emerged on basal sprouts. **Only vertical stem material of the basal sprouts should be used.**

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• TORREYAS GROWN FROM LATERAL BRANCH CUTTINGS FORM MASSIVE SHRUBS

 

ABOVE: Torreya Guardian **Fred Bess (Cleveland, OH)** with a shrub form of Florida Torreya at **Spring Grove Cemetery (Cincinnati)**.

BELOW: A 30-year-old shrubby form of Florida torreya at a horticultural planting in **Medford, Oregon**.

 

QUESTIONS re the above shrubby torreyas:

1. Why have none of the thin sprouts emerging from the thick, lowest stems surged upward vertically? (Are they **not authentic "basal sprouts"**?)

2. Does this **confirm the inability of a rooted lateral cutting** to ever reorient on its own into a tree form?

3. Are rooted lateral cuttings **unable to develop a lignotuber and to sprout true basals**?

4. Could **early staking of an off-kilter stem growth** have corrected the problem and thus eventually yielded a tree?

5. Or **is it impossible for genus Torreya to achieve a tree-form** from a lateral cutting at a late age — and perhaps even soon after rooting?

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• **CUTTINGS FROM BASAL SPROUTS readily grow into a TREE FORM**

ABOVE LEFT: October 2017 Torreya Guardian **Clint Bancroft (near Chattanooga TN)** **collected cuttings from the profusion of basal sprouts** in the grove of Florida Torreya trees at **Harbison House in Highlands NC**.

ABOVE RIGHT: 2.5 years later (April 2019) Clint documented that this basal tip cutting had **rooted and achieved budburst of a classic radial structure**. This was a sign that the tree form would likely be maintained on its own, and with no less vigor than what a seed achieves naturally.

BELOW: One year later (March 2020), Clint was ready to plant this successful rooting of a basal tip cutting. He photographed the plant just out of its pot, and was thrilled to see **the richness of its root development**.

• BASAL SPROUTS that have adequately ROOTED can recover from HERBIVORY

Also in April 2019, another of the basal tips that **Clint Bancroft** had cut in 2017 at Harbison House (Highlands, NC) had rooted, but then herbivory struck! He wrote:

> "I had an **apical cutting of a basal from Highlands NC, about 6 inches tall**, that had rooted. This year it put up its first fresh vertical (another 6 inches, but no lateral growth yet). It looked beautiful! I left it sitting on top of the cage, 4 feet off the ground, and damned if something did not **eat ALL of the new vertical and also about 2 inches off the top of the original cutting**. I suspect it will survive, but I have lost a whole year's growth. It will be interesting to see if a chopped off, rooted, apical cutting will establish a new leader."

ABOVE: June 2019 Clint Bancroft sent the above two photos with this note:

> "Regarding my accidental experiment in which a rooted apical cutting had put up a new 6 inch vertical and then all but a few inches of the whole plant was eaten down. Well, **in just 2 months, the eaten-down stump is putting up what appears to be a new vertical leader**."

CONNIE BARLOW replied to Clint Bancroft, August 2019:

> "I am reading about **Coast Redwood basal growth** and propagation now. Genus *Sequoia* and *Torreya* have both probably survived this long thanks to their ability to produce new stems from basal growth if the original stem fails (or is logged). The term for what we see in the close-up photo you sent (above) is an **axillary bud**. That bud is doing what it evolved to do: produce a new vertical leader.
>
> Apparently, **all single leaves produced on the vertical main stem of a basal** each carry on their upper side a **suppressed axillary bud**. For redwoods, **each of those buds**

can become either a vertical leader or a root, depending on whether it senses air or soil when hormones direct it to wake up.

> Torreya, we now see, can do the same. We should be able to obtain more than one vertical clone from each basal sprout we cut from. It is possible that not only rooting but also **new leader growth may be even easier to induce in segments of the stem BELOW the uppermost top** that you have used in your first experiments."

CLINT BANCROFT collected more basal apicals at Harbison House in Highlands October 2019. He wrote:

> "The Highlands Torreyas all look to be healthy. **I took about 20 apical cuttings [of the prolific basal sprouts].** Jack took a bunch of laterals. **I am about through with laterals, since they have been failing to put out new growth in spite of having rooted some years ago.** So maybe this latest group will do well. Hated to appear greedy, but the property is for sale and I never know if this will be our last access to this grove.
>
> UPDATE on previous seed/cuttings collecting at Highlands: I have one seedling that grew from a Highlands seed and **several Highlands cuttings (apical) that are coming along well.**

MORE PHOTOS by **Clint Bancroft** of his success in propagating tree forms from the **apical tips of basal sprouts** of FLORIDA TORREYA.

ABOVE: JUNE 2020, Clint reported that **7 more of the basal tips** he had collected OCTOBER 2017 from Highlands, NC had put forth a **first flush of new growth**. Two of the seven documentation photos are above.

LEFT: September 2022:, **a basal sprout has formed on the lower stem of a rooted apical cutting of a previous basal stem** that had been harvested October 2017 at **Harbison House in Highlands, NC**.

RECOMMENDATION (in 2023): The (redwood timber company) literature recommends **cutting basal sprouts into segments that each contain no less than 3 leaves or visibly unopened buds**. This way, at least one axillary node will be above the ground surface and one below. The upper will become a new leader and the lower will develop the roots.

Equally important is that **the longer a stem segment is, the more difficulty it likely will have in rooting and budding**. This is because a greater length of stem must be kept alive while the initial root is forming. So cutting up a long basal into segments of no more than 3 or 4 nodes may produce the best results. **Torreya Guardians are now testing "non-tip sections of basal sprouts."** (See the Clinton NC photo-section below.).

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• TESTING NON-TIP VERTICAL SEGMENTS OF BASAL SPROUTS CUTTINGS

November 2019, in **Clinton, North Carolina**, Clint Bancroft collected cuttings from basal sprouts at the large, seed-producing Florida Torreya tree in the front yard, along with several of its older offspring in the backyard.

ABOVE: Remarkably, **the apical tips of BASAL SPROUTS began to show fresh budding of leaves in March 2020** — just 4 months after they were harvested.

Additionally, **lower segments of the long basals are also in pots for rooting and being tested for possible leader growth**. As of March 2020, the non-tip segments had not died — but they hadn't shown any above-ground evidence of new growth yet. Clint wrote:

> "The tip cuttings all had buds ready to go, so it is not surprising that they took off. **I think the non-tip sections of basals will put up verticals later, but are putting all their energy into establishing roots first.**
>
> The stems probably benefited from having **their lateral growth trimmed**, but that was coincidental. The reason for the trimming was to make the cutting fit under the cloche!"

EDITOR'S NOTE: The possibility that the non-tip vertical segments also rooted and began flushing new leafy growth is significant. Also is the possibility that trimming buds off some of the lateral growth may be beneficial, too. Therefore, an UPDATE ON THE PROJECT will be sought, and posted.

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• TESTING UPWARD, RADIAL TIPS OF NON-BASAL STRUCTURES FOR ROOTING

QUESTION: Can the upright, radially leafing tips of Torreya branches in full sun be cut and rooted into tree-forms?

ABOVE and BELOW: A pair of **30-year-old FLORIDA TORREYA seedlings that grew into trees are in full sun at a private home in Medford, Oregon** (where it is essential that they be watered during summer droughts). Especially along the sidewalk where lower branches have been pruned, the regrowth trends toward upright tips with radially patterned leafing structure (photo above). Because of the full sun, even the lower-most branches of both trees are still intact and leafy, and therefore contributing photosynthates (photo below).

ABOVE: October 2019 Connie Barlow visited Frank Callahan, who had planted these torreyas. She received permission to cut some of the branch tips for rooting tests.

ABOVE: Equally old are two shrubby Florida Torreyas that Frank Callahan donated to Medford's Hawthorne Park. **Originating from rooted branchlets**, this pair is **still growing in a multi-stemmed, angular ("plagiotropic") pattern**.

ABOVE and BELOW: Connie Barlow took cuttings from both of the shrubby torreyas. She selected the most vertical, radially tipped upward stems growing near the base, similar to true basal sprouts (photo above) and also on the outer branches (photo below).

DESTINATION OF CUTTINGS: Connie sent half the cuttings to Jack Johnston in n. Georgia and to Clint Bancroft in sw Tennessee. Clint reported 5 months later (March 2020):

> "Here's an update on the **Medford OR cuttings** that Connie sent me October 2019: The Medford cuttings were kind of stressed looking when they arrived and I thought their prognosis was guarded. As with any group of freshly collected cuttings, **some perished rather quickly. It appears some of the rest have rooted.** I have not tugged on them. They still look as good as when they first arrived. But that alone is not proof of root formation. I have had cuttings that still looked fresh after a couple of years under the cloche but which never rooted. They just keep their color for a long time. That explains why Mrs. Kennedy (Clinton, NC) prizes them for Christmas decor!"

Visit **Clint's Torreya page** to see these photos and many more of his progress reports.

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• CUTTINGS FROM TIPS AND BRANCHES OF BASAL SPROUTS OF THE COLUMBUS, GA TORREYA

ABOVE: The profusion of bright green growth are the lush branches of the tall basal sprouts of the last remaining **century-plus Florida torreya in Columbus, GA**. Two other torreyas of the same age had recently been cut down on this same block. The street is right along the Chattahoochee River.

FEBRUARY 2015: **Connie Barlow was the first Torreya Guardian to collect cuttings from the profusion of basal sprouts.** At the time, she wasn't aware of the importance of basal stems, so she simply cut 3 leafy tips off the horizontal branches of the basals. Thus, if rooting were successful, plagiotropic rather than treelike growth would naturally follow.

Connie sent the cuttings to **Jeff Morris in Spencer, NC** for propagation. (Photo below.)

JEFF MORRIS wrote:

"I spent a large portion of yesterday afternoon preparing about 20 cuttings off the male branches you had sent to me, for micropropagation. I'm hoping the fungicide/biocide I used will prevent them from dampening off (molding). I should know within 3 weeks if this experimental method of reproducing *Torreya taxifolia* is going to be productive. It would be great to have a potentially new strain of genetic diversity to introduce to the species!

The **micropropagation method** we're using is designed to root the terminal shoots of the cuttings, as opposed to creating thousands of plants from a single needle. **By using only the 'terminal' shoots, we should be able to propagate individual seedlings that grow upright**.

Note: We need to learn the results of Jeff's experiment. This is especially the case because, at the time when he sent us the above photo of his rooting system, Jeff Morris may well have had the **most success thus far in producing vertical growth from cut lateral branchlets**. He wrote:

"The method we use in the greenhouse that has worked for me is to **stake it with a metal tree stake for the season**, and when there is no doubt as to the health of the root system, I carefully transplant it into a new pot. **Two seasons of this, and I achieved an upright growth for two *Torreya taxifolias*.** A third tree was not predisposed to this type of transplanting due to advanced growth of the root system that would have resulted in damage. But **if it's less than 4 years since rooted, you'll probably have some success**."

U.S. FOREST SERVICE colleagues concurred with Jeff, in part:

"In our collective view, if taken care of properly (tie the tops up, trim laterals) and conscientiously, **they should forget that they're branches in 4-5 yrs and grow 'right'**. So, just relax and go along with the flow. (But really, our collective view is to tell them to get seedlings!)"

NOVEMBER 2016: Jack Johnston and Clint Bancroft collected branchlets from the basal sprouts. Clint wrote:

"Jack Johnston and I made a pilgrimage to Columbus where we collected **6 gallon-size bags of cuttings** from the old Torreya. These have been distributed among **four different propagators**, so we hope for the best. I have probably a hundred cuttings myself, so if we have even modest success we will have succeeded in saving the genes of this venerable tree.

"Jack and I were able to measure **the living tree's circumference**. At four feet from the ground it measures an impressive **80 inches**!" "**All the cuttings we took from the Columbus tree are upper portions of the basal sprouts.** I told the owner to never let anyone remove them completely from the base of the tree. **The basal sprouts were 3 to 4 feet tall**."

UPDATE 28 SEPT 2017: Clint Bancroft reports that of 3 propagators of the branchlets cut in 2016, only his have rooted and stayed alive. He grew his "under domes":

"It appears **I have had success with the Columbus, Georgia cuttings.** Not 100% survived but it appears many did. Jack Johnston lost all of his portion, as did Nearly Native Nursery in Fayetteville, GA. I don't know what technique was tried in Fayetteville, but Jack tried rooting his in plastic bags. I grew mine under domes, and kept some outdoors and some indoors the first Winter. I did try a few in a sealed container (not unlike a plastic bag) and lost ALL of that bunch after they had survived the Winter (these were kept indoors in an unheated room) and had even put on new growth in Spring, but then all turned brown within days of each other and suffered what we (in Anesthesia) used to call "severe death". So maybe trying to root them in sealed containers is not a good option. It appears so."

UPDATE 11 OCTOBER 2017: Clint Bancroft reports:

"I previously wrote you about Jack Johnston's having lost all of his cuttings from the Torreya in Columbus, GA. Jack had put his cuttings in pots sealed in zip lock bags. I, on the other hand, appear to have had **success with all the Columbus tree cuttings that I kept under domes (cloches). I lost all of the ones I put into pots, using the same medium as the ones under domes, and putting the pots into a sealed plastic storage box (essentially like a zip lock bag).**

"I told you that Jim, at **Nearly Native Nursery in Fayetteville, GA**, had also received Columbus cuttings from us. I knew from Jack Johnston that all Jim's cuttings had died, but at the time I wrote you I did not know how Jim had handled his cuttings. Today I saw him for the first time since we gave him the cuttings last November. I asked him how he had handled his Columbus cuttings and he said, "I followed Jack's lead and put them in zip lock bags!" Of course this proves nothing (or does it?) but it seems that **rooting cuttings in sealed bags (or sealed plastic storage boxes in my case) yields negative results.** *My guess is that while the cutting itself needs continual high humidity, the soil needs exposure to fresh air.* Using the dome technique the soil around the dome is exposed to ambient air whereas with the sealed techniques the soil is not exposed to fresh air or movement of air. I tried rooting a bunch of round leaf birch cuttings this summer and used zip lock bags since I was out of domes. I lost every single cutting."

20 FEBRUARY 2018: CLINT BANCROFT reports:

"The original Columbus cuttings are rooted and Jack Johnston said "they look fabulous". I have made 2 more trips through Columbus and took more cuttings in Dec. 2017 and Feb. 2018. The big tree there still looks healthy in spite of its many scars."

26 SEPTEMBER 2019: Clint Bancroft reports:

"The first Columbus cuttings Jack and I collected in October several years ago have not done well at all. Jack and Jim (Mail Order Natives) lost all of theirs. I had them to root and look good until spring whereupon most died. I still have maybe 3 of that batch left. Not a one has put on any new growth in, I believe, 3 years. Maybe October is not an optimal time but that was only an isolated instance."

PHOTO LEFT: 16 SEPTEMBER 2019

Clint Bancroft reports:

"The 16 apicals I got from my last Columbus trip seem to be doing very well. And as we learned

from the Highlands apical cutttings, they continue to grow with radial symmetry!

"... The Columbus cuttings in the picture were carried home in no particular position in a zip lock bag, refrigerated overnight, and by the next morning each one was under a cloche. They were not kept in an upright position during transport but **were vertical within 24 hours**. The way they look in the photo (left) was how they looked when cut."

4 OCTOBER 2019 UPDATE: Clint writes:

> "One, and only one, of the last cuttings I got from Columbus wilted at the tip after it was stuck. I kept all the cuttings indoors. They are still indoors. I moved the wilted one into deeper shade (indoors) and it slowly perked up and eventually rooted."

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6. Bark beetle evidence on fallen branch of old Coast Redwood at Prairie Creek State Park

September 2019
photo-essay by **Connie Barlow**

The photos below **document the ability of bark beetles to penetrate the thin bark of high branches of Coast Redwood**. A common misunderstanding is that bark beetles cannot hurt this species because its bark is too thick and stringy for a beetle to penetrate. That is true, however, only of the vertical trunk itself. High up in the branches, the beetles may be active — and would have **coevolved in a commensal relationship** with the tree. Here is how:

Coast Redwood self-prunes as it grows taller. This is especially true on any side of the trunk that is shaded by another tree. **When self-pruning, the tree shuts down sap delivery to the branch**. That enables beetles to burrow through the thin bark without being pushed out by a gush of flowing sap once the cambium layers are penetrated.

Under drought conditions, a tree might greatly reduce photosynthesis and transpiration, along with a corresponding reduction in sap flowing through its canopy. **During drought,**

bark beetles can enter and lay eggs in the living tissue — even though the tree's behavior has nothing to do with self-pruning. Thus far, bark beetle entry into branch cambium in ways that can result in tree death has been **documented only in Giant Sequoia groves of the Sierras — not yet in coastal redwood groves**.

ABOVE and BELOW: Wound of fallen branch on a large double-stemmed redwood at forest edge, sunny side at 9:00 a.m. September 30, 2019. The small visitor center alongside **Elk Creek Campground** is directly behind photographer Connie Barlow. Staff told Barlow that the branch fell off about a week before. Notice the greenery of another elbow branch directly below the large wound, and a smaller horizontal branch directly above the wound and stretching toward the left but with a vertical stem emerging from it near the main trunk.

ABOVE: Side view of the elbow branch still living whose top green portion is visible at the bottom of the first two photos above. So the elbow branch that fell was above this still green and healthy one, though possibly part of the upright trunk on this lower elbow was broken off too.

BELOW: Barlow has only (and rarely) seen this **fern** species on low or fallen branches of redwoods. Here it emerges directly from the underside of the elbow section of the fallen big branch. Notice healthy reproductive (male?) buds at far left of photo.

ABOVE: The ground area was a jumble of broken branch and lots of lush green leafy little branches. Here **you can see how thin the purplish branch bark is**. A group of perhaps 20 green full-size cones attached to healthy green branchlets were easily visible in one section of fallen greenery, without Connie having to dig through the jumble.

BELOW: While staff was watching, Barlow pointed out a section of **purple bark that had bark beetle holes in it.** Barlow then peeled away bark with her fingers, revealing **tunnels created by the beetle larvae**. Tunnels are evident both on the wood itself and on the inner side of the easy-to-remove bark, a section of which is shown below. Notice **the 2 black holes on the left side of the inner bark**; more are clearly visible on the outer side of the same bark piece. The inner bark side reveals the **"gallery tunnel"** structure.

Barlow donated this bark sample to staff at the visitor center, then posted photos on this new webpage. **She alerted National Park Service staff to this photo-essay** and thereby to the possibility that, as with Giant Sequoias in the Sierra parks, **beetle damage could become severe in stressed Coast Redwood — and at a height not visible from the ground**.

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