Tales from Tree Rings

Trees are marvelously adapted to survive environmental challenges and achieve great heights on Earth’s terrestrial landscape. At least two features of tree growth provide the means for overcoming gravity, surviving back-lashing winds, and the burden of snow and ice. Trees grow in three dimensions. Primary or reaching growth occurs near the tip of stems and is the only location above ground where the tree increases its height. This primary growth produces new leaves, lateral buds, and the length of stem to display leaves. During winter months these young growth tissues are hidden beneath the protection of bud scales on both lateral and terminal buds. Roots also have primary growth near the root tips and this is the only location on roots where their length is increased.

Trees also grow in girth or circumference along all twigs, stems, end walls or open or heavily pitted to allow branches, trunk, and even roots. Secondary growth is the result of new tissues produced from a single layer of cells separating the bark and the wood called the vascular cambium. The vascular cambium divides in two directions to provide new bark tissue to the outside and new wood tissue to the inside (Figure WOOD ANATOMY).

The vascular cambium produces new bark towards the outside of the stem, branch or trunk. Phloem is a tissue within the bark that functions by transporting hormones and photosynthetic products vertically in the tree. The thin-walled living cells of phloem are responsible for the transport while fibers provide support and some protection. Bark fibers do possess the thick cell wall similar to wood fibers. Bark tissues are exposed to physical stress as the tree grows in circumference. The bark stretches and compresses as the trunk expands. Stretched cells and tissues split, dry and perish, but the bark remains whole, functional, and intact. The longevity of bark is due to the regenerative properties of some cells that begin to grow, divide and produce a new layer of corky tissues. This cork contains a wax that is impermeable and protects the inner living tissue of tree stems from the environment. Any remaining living cells to the outside of the cork are sealed off and no longer receive food or water and they ultimately die. Each year the tree repeats this process of isolating the weakening outer bark layers from the more living portion of near the vascular cambium. Eventually layers of cork and crushed phloem die in a species specific pattern of dead bark. For most trees pieces of dead bark are shed on an annual basis.

The vascular cambium has seasonal periods of growth and rest. Early each spring before buds break and the leaves expand, the vascular cambium begins to grow vigorously. The cells in springwood expand greatly as the supply of water is usually quite generous at this time of year. The fibers and vessel elements produced in the spring have relatively thin cell walls and less lignin as compared to later produced wood. The spring wood provides the fresh flush of leaves with ample water to complete their development and expansion. The warmer and drier summer environment results in summerwood with narrow cells that are dense and dark in color. This pattern of growth results in concentric rings of light-colored springwood and dark-colored summerwood when viewed in a trunk cross-section. Each ring represents the wood growth for a
particular year. The smallest, innermost ring on the tree trunk, branch, or stem is the oldest for that part of the tree.

Wood of our broad-leaved deciduous trees includes a variety of cell types that give oak, hickory, ash, and maple their unique characteristics (Figure Hard versus Softwood). Wood fibers are long cells with thick, rigid walls. Fiber cell walls are lignin rich. This natural chemical along with an abundance of cellulose makes the wood of oak and hickory hard, stiff, and durable. Water, minerals, and other sources of nutrition flow through other cells call tracheids and vessel elements. These cells form efficient pipelines from roots to leaves because their cell walls are open on the ends or have numerous pits to permit the free flow of water. Fibers, tracheids, and vessel elements are functional only upon their death. As a cell produces its thick secondary cell wall its life is sacrificed, but it leaves behind a cellular skeleton that remains functional in water transport and support. For oaks, springwood is very lightly colored and is heavily pitted with large diameter vessel elements. In other trees like maple, the vessel elements are produced in a more diffuse pattern through both spring and summerwood. Heavy lignin-rich woods like oak and hickory are stiffer and more decay resistant that woods like maple and ash that have less lignin. The density and distribution of lignin and vessel elements are two important traits that give unique characteristics to cabinetry, paneling, and furniture.

Wood of conifers is very different anatomically. Conifer wood is dominated by tracheids of various sizes. While tracheids lack the water transport efficiency of vessel elements and the strength of wood fibers, they are an excellent compromise that provides the best qualities of both cell types. The homogenous nature of the wood provides greater flexibility to the tree. In addition, the numerous pits of tracheid cell walls provide many avenues of water flow. This former trait is very important during cold winters. As water freezes in tracheids, dissolved gases are squeezed out of water to form air bubbles. When the wood thaws in the spring, the air bubbles remain and partially block water flow through tracheids. However, water can easily pass laterally through pits to circumvent the air embolisms. Granted water movement is impeded by air bubbles, but it is better than having no water delivery system as might happen in frozen vessel elements. Thus, the sacrifice of strength and water transport efficiency is well worth it in boreal areas where more than two-thirds of the year is below freezing.

The living component of wood is found in thin layers of rays that grow like spokes radiating continuously from the center of the tree through the wood, across the vascular cambium and into the bark. Ray cells bear a thin, flexible cell wall to protect the living watery protoplast of the cell. Rays are most easily visualized in wood that has been cut and allowed to dry. As water evaporates form the wood, the flexible, thin walled cells wither away and produce radial splits in the wood. Both conifers and hardwood have rays, although they are thicker and more prone to slitting in hardwoods. Conifers possess one other evolutionary novelty in their wood, resin ducts. Ducts are a network of tubes lined with living cells that secret a viscous resin filled with noxious terpenes. Resin ducts likely play a defensive role by protecting trees from insects,
bacteria, and fungi. The preservative qualities of resins were well-known by ancient Egyptians who used some resins to mummify human tissue. The nature gem, amber, is a fossilized plant resins that preserve the remains of insects, fungal spores, and pollen that became trapped in the sticky matrix.

Tree rings in the north temperate latitudes offer an amazingly accurate method of aging wood and examining variation in environmental and climatic conditions. For example, weather patterns in some years provide unusually cooler and moister summers that result in very wide annual rings of light colored wood. On the other hand, summers that arrive unusually early and dominate the spring with hot dry weather will produce rings that are narrower and darker in color. Climatologists can study the history of rainfall and temperature by measuring the density and width of tree rings. Trees most useful in climatic studies grow on land that is sensitive to fluctuations in temperature or rainfall. Spruces growing on Adirondack mountain tops are more sensitive to annual variation in precipitation because of limited ground water than say a moist forest at a lower elevation with a higher water table. Although some tropical forests have seasonal growth associated with dry and raining seasons, tree rings are less reliable at providing exact years or dates for historical information.

A long chronology of tree ring variation can be assembled by cross-dating rings from a living or reference wood sample with a series of dead and undated wood samples. The technique of cross dating relies on the assumption that trees for a given species from a particular region will show a unique pattern of ring width and density. By identifying key time periods of intense drought, rainfall, heat, or excessively cool weather, the rings for these periods can be identified on non-living samples of wood. This technique has provided valuable information for extending the climatic chronology on pines from the southwestern U.S. to 10,000+ years in addition to providing an effective means of dating human artifacts.

Dendrochronology has provided remarkable information on the age and identification of old growth forests, the natural history of fires in redwood forests, climatic conditions, periodicity of insect infestations, occurrence of global volcanic impacts on tree growth, and even aspects of human history.

Ancient forests do exist in eastern North America. Although the ancient trees of eastern North America are pale in comparison to the 4,800 year old bristlecone pines of the White Mountains or the 3000 year old giant redwoods of northern California, white cedars on the Niagara Escarpment in Canada and bald cypress along coastal rivers in the southeastern United States have yielded record trees that date nearly 900 and 1600 years of age, respectively.

Old growth forests can most easily be described as those forests that have persisted without the influence of European American. Old growth forests can also be described by a suite of physical and ecological characteristics that develop only in the absence of man (Figure Old Growth Oak). Old growth forests will possess trees shaped by old age into asymmetrical forms with flattened tops, sparse thick branches, crown dieback and heartwood decay. The largest and oldest of each tree species
will be near the maximum recorded for that species. Old growth forests will sport many fallen limbs and trunks of various stages of decay and age. The soil will be protected by a thick layer of humus and a diverse layer of herbaceous perennials. Old growth forests have an uneven age distribution that will be evident as a multi-layered canopy and understory. This suite of traits can’t develop if timber has been harvested or if the land has been altered for agricultural or other use.

Adirondack Park in northern New York holds one of North America’s largest uncut tracks of old growth forest. The park was established as a forest preserve in 1895. Today, the park totals more than 6 million acres of public and private land. Approximately 500,000 acres are considered old growth forest. The magnitude of this area is more meaningful when compared with the area of New York City at 195,000 acres, and the state of Rhode Island at 668,000 acres. Adirondack Park is larger than any other state and national parks in the lower 48 United States. Stands of eastern hemlock in excess of 400 years old and many sugar maple and yellow birch between 300-400 years of age constitute the Adirondack old growth forest. New York also boasts a second significant tract of old growth forest totaling some 54,000 acres in Catskill State Park.

Other tracks of eastern old growth forests may not be as large as those in the Adirondacks, but there diversity and unique attributes far exceeds their size. Mary Byrd Davis has compiled an incredible list of old growth forests and their attributes for every state east of the Mississippi River. As of June 2008, her text “Old Growth in the East: A Survey” was available for reading at Primal Nature website. (http://www.primalnature.org/ogeast/survey.html). One can read about the old growth White Cedar swamp at Norton Pond Swamp in Vermont, old growth slash pine in Charlotte County Florida, the 400 year old pitch pines of Fodderstack Mountain North Carolina, or the 150,000 acres of old growth in the Great Smoky Mountain National Park.

In their own right, old growth forests hold tremendous aesthetic beauty and scientific value. They are also centers of diversity for herbaceous flowering plants, amphibians, lichens, fungi, insects, mammals, and birds. Old growth forest offer carnivorous mammals such as black bear, gray fox, and fishers a multitude of den and hibernation sites among tree cavities in snags, under and within logs, and amongst uplifted tree root masses. These den sites in old growth forests result in energetic savings to wildlife by providing better insulation from cold air masses and thermal stability during summer months. The diversity of cavities in old growth forests provides optimal shelter for non-migratory songbirds, woodpeckers and owls. Although there are few old growth forest bird specialists, the disappearance of bottomland old growth pine forest in the southern states has contributed to the decline of the red-cockaded woodpecker and the extinction of the ivory-billed woodpecker. Old growth forests in the northeastern United States do increase the number of available territories for neotropical bird migrants such as blackburnian warbler (Dendroica fusca), brown creeper (Certhia americana), blue-headed vireo (Vireo solitarius), and Swainson’s thrush (Catharus ustulatus).

Dendrochronology of ancient bald cypress from the southeastern United States has shed light on the difficulty of settling North American in the 16th and 17th centuries. Roanoke Island of the North Carolina outer banks was colonized by 90 men, 17 women, and 11 children in
August of 1587. Two years of war with Spanish kept English supply ships from revisiting Roanoke Island until 1589. Upon return to Roanoke, the English found no colonist, no sign of war, and only the skeleton of a single man. Although search parties were executed no signs of the disappeared colonists were found. Jamestown colony on the coast of Virginia suffered great mortality early in establishment between 1607 and 1625. Nearly eighty percent of the colonized perished from malnutrition and disease at Jamestown during this period.

Bald cypress is the longest living tree species in eastern North America with oldest at 1600 years found on the Black River of coastal North Carolina. Dendrochronology of ancient coastal bald cypress has provided accurate climate records for more than 800 years. Data from these studies reveal that the driest three-year period co-occurred with the disappearance of the Roanoke colony between 1587 and 1589. Similarly the driest 7-year period during the 770 year bald cypress chronology coincided with the early establishment of Jamestown. Whatever the impact poor planning by colonists, poor sanitation, and war with native tribes presented the colonists, the ultimate effects were most certainly augmented by the stress of finding fresh water, food, and the ability to grow crops in a drought-stricken region.

Over the past 25 years, fire has gained great respect as a natural ecological disturbance that shapes community structure. The seminal event that awakened the U.S. Forest Service to using fire as a management tool was the large scale destructive burning of Yellowstone National Park in 1987. Suppression of fire leads to the build-up of flammable organic fuel over time. When fire occurs in a fuel laden environment it becomes uncontrollable and highly destructive to the ecosystem. This concept has been borne out by a dendrochronological study of fire scars in giant sequoias from California. The 2000 year fire chronology illustrates a negative relationship between fire frequency and magnitude. As fires become less frequent, the severity increases due to the build-up of organic fuel.

Tree ring analysis can provide insight into unexplained historical natural phenomena. May 17, 1780 was a dark day across New England was dark clouds rolled in from the southwest. Sunlight was reduced by 90% and people read and worked by candle light, crepuscular wildlife became active, and flowers closed during the morning hours. To a New Engander the unexplained phenomena must have been a divine sign, black magic, or the work of the devil. There was no internet, no orbiting satellites, and no phones to communicate that the forests in the area now known as Algonquin Provincial Park in southern Ontario were a blaze. The report would arrive more than two centuries later to reveal that the dark day could be naturally explained. Tree ring analysis told the story of a large scale natural fire in Ontario during the early spring of 1780. The spring 1780 tree ring on red pines had begun to form but growth ceased on sections of trees that had been scared by fire. Tree rings in subsequent years were wide as competition was reduced on the rejuvenated nutrient rich soil. The dark day resulted when a low pressure weather system drew smoke from the intense Algonquin fires to the cities of Boston, Providence, and Portland Maine.

Fire ecology and insect outbreaks are important natural forces that can shape ecosystem structure in eastern forests as well. Fire is a frequent phenomenon in boreal forests of northern Canada. Unlike sequoia fire ecology that determines understory diverse and recruitment dynamics, fire in the northern boreal forest drives a successional cycle reverting predominate
spruce-fir-white cedar forests to quaking aspen-paper birch dominated forest. In addition, insect infestations such as spruce budworm, larch sawfly, and forest tent caterpillars can be identified in the tree ring record as host species will produce incomplete rings or unusually narrow rings in years when growth conditions are optimal.

Tree ring analysis illuminates complex relationships among members of food chain in nature. On Isle Royale N.P. in northern Lake Superior, tree ring growth of Balsam fir is controlled by a predator-prey relationship of moose and wolves (McLaren and Peterson, 1994). Balsam fir twigs and needles constitute 59% of moose winter diet on Isle Royale. When moose population densities are high, more balsam fir is browsed, and the reduction in photosynthetic leaf area suppresses growth and width of tree rings the following summer. The moose population on Isle Royale is controlled by wolves that preferentially prey upon the elder members of the population. The wolf population density lags behind and responds to moose density. This predator-prey relationship is cyclic and the population density of both parties oscillates through time. As the number of moose eating balsam fir decline, tree ring growth increases. Similarly, when wolf density is low the moose population increases and tree ring growth is suppressed. The wolf, moose, fir food chain is an example of a top-down trophic cascade. The population numbers of moose and tree growth is controlled by the population density of the top-level predator, wolves on Isle Royale, in the food chain.

Literature Cited:


