Letter From the Desk of David Challinor
August 1998

The size and longevity of the California redwoods has long fascinated me. As one of earth's largest living organisms, the trees' ability to pull water and nutrients 300 feet into their canopies still astounds scientists. This letter will discuss redwoods and explore the theories as to why their present range is so restricted.

In 1960 I started working at Yale's Peabody Museum of Natural History where Dillon Ripley, then a Yale Professor of Biology, had just been appointed Director. I became Deputy Director under Ripley and on his departure four years later for the Smithsonian, I became Acting Director. In the latter capacity, I arranged to have a Dawn redwood (Metasequoia glyptostroboides) transplanted from Yale's Marsh Gardens to the front of the Museum because until 1941 trees of this genus had been known to scientists only from fossils. The Peabody is famous for its fossil collections and so the tree, which was grown from seed sent from China a few years after its discovery and identification, was most appropriately located.

I was fascinated by the story of the Dawn redwood's then recent discovery and the distribution of seeds to arboreta around the world during the brief interval in 1946 when China was still open to the world. Fortunately, not only did the distributed seed germinate readily, but this tree can be easily propagated from cuttings. It grows rapidly in full sun on well-drained soil and its attractive feathery foliage, which turns pink in the fall before dropping off, has made it a popular horticultural specimen. On good sites in the eastern United States individual trees are approaching 75-80 feet in height.

Sparked by the discovery of this relict species, I was fascinated to learn on a trip to Iceland in 1964 that redwoods once grew there too; fossil imprints of their leaves and cones are frequently found in that country. If sequoia trees once grew across the northern hemisphere in the lower Pliocene era (about 8 or 9 million years ago), it is puzzling why there are only three genera left today: 1) coastal redwood (Sequoia semperviens) along a narrow California coastal belt (450 miles long and 20 miles wide) extending from south of San Francisco north to the Oregon border; 2) the Big tree (Sequoiadendron giganteum) on the west slopes of California's Sierra Nevada mountains; and 3) Dawn redwood growing only in a 320 mile square area of China's eastern Szechwan and western Hupeh provinces. The answer seems directly related to the chilling and drying of their former range which allowed other conifer species, better able to adapt to the climate change, to replace them where they once flourished. Despite being unable to compete with pine and spruce in contemporary northern forests, all three redwoods grow well when nursery-raised and planted far beyond their natural range. Spectacular large redwoods of all three species thrive in Britain, France and Switzerland.

I even unexpectedly found a planted metasequoia, bearing numerous tropical epiphytes, growing in a high valley in Honduras. Although many will bear viable seed in their exotic locations, few seedlings can compete with local trees and rarely survive.

Illustrative of how widespread was the original range of redwoods is the recent discovery of “mummified” plant remains of twigs, foliage and cones on Axel Heiberg Island in the Canadian arctic (80°N, 90°W). Buried in a low, mile-long ridge not far from the Arctic Ocean shore, tree and plant remains dating back 40 million years were discovered by paleobotanist Ben LePage. Unbelievably, these remains were not fossilized but had been preserved by being buried in an oxygen-free, acidic environment that prevented oxidation. This botanical treasure trove included specimens of ancient redwood, larch, ginko and sycamore, all closely related to those species growing today in the northern hemisphere.

Professor LePage of the University of Pennsylvania has also been working on fossilized plant material from around the northern world for more than a decade, seeking to understand why the ranges of redwoods began to shrink starting about 40 million years ago. During the previous 100 million years they had grown in mixed forests with pine species, which were at that time actually a relatively small part of the tree species mixture. By the Miocene era (25 to 11 million years ago), the pines started to expand their range in the northern hemisphere.

From the material excavated on Axel Heiberg Island, LePage concluded that the composition of the ancient forest on this now remote Arctic island must have resembled that of southern Louisiana and Mississippi today, despite the trees then having to endure three or four months of no sunlight. To the surprise of the scientists, their growth rings matched those of today’s temperate trees, indicating that the darkness had little effect on tree growth. The number of pond cypress remains on Alex Heiberg Island showed that the climate must have once been mild with little freezing, as today’s pond cypress normally ranges only as far north as coastal New Jersey.

It appears that what kept northern Canada warm was the configuration of the land masses that were then quite different from that of today. From about 70 to 45 million years ago (late Cretaceous and early Tertiary eras), unbroken land connected northeast Canada with Greenland, preventing Arctic Ocean water from entering the northwest Atlantic. North flowing ocean currents that predated the present Gulf Stream brought warm water almost to southern Greenland, thereby heating the air not only over northern Canada and Greenland but also Siberia, which was then covered with thick temperate forests containing many redwoods.

At the beginning of the Oligocene (38 million years ago), submarine tectonic plate movement opened large channels in the North Atlantic that allowed cold, very salty water from deep Arctic Ocean basins to drain into the North Atlantic. In less than a million years the former warm currents were pushed south and the course of the present Gulf Stream began to stabilize. Northwest Europe was thereby kept relatively warm but Canada, at the same latitude, became cooler and drier – so much so that the redwoods were first forced south, where it was warmer and wetter. Eventually as the Rockies and the Sierra Nevadas became higher, the redwoods were confined to coastal California in order to avoid the rain shadow east of the slowly growing mountains. Thus today the two redwood species are confined between the mountains and the coast. Similarly, the rise of the Himalayas in Asia reduced the habitat for Dawn redwood until they now survive only in south central China.

As the ancient northern temperate forests retreated south, they were replaced by tundra which in turn reflected more heat back to space than tree canopy did, thereby producing ever colder and drier conditions. The altered environment was clearly unfavorable to the redwoods, but the question remains: Why could pines and spruce adapt to become the dominant northern trees but the redwoods could not?

LePage's earlier research on fossil fungi led him to conclude that the answer to the persistence of pines in the colder north (pines do not grow naturally south of the equator) lay in the assimilation of nutriments. Just about every tree species has symbiotic fungi called mycorrhiza growing in their roots. This fungi is often crucial to tree survival, because in marginal habitats fungi increase the surface area through which the roots absorb water and nutrients. An example of the failure to realize the importance of mycorrhiza was the planting of trees as windbreaks (shelter belts) in the Great Plains in the 1930's. Many plantations failed because tree mycorrhiza was absent in grassland soil; not until the prairie soil was inoculated with forest soil mycorrhiza did many shelter belts flourish.

There are two kinds of mycorrhiza: 1) endomycorrhiza from which hyphae (white hair-like fungal "roots") penetrate the cell walls of the tree's root tips; and 2) ectomycorrhiza in which the hyphae do not penetrate root cell walls but grow along and against the surface of tree roots. Redwood roots have endomycorrhiza and pine roots have ectomycorrhiza; each kind has different advantages. Endomycorrhiza are particularly effective in helping the tree extract phosphorous (an essential nutrient) from the soil in wet, warm environments where it would otherwise be so closely bound to soil hydroxides that it would be practically impossible for the tree to take up phosphorous without the help of the fungi. Redwood roots, with their associated endomycorrhizae, therefore absorb this essential chemical nutrient and insure the tree's healthy growth. Where it is dry and cold, litter decomposes slowly and the soil becomes acidic. Such soil hinders trees from taking up nitrogen, another essential nutrient. Ectomycorrhizae on pine roots assist the host tree in acquiring nitrogen, thereby enabling pines to grow under cold and often dry conditions in the north.

LePage's research found that pine roots developed this symbiotic relationship with mycorrhiza about 48 million years ago, so that pines could grow in marginal areas unsuitable for redwoods. Later, when climatic conditions in the north became uniformly cold and drier and the soil more acidic, pines, which had long been waiting in the wings, thrived and dominated the forests of the northern hemisphere.

Trees migrate slowly over millennia under natural conditions, but exotic trees introduced by humans often spread rapidly as has happened with the Brazilian pepper tree in Florida. The future distribution of trees is impossible to predict, but it may not be too farfetched to think that global warming might allow the redwoods to spread out from their present confined habitats and once again thrive in warm, damp forests across the northern hemisphere.

David Challinor
202-673-4705
202-673-4607 Fax

Many of the details in this letter came from an interesting article by Adrian Barnet called "How the North was Won" in New Scientist of 20 June 1998.