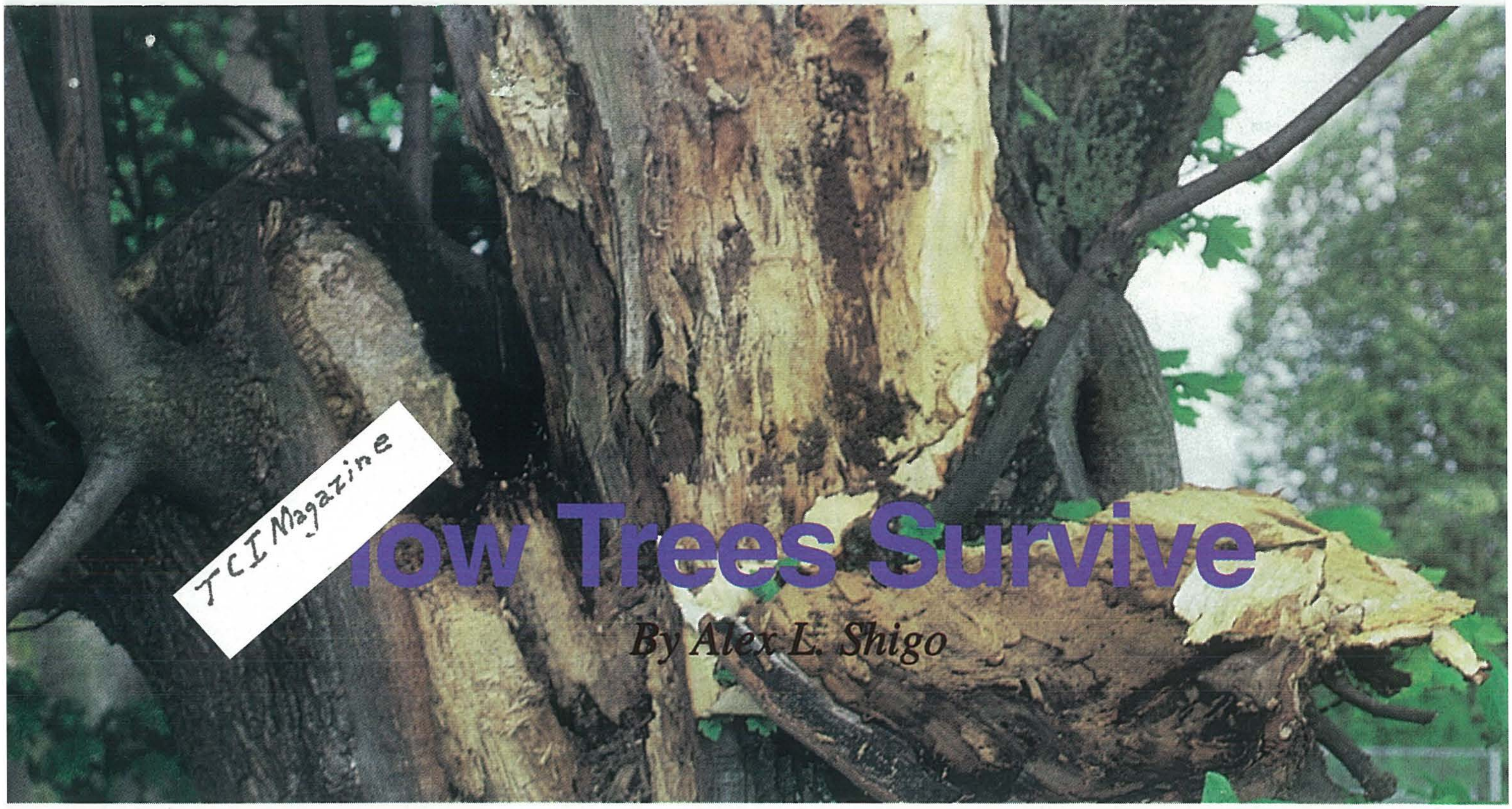


How Trees Survive

By Alex L. Shigo

Trees are the tallest, most massive, longest-living organisms ever to grow on earth.

Trees, like other plants, cannot move. However, trees, unlike other plants are big, woody and perennial, which means they are easy targets for living and non-living agents that could cause injuries. Trees cannot move away from potentially destructive conditions. Wounding agents and destructive conditions do destroy trees, but somehow, trees have grown in ways that give them super survival powers.

The big question is, how do trees do it?

The answer lies in concepts of biology and mechanical engineering.

The purpose of this paper is to examine the question of tree survival power more from the concepts of biology, but also to be aware of concepts of mechanical engineering.

I will focus on subjects that need more clarification. Details on all subjects given here are in my books.

Because different disciplines often use similar terms that have different meanings for their work, it is important to start with some definitions of terms I will use. You may not accept my definitions, but you will know what I mean when I use a term. I believe if a person cannot define a term in 25 words or less, they should not use it because they probably do not understand it.

Keyword Definitions of Terms

(Keyword definitions give the most important words that define a term. Complete sentences are not necessary.)

Capacity - What you have as a result of your genetic code; a potential source for some future action or product.

Ability - What you are doing with what you have; a dynamic or kinetic process.

System - A highly ordered connection of parts and processes that have a predetermined end point - product, service.

Stress - A condition where a system, or its parts, begins to operate near the limits for what it was designed.

Strain - Disorder and disruption of a system due to operation beyond the limits of stress.

Vigor - The capacity to resist strain; a genetic factor, a potential force against any threats to survival.

Vitality - The ability to grow under the conditions present; dynamic action.

Health - The ability to resist strain.

Disease - A process that decreases the order and energy of a living system to the point of strain.

Survival - The ability to remain alive or functional under conditions that have the potential to cause strain.

Generating system - New parts and processes form in new spatial positions; plants.

Regenerating system - New parts and processes form in old, or preoccupy, spatial positions; animals.

Wood - A highly ordered connection of living, dying and dead cells that have walls of cellulose, hemicellulose and lignin.

Symplast - The highly ordered connection of living axial and radial parenchyma in wood and bark.

Apoplast - The highly ordered connection of dead cells and cell parts that make up the framework that holds the symplast.

Quality - The characteristics that define a product, service or performance; quality can be low or high.

Hypothesis for survival

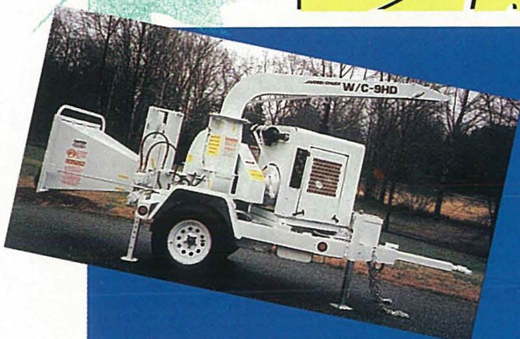
Because trees cannot move away from potentially destructive agents and conditions, they have grown in ways that give them the capacity to adjust rapidly after being threatened by agents or conditions that could cause strain or death.

The capacity to adjust is a genetic feature called vigor. The program of vigor of an organism is defined by the limits of factors essential for survival. For example, one tree may have broad limits for water utilization. When drought occurs, it will still survive. Another tree may have very narrow limits for water utilization. Even the slightest disruption in availability of water would lead to strain or even death.

A vigor code then determines the lim-

THE MOST EXPERIENCED MANUFACTURER IN THE INDUSTRY

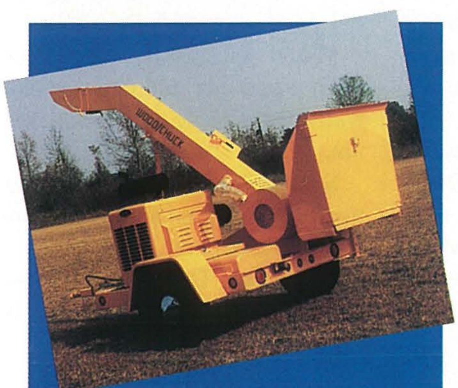
WOOD/CHUCK



WOOD/CHUCK
W/C-9HD

COMMERCIAL TREE CARE TAKES COMMERCIAL QUALITY

WOOD/CHUCK
W/C-17



WOOD/CHUCK DRUM

WOOD/CHUCK W/C-19

WOOD/CHUCK ECOCHIP

Used by the largest right-of-way contractors

MEMBER NATIONAL ARBORIST ASSOCIATION

WOOD/CHUCK
CHIPPER CORPORATION

1-800-269-5188
1-704-482-4356
Shelby, North Carolina

Please circle 63 on Reader Service Card

its for such essential factors as space, water, elements, temperature and soil pH.

The vigor of an organism cannot be measured until a life-threatening stimulus contacts the organism.

When any potentially destructive stimulus occurs, the ability of the tree to adjust will be due not only to its vigor, or genetic code, but to its vitality. A tree that is very vigorous by nature of its genetic code may be growing on a rock. It would not be very vital. What this means is that for survival, both the vigor and vitality of a tree must be optimized.

Forest tree, city tree

Trees became tall, massive and long-living plants as they grew in groups. Trees not only connect with other trees by way of root grafts but also by way of the fungi that are associated with non-woody roots; the organs are called mycorrhizae. Trees also connected with many other organisms, very large to very small, in ways that benefited the trees and their associates. Synergistic associations are important parts of the tree system.

A forest is a system where trees and many associates are connected in ways that ensure survival of all members.

It is important to remember that the genetic codes for survival, or vigor, came from trees growing in forests.

When the forest-coded tree is brought into the city, the factors that affect vitality become extremely important. The architecture of most city trees as they grow as individuals is different from most of their relatives in the forest where trees grow in groups. Forest trees have group protection and group defense. The individual tree has neither.

The good news, the bad news

The good news is that most of our city trees have strong vigor codes that have made them super survivors for hundreds of millions of years.

The bad news is that many human actions and mistreatments affect vitality and undo all the benefits of wondrous vigor code. It is only because most trees have such strong vigor codes that they still survive in cities.

There is no doubt in my mind that the greatest threat to survival faced by city trees are mistreatments by humans. Many trees tolerate mistreatments. Too often their tolerance is perceived as justifications for the mistreatments. I have heard it said many times that the tree did not die, so therefore the treatments must have been correct.

How do trees adjust?

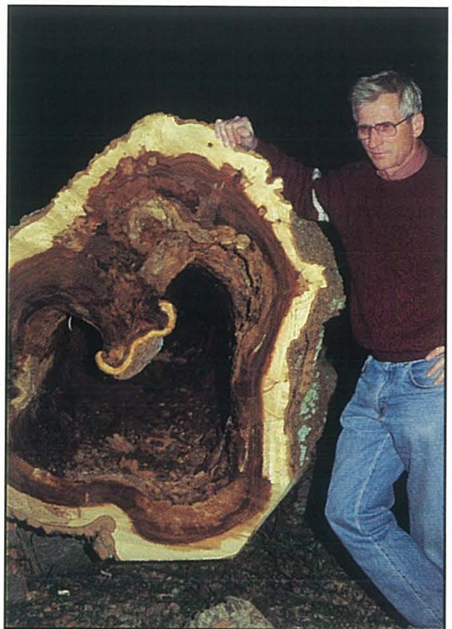
Trees have two basic adjustment codes.

1. After injuries, boundaries form that resist spread of infections. By resisting spread of infections, the boundaries protect and preserve the water, air and mechanical support systems of the tree. Two types of boundaries form: reaction zones and barrier zones. The reaction zone is a chemically altered boundary that forms within the wood present at the time of wounding. The barrier zone is an anatomical and chemical boundary that forms after wounding. The barrier zone separates the infected wood from the new healthy wood that continues to form in new spatial positions. The tree is a generating system. The tree has no mechanism to form new, healthy cells in the same positions as those that are infected. Regenerating systems in animals do restore, repair, replace and regenerate parts in the same spatial positions. Animals have a process call apoptosis, which means programmed cell death followed by lysis, and new cells forming again in the same positions of those that died, lysed, and were eliminated. This normal process of apoptosis accelerates after animals are injured and infected. This accelerated restoration process is then called healing. In this sense, trees have no healing process.

A typical cracking pattern associated with multiple stems. The willow oak was growing in a city. Cracks that separate multiple stems often lead to fractures. The tree shown here was one of many that was a victim of Hurricane Hugo.

Trees are highly compartmented, woody, shedding, perennial plants. Trees are generating systems. Every growth period, trees form new compartments over older ones. Trees grow as their apical and vascular meristems produce cells that differentiate to form all parts of the tree. The important part to remember is that

Rot associated with Armillaria mellea in a root of red spruce. The tree root did compartmentalize the infection, but in doing so the volume of root wood that could store energy reserves was decreased.



Klaus Vollbrecht stands beside an elm in Sweden that was felled because of extensive root and trunk rot. As trees grow older, the rate of growth of the fungi that cause decay may be more important as a survival factor than the rate of growth of the tree.

trees grow as new parts form in new spatial positions.

Trees cannot "go back" to restore, repair, replace or regenerate parts. You do not restore a church by building a new one next to it. All words in English that start with "re" mean that new parts will go back in previously occupied positions or back to an original state. These words have no meaning for trees. These words have been the basis for great amounts of confusion. A tree cannot function in the same ways as animals do after injuries or threats to their survival. The continuing use of such meaningless words for trees is a strong indication why tree basics should be understood by people who work with trees.

2. Now for the second adjustment feature of trees. After wounds or threats to their survival, trees also grow in ways that will maintain their mechanical structures. Now we come to the mix of biology and mechanical engineering.

There are two basic ways trees adjust to maintain and strengthen their structural stability: reaction wood and woundwood.

Reaction wood can be of two types. Compression wood forms on the down side of leaning trunks and tension wood forms on the upper sides. Compression wood is common in conifers and can be seen on a transverse dissection as dark bands in the wood, usually resin soaked. Or the growth increments could be larger in width and still be dark and resin soaked.

It is not possible to see tension wood because the changes take place in the cell walls. A gelatinous layer forms in the cell walls, and this layer can only be seen when properly stained and viewed under a microscope. The important part here is to know that these altered cell forms occur and that they occur after a stimulus that threatens survival mainly because of a lean in the stem that could lead to a fracture.

Woundwood is altered wood that forms about the margins of wounds. When wounds release the pressure of the bark, some of the still living parenchyma in the symplast begin to divide and produce new cells in new positions. These new cells no longer are held in place by the pressures of the bark or of the apoplast. The new cells become rounded and have a thin, primary cell wall. The cells exercise their ability (now) to divide and divide and divide. Because they are thin-walled, dividing cells, and because they contain the genetic codes for forming all parts of the tree, some of the cells begin to differentiate to form sprouts, prop roots, roots or flowers. This capacity for division and differentiation is called meristematic.

Meristems are groups of cells that have the ability to divide and differentiate to form all parts of the tree. There are apical meristems that increase the length of stems and roots, and also produce flowers, and vascular meristems - cambial zone - that increases the girth or circumference of a tree.

The symplast is a meristematic tissue. This means that the parenchyma in the symplast have the capacity to divide and to differentiate. However, they are not able to exercise this capacity so long as they are "trapped" in place by the strong apoplast and the pressure of the bark.

When wounds "release" the symplast, then the capacity to divide and to differentiate is converted to an ability.

Callus is the name given to the thin-walled, mostly round, meristematic cells that first form after wounding about the edges of the wound. Callus has very little lignin, the tough "natural cement" that gives cell walls great strength.

After callus cells continue to form, the pressure begins to build again as internal round callus cells begin to squeeze against other callus cells. As pressure increases internally, the shape of newly formed cells begins to change.

Within a few weeks to a few months after wounding during the growth period, callus formation begins to diminish and woundwood formation begins.

Woundwood has fewer vessels than "normal" wood. The cell walls are usually thicker than normal and usually contain more lignin. The woundwood cells cease to be meristematic. A new vascular cambium forms and continues to form woundwood. These woundwood tissues are seen as ribs about the margins of wounds. The woundwood ribs also add new strength to the weakened side of a stem, branch or woody root.

When woundwood closes wounds, then normal wood continues to form. The internal boundary-forming processes of compartmentalization are separate from the processes of callus and woundwood formation.

What can go wrong?

It appears that trees could live forever. Of course, that is not so because the tree system, like all systems, must obey natural laws. And, again, the laws bring together biology and mechanical engineering.

Because a tree is a generating system, it is bound by its genetic codes to increase constantly in mass. The second law of energy flow begins to take its toll. The second law states that no system can remain in an orderly condition without a continuous supply of energy. As the tree system begins to increase in mass, the demands for energy to maintain order in the system begin to increase at exponential rates.

The tree still has ways of living within the limits of this law. The tree is a shedding organism. It uses and sheds non-woody and woody parts as they die. Decayed wood that develops within boundaries is even a form of shedding. Also, as trees age, the percentage of the entire tree that is symplast begins to change. The ratio of apoplast to symplast increases. So, the tree has both dynamic mass - symplast - and apoplast.

As the inner cells in the symplast die, the inner apoplast that now has all dead cells is called protection wood.

Protection is a static feature. Defense is a dynamic action. Protection wood is more protective than the sapwood because protection wood often contains substances called extractives that resist decay. Protection wood may also be so altered that its water, pH and available elements may not support growth of microorganisms.

Sapwood has a symplast. When sapwood is injured and infected, dynamic processes take place. There are two types of sapwood: sapwood that conducts free water, and sapwood that has its vessels plugged and does not conduct free water.

When protection wood is injured and infected, the intrinsic characteristics of the wood resist spread of infections. There are four types of protection wood: heartwood, false heartwood, discolored wood in early stages and wetwood. (See ***Tree Anatomy*** for details.)

The biology of fractures

Trees, like all organisms, die in three basic ways: depletion, dysfunction and disruption.

Depletion means that energy decreases to the point where disorder increases and the survival of the system is threatened. Examples are infections and starvation.

Dysfunction means that highly ordered parts and processes begin to become disordered to the point where survival is threatened. Some examples are genetic problems and toxins.

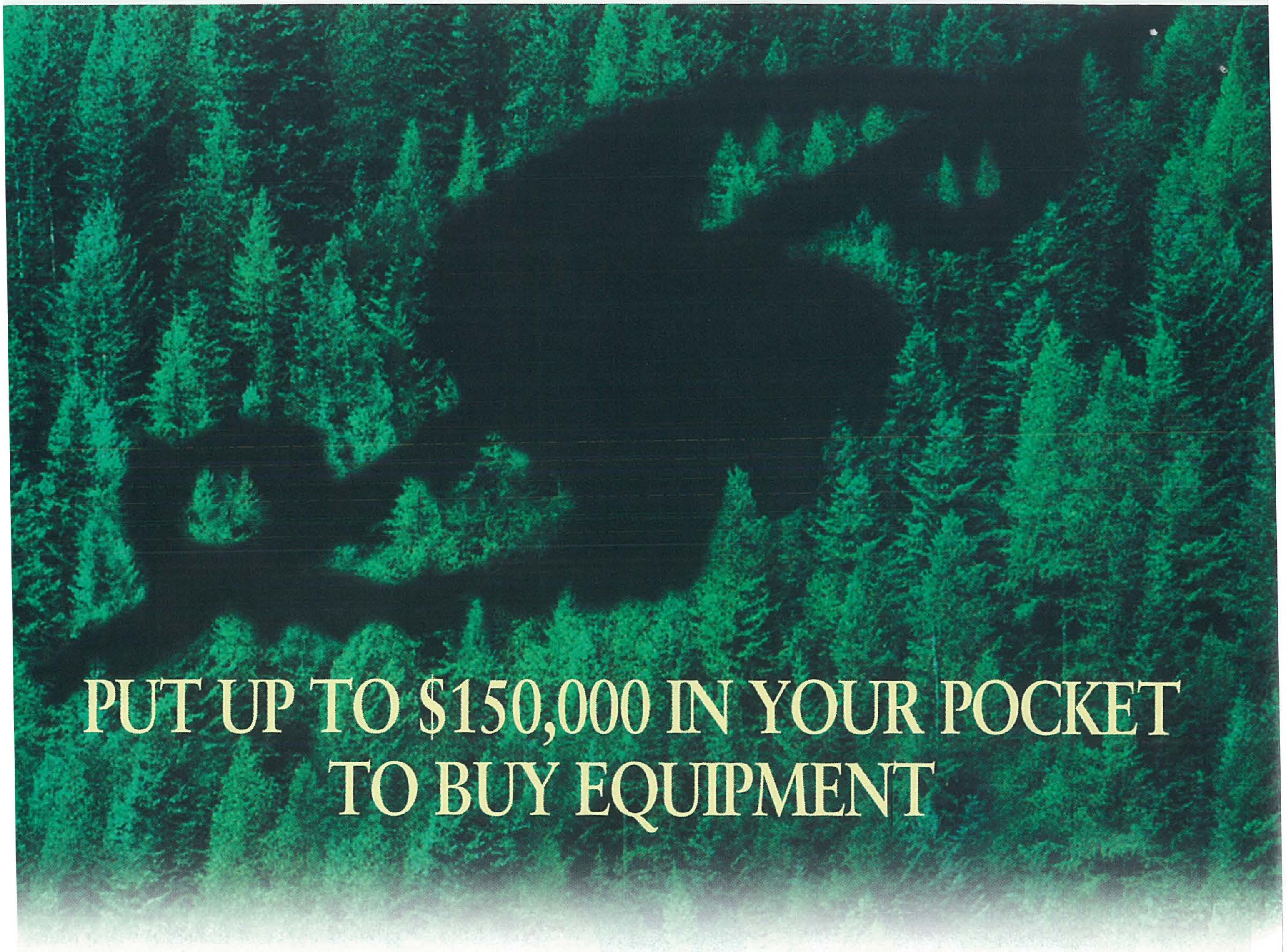
Disruption means that the highly ordered structure of a system is disordered to the point where survival is threatened. Some examples are storm injuries and wounds inflicted by large machines.

Trees grow as increments of new cells envelop older increments. In a sense, trees grow as cones of tissues envelop older, smaller cones. The tough structural parts of a tree are aligned in axial or vertical arrangements of thick-walled fibers or fiber tracheids, and vessels or tracheids. Every park of the tree framework is self-supporting, unlike animals that have thin-walled cells that are held in position by a boundary called skin and an internal framework of bones. The animal system allows movement as evasive defense against some destructive agents.

The tree also has a radial arrangement of parenchyma cells. Remember that the parenchyma cells usually have thin walls with little lignin. Bands of radial parenchyma cells are called rays. They are often the sites of internal cracks.

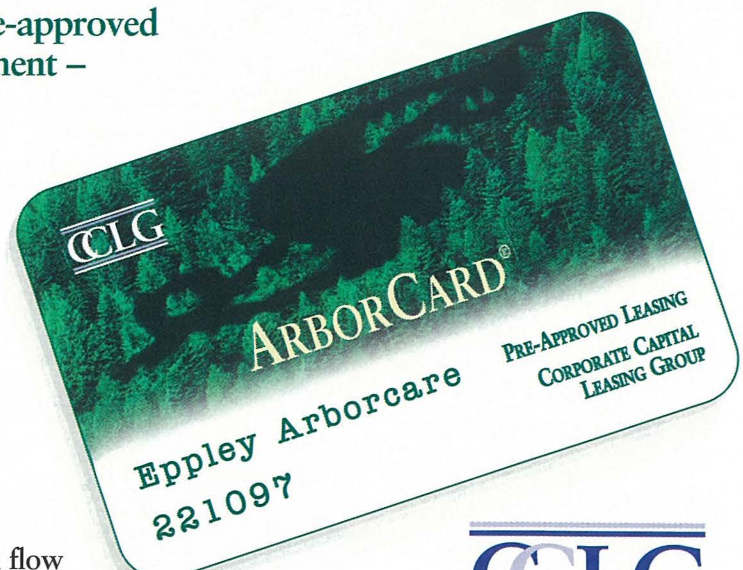
No absolutes

There are no absolutes. There are no perpetual motion machines. Every system has its limits for survival. The tree system also has its limits for survival. As it increases in mass and gets older, the likelihood for injuries increases. A mature, healthy tree may have thousands of com-



Call today to apply for ArborCard – the pre-approved lease card that makes it easy to lease equipment – without financial statements!

Now you can walk into any dealer, select the equipment you want, and simply hand them your ArborCard – the powerful and convenient way to arrange affordable, tax-deductible leasing for your business. We take care of all the paperwork – for you and the dealer! Just call today and apply. We'll pre-approve you and send your ArborCard – for up to $150,000 in purchasing power.



- Instant credit approvals without financial statements
- Up to $75,000 per transaction: $150,000 total
- Financing for new and used equipment
- Fast and easy application by phone
- Flexible payments and terms to fit your seasonal cash flow

Call today for a free brochure and easy pre-approval!

1-800-537-9108
Fax: 1-800-344-7712

Each time an ArborCard is used to lease new or used equipment, Corporate Capital Leasing Group, Inc. will donate $50 to the National Arborist Foundation, to be matched by a grant from the U.S. Forest Service.

CCLG

CORPORATE CAPITAL LEASING GROUP, INC.
109 East Evans Street, Box 504, West Chester, Pennsylvania 19381
Phone (800) 537-9108 Fax (800) 344-7712

Associate Member, National Arborist Association

Associate Member, International Society of Arboriculture partmentalized infections. Yet, there comes a time when even the limits of a super survivor begin to be approached. There are no absolutes.

When trees are young, depletion and dysfunction are the major causes of death. As trees get older and have survived thousands of injuries and infections, disruption becomes the greatest threat for high-quality survival. When a branch fractures and falls, it dies. When a trunk splits and falls to the ground, it dies. And, as larger and larger wounds result from such fractures, the likelihood of more fractures increases greatly.

When the pattern of fractures begins in city trees, not only are the trees in potential trouble, but so is the property near the trees. Also, people who go near the trees could have problems if trees or their parts fracture and fall.

The tree's architecture

A tree is a central beam with secondary lateral beams called branches and twigs. The tree is unique as a living system because it connects living and dead cells, and, in a sense, still maintains some control over the dead parts. The cell walls of dead fibers still hold bound water that acts as a strong protection feature against infection by microorganisms. So long as the bound water and the free water in the lumens saturate the wood, infection will be resisted. It is possible also that some of the bound water could be "released" and used as free water in living processes. This is probably the case in tissues behind buds where high amounts of starch are stored during the end of the growing season. In spring the starch is enzymatically converted back to glucose, which greatly increases the osmotic pressure, and may "pull" bound water from cell walls. Water does not flow from tissues behind buds when cuts are made very early in the spring, often before soils are thawed in areas where they normally freeze.

Because trees are constructed of living and dead parts, the concepts of biology and mechanical engineering are all the more appropriate. They are connected.

We say trees do not move, and in the sense of changing spatial positions, this is correct. Yet trees are constantly in motion. As they sway, new tissues that form in new positions constantly adjust to potential weakness.

If all this is so, why do tree failures occur?

Now, back to the idea that there are no absolutes. There are limits to all parts and processes that make up a system. As the limits are approached, we have increasing stress. When the limits are exceeded, we have strain. When the strain is physiological, we have a disease. When the strain is structural, we have a fracture.

Branch attachments

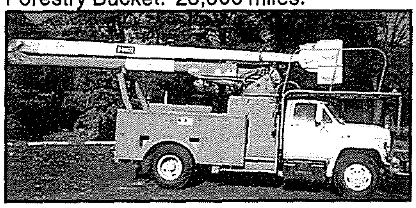
Branches are subdominant stems. As buds grow, some develop as leaders that extend the central trunk or beam. Other buds that do not grow as central leaders become subdominant lateral branches. For example, if a young tree is pulled partially out of the soil and tied horizontal to the ground, soon a series of leader trunks will form along the procumbent trunk. They would be called trunks, not

130
Specialized Trucks In Stock

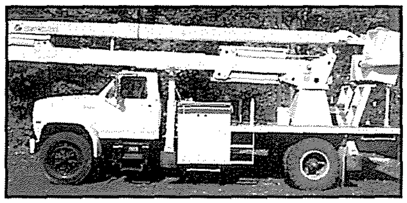
1991 Int'l 4900 .... $54,500
DT466 13 Spd. Air Brakes, Chip Box, Built in Vermeer Chipper, Holan 819-50-3 Forestry Bucket. 23,000 miles.

1988 GMC V/8 .... $39,500
5 Spd. with Aerial Lift of Conn. 50' Bucket and Chip Box. Others available.

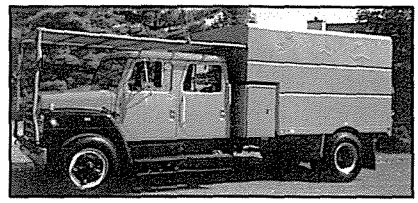
(2) 1990 Ford F800... $39,500 each
6.6 Diesel, 6 Spd. Chip Body and Holan 819-50-3 Forestry Bucket.



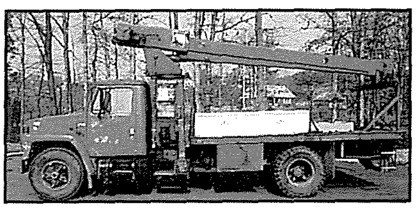
1987 GMC V/8 .... $29,500
5 Spd. with Hi Ranger. 52' Bucket.



1989 Ford $39,500
6.6 Diesel 6 Spd. with 48' Reach All Bucket.



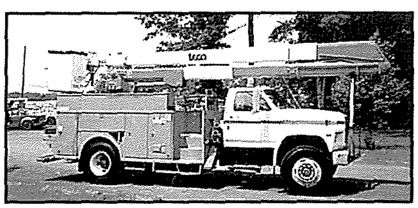
1989 Int'l Crew Cab $24,500
12,500 Orig. Miles. 10 Chip Body Trucks in Stock.



1981 Int'l DT466 .... $12,900
5 Spd. with 6 Ton RO Crane, 36' Hook Height.

1987 GMC V/8 .... $31,900
5 Spd. with Holan 819-50 Forestry Bucket and Chip Box.

(3) 1989 GMC V/8 ..... $29,500 each
5 Spd. with 48' Hi Ranger. Double Buckets.

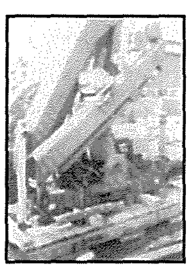


(5) 1987 Ford .... $31,500 each
8.2 Diesel w/ 50' Teco Buckets. Util. Bodies.

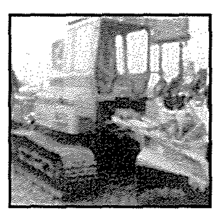
1979 Ford F700 .... $7,900
Crew Cab. V/8 Auto 11' Stake and Lift Gate.

1985 Ford LN8000 .... $69,500
3208 CAT 13 Spd. w/National 17 Ton Crane Model 875 with 35' Jib, 120' Hook Height.

1986 Ford $22,500
C/O 8,000, 3208 CAT. 5 Spd. 26,350 Orig. Miles. Chassis & Cab.
With 2 Spd., 7.5 Ton RO Crane 44' Hook Height. **$29,500**

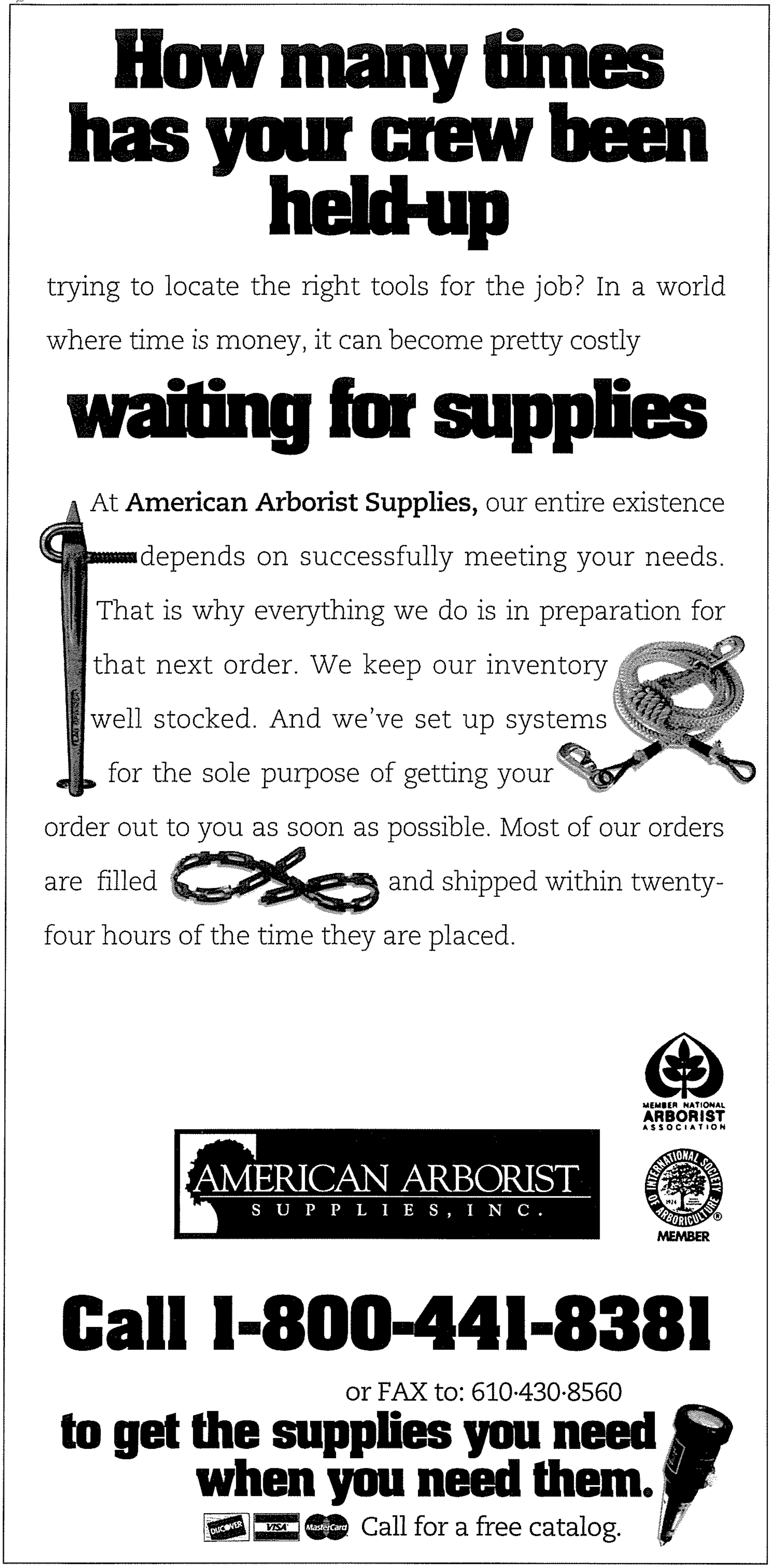


(10) HIAB
$4,500 and up
IMTCO. National, Etc. Knucklebooms Unmounted or Mounted.



Rayco Hydra Stumper (New)
$121,900
175 HP CAT. Undercarriage for the big land clearing of stump removal jobs. With A/C
No Air **$118,000**
1993 Rental Return: 250 Hrs **$107,000**
Also Rental Available, Call For Details.

OPdYKE INC.
Truck and Equipment Sales
(215) 721-4444
3123 Bethlehem Pike • Hatfield, PA 19440



branches. However, if the tree was not tied down, the usual leader and branch architecture would develop.

As the branch grows, branch tissues at the base of the branch turn abruptly about the branch base and then continue downward on the trunk. The trunk tissues grow around the branch tissues at the branch base. The branch tissue forms a collar called the branch collar and the trunk tissues form a collar called the trunk collar. For ease of reference, the two collars are collectively called the branch collar.

The tissues of both collars usually mix and mesh to form a swollen place about the branch base. When branches die, protective chemical zones form in these swollen basal tissues. The protective zone within the branch base resists infection into the tree from microorganisms that grow in the dead branch.

A better understanding of branch attachment has led to adjustments in pruning. Cuts should be made as close as possible to the branch collar, but the collar should not be injured or removed. Removal of branch collars - flush cuts - are major starting points for many serious tree problems - cankers, rots, cracks, insect infestations.

A brief look at decay

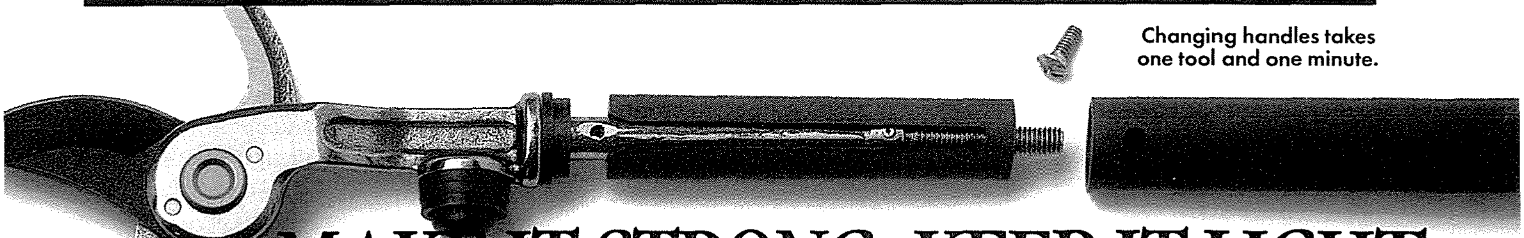
Decay is usually considered the major cause of tree failures. I do not believe this is entirely correct. I believe that cracks are much more of a problem, and I will discuss them after a few words about decay.

Decay is a process that increases the disorder of any highly ordered system. Tree decay is the breakdown of the highly ordered structure of cell walls. Tree decays are the most serious and most common group of tree diseases, worldwide. Decay is a disease because it affects the health of the entire organism. Pathology must consider the entire organism, not only its parts.

For many years, decay was not considered a disease because the microorganisms infected only dead parts.

Two of the most serious myths that have held back understanding of a tree, and consequently our understanding of correct tree treatments, are that wood is dead and that decay is not a disease.

The entire myth of wound paints to stop decay was built on these two myths. Sad, but these myths are still alive and eco-

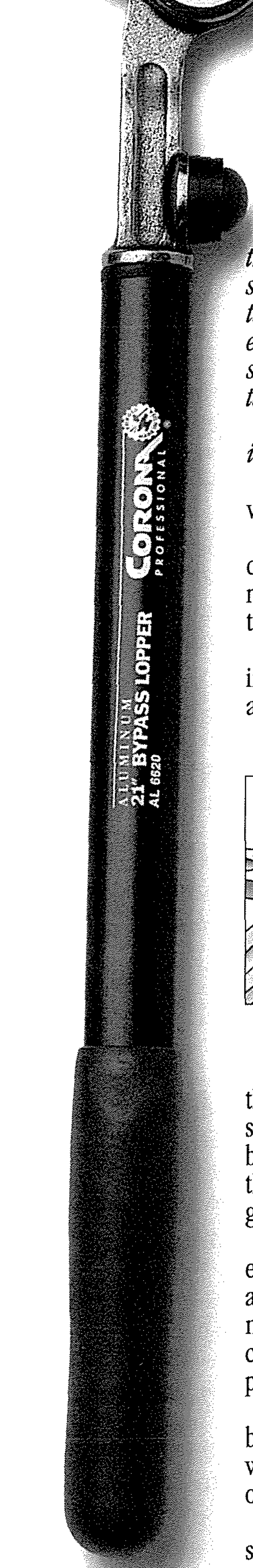


Changing handles takes one tool and one minute.

MAKE IT STRONG. KEEP IT LIGHT.

MAKE IT CUT CLEAN AND FAST AND EASY.

DESIGN IT TO REDUCE WORKER FATIGUE AND INCREASE PRODUCTIVITY.



21-inch AL 6620 cuts limbs up to 1½ inches thick.

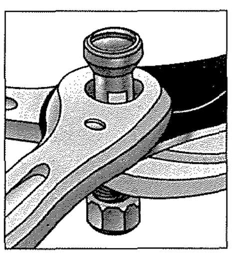
Give us more cuts per hour, especially during those last hours of long days at the end of the pruning season. Give us a blade that we can replace without taking apart the handles – one that holds its edge, is easy to sharpen and simple to adjust. The handles should never need replacing but, if they do, it should take only seconds and require no special tools.

By the way, make it unbreakable and guarantee it forever.

That's what you told us it would take to make the perfect vineyard and orchard loppers. So we did it. And then some.

Our new line of aluminum-handled loppers cut so clean, so fast, so easy and are so strong and simple to maintain, that virtually everyone who has tested them says they're the best loppers they've ever used.

The blade cuts with astonishing ease. Long, to reach into tight areas; large, to slice easily through mature vines and branches; the blade is Radial Arc™ ground and clad with a tough, slick, three-layer fluoropolymer that reduces friction to a bare minimum. This blade requires one-third less force than a conventional blade to make the same cut.



Self-aligning Pivot bolt

The blade is a separate component. Changing it takes one tool and one minute.

The forged hook is designed to draw the material being cut closer to the pivot. This maximizes leverage and minimizes the effort required to make a cut. The hook's curvature is shallow enough to easily slip between dense, tangled branches and support wires. Yet it is deep enough to hold the branch securely as the cut is being made. The sap groove is deep and wide for improved self-cleaning.

The square-shouldered, right-threaded pivot bolt that enables quick blade change is positioned so that the hook and blade open wide with a minimum of handle movement – in other words, with less effort. And the same coating that makes cutting so easy also self-lubricates the pivot action.

The Santoprene® bumpers, which provide a cushy rebound at the end of each cut, are located low on the tang well clear of the action. Replacing a worn bumper takes only seconds. Tools needed? Your thumb and forefinger.

Our patented new handle design has astonishing strength. The thick-walled aluminum tubing is oval – inherently stronger than round or rectangular stock. That strength is then compounded by an internal wedge of high-density, glass-filled nylon that expands as it is compressed during handle mounting. Even given severe abuse, these handles are almost impossible to break. Given proper use, they're indestructible.

The hand grips are designed for comfort and durability. They're thick, to minimize hand fatigue. They're molded of tough polyethylene and the bottom is extra thick for longer wear when used to drag brush along the ground and into a pile.

Our new aluminum handled loppers come in three models. A 21-inch version with a 1½-inch cutting capacity suitable for vines and shrubs. And 26 and 32-inch models with a 2½-inch cutting capacity for tree pruning.

LIFETIME WARRANTY

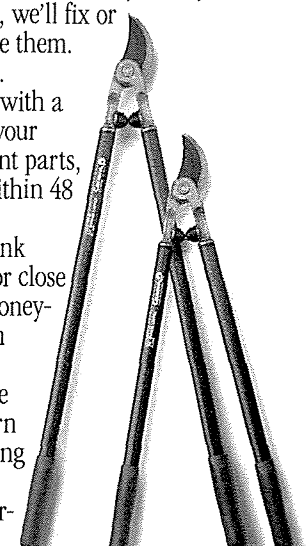
Like all our professional tools, these loppers come with a lifetime warranty. If they break, we'll fix or replace them. Period.

We're also backing these tools with a "Fast or Free" parts warranty. If your Corona dealer is out of replacement parts, call us. We'll have them to you within 48 hours or they're yours free.

If you try these loppers, we think you'll agree that they're perfect, or close to it. So we're making you this money-back offer. Buy a pair. Prune with them for two weeks. Use 'em and abuse 'em. If you agree they're the best, buy more. If you don't, return them to us along with a note telling us what you think would make them better. We'll refund your purchase price. Fair enough?

For further information, contact your Corona dealer or call us at

1-800-234-2547.



26-inch AL 6640 and 32-inch AL 6660 cut limbs up to 2½ inches thick.

CORONA CLIPPER®

1540 East Sixth St., Corona, CA 91719

A Harrow Company

® Santoprene is a trademark of Monsanto

nomically active today. (It is more productive to talk about decays.)

Trees have grown in ways that greatly decrease the potential impact of decays.

Trees compartmentalize decayed wood. Compartmentalization is the tree's defense process. The tree is a living system that has many associates. When trees are injured, they will always be infected. There is no tree process that prevents infection. After wounding, the tree responds in ways that ensure continual survival.

The original concepts of decay did not treat the tree as a living, responding organism. The so-called tree decay concepts were really wood decomposition concepts. All wood darker than the sapwood was considered heartwood or a type of heartwood - wound heartwood, pathological heartwood. Heartwood was considered a dead tissue that was invaded by decay-causing fungi after wounding. Tree decay was the breakdown of the heartwood. Many different types of decay patterns and decay-causing fungi were identified. Wood product researchers took over the study of wood decay. This is the time the "wood is dead" myth started. It was true for products, but not for the tree. Wood anatomy was studied by many researches. To this day, many people confuse wood anatomy with tree anatomy. Tree anatomy is about a living organism. Tree decay and compartmentalization are about living, responding organisms.

Decay and tree failure

Decay is usually considered the major cause of tree failures. This may be so in parts of the world where digging into cavities is a regular practice. In the digging process, natural protection boundaries are destroyed. Also, the strong woundwood ribs are removed. Then, decay is cited as the cause of failure.

Harsh pruning cuts that remove the branch collar have been major starting points for cavities. Thick coatings of wound paints over such wounds greatly increase the spread of decay.

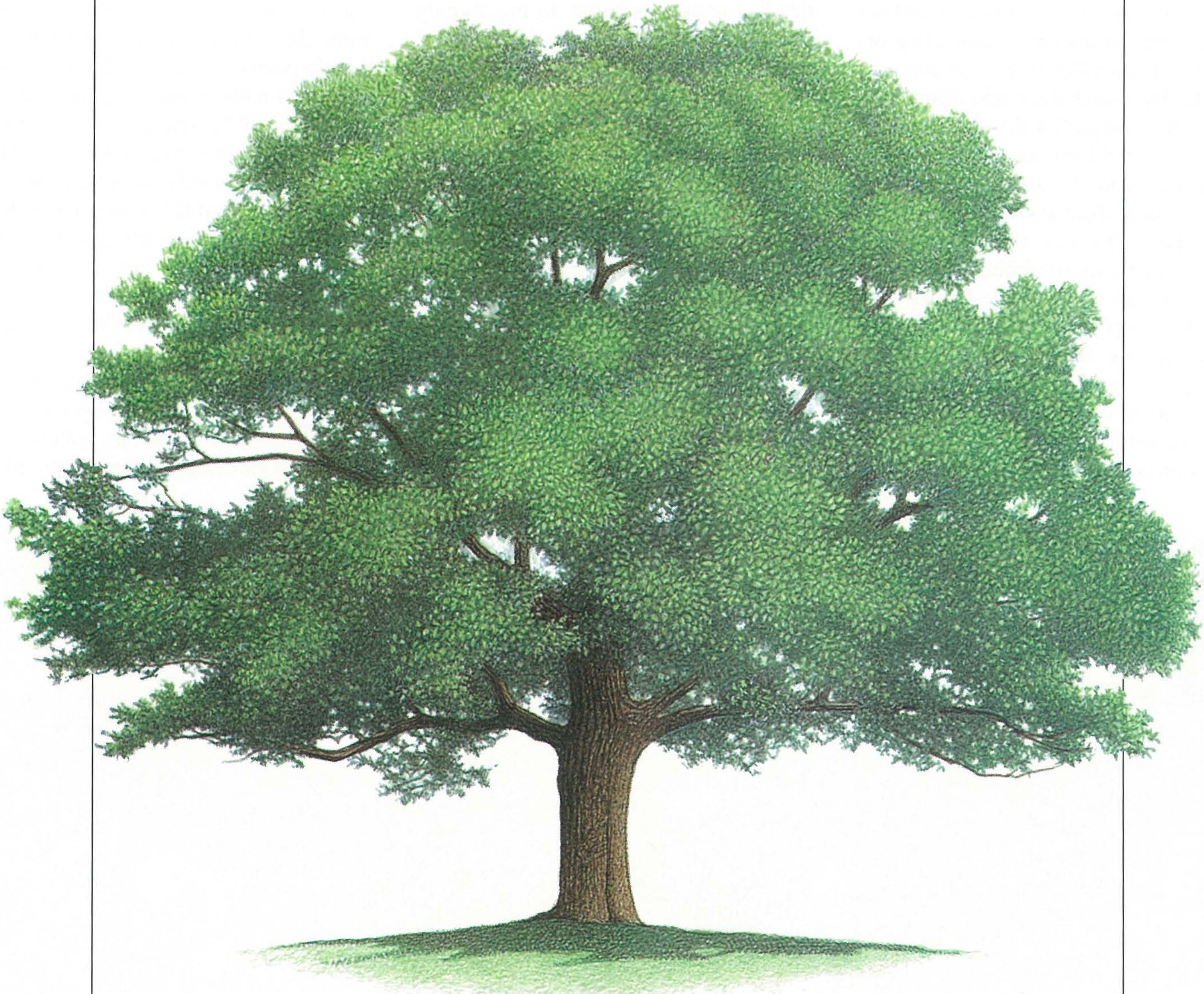
Cutting branches flush to the trunk - flush cuts - painting wounds and digging out decay have been the three major treatments of the industry. There is no doubt in my mind that these three mistreatments have caused more tree problems than all the diseases, fires, floods and insect infestations added together.

Modern arboriculture means that tree treatments are based on tree biology. Trees are living systems.

In the U.S., the practice of digging into cavities is rarely done. The use of wound dressings has decreased greatly. The correct pruning of trees is increasing greatly. More and more, people are basing treatments on an understanding of tree biology.

Now, back to trees and decay. Decay was the greatest threat to the plants that were developing as tall, long-living, woody plants. Decay had the potential to break down the framework for the developing tree. If the framework was broken down as wounds were inflicted and as branches and woody roots died, the tree as we know it today would never have developed. Some combination of processes and structures "had to happen" or the plant would never have become a tall, massive, long-living tree. Or, you could say, the mechanical design of the tree developed in such a way that decay was usually resisted. For these reasons, I see decay to the point of failure in the natural forest as a last stage process in the life of

THIS IS OUR PRODUCT.



BUT THIS IS WHAT WE'RE SELLING.

Inside every container of Alamo® you'll find a strong, healthy tree. Because Alamo is the only fungicide that's effective in preventing oak wilt and dutch elm disease. Just call 1-800-395-TURF for more details on how it can help preserve a beautiful environment. Which, as you can see, is what we're really selling.

Sponsor Environmental Steward Award. *Turf and Ornamental Products, Box 18300, Greensboro, NC 27419.*
 Always read and follow label directions.

a tree. Decay has become a major cause of tree failure in younger city trees mainly because the mistreatments of humans has occurred at rates much faster than the trees' ability to adjust. And to add insult to injury, the trees' adjustment tissues were the first to be destroyed.

For these reasons, I see tree decay as an increasing problem in cities where mistreatments have routinely destroyed the trees' systems for defense and protection. It will take a complete new generation of trees and modern arborists at work before this problem is corrected. In many cities of the world the problems have been corrected. To start, I invite you to my town of Durham, New Hampshire, where you will see full-crowned beautiful trees. You will not see topped and mutilated trees, no wound dressing and no cavities that have been dug into. In fact, you will rarely find a cavity, even on the largest and oldest trees. So, I am optimistic; it will take time.

Cracks

Just as trees developed as highly compartmented systems that compartmentalized decay, they also developed in ways that sustained survival after cracks formed.

I see tree decay as an increasing problem in cities where mistreatments have routinely destroyed the trees' systems for defense and protection.

There are two basic types of cracks in wood. Ring shakes are cracks or separations along the circumferential growth increments. Ray shakes, or radial cracks are separations along the radial plane.

Ring shakes occur commonly along the plane of the barrier zone that forms after wounding. The barrier zone is a strong protective zone that separates infected wood from healthy wood that continues to form after wounding. Suberin forms in the cell walls. In a sense, barrier zones are like an inside bark. The barrier zone is weak in a structural way.

Ray shakes or radial cracks usually start from ring shakes. Ray shakes also start as the woundwood ribs curl inward at the vertical margins of wounds. When the woundwood ribs grow rapidly, the likelihood of cracks forming at the wound margins increases. Wound dressings that stimulate woundwood formation also increase the chances for cracks.

Compartmentalization was the trees' "answer" to decay. What did the trees "do" about cracks? First, the tree "produced" more cracks, and second, it "invited" anaerobic bacteria into the cracks. Now for some details.

Rarely have I found forest trees with only one or two radial cracks. I have dissected thousands of trees that had internal cracks. Usually there are many cracks, and they form at different positions around the base of the stem. There appear to be two survival benefits to multiple cracks. First, the trunk continues to bend as a vertical multiple beam. And, when a radial crack does rupture the cambium, then woundwood formation starts. The woundwood then adds strength to that portion of the trunk. As radial cracks propagate toward the cambial zone, the new ray tissues that form appear thinner. The survival benefit would be that the radial crack would propagate even faster when it approached the thinner ray tissues. Then, the likelihood for disrupting the cambial zone would increase, and then the formation of woundwood would begin. Woundwood cannot begin to form until the cambial zone is ruptured. For years I was aware of this phenomenon, but I did not understand how it could be beneficial for survival. Now it makes sense.

The second way trees "deal" with cracks is to have the cracks infected by anaerobic wetwood-forming bacteria. The cracks are perfect sites for the bacteria. It was common to have water and wetwood fluids flow from dissected trunks that had cracks. Research has shown that wetwood resists decay.

Cracks are not major causes of failures in forest trees, but they are major causes of failures in city trees. Why? In forest

SUPER VALUES

MODEL 3500

MODEL 6500

Carlton Models 3500 and 6500 offer economical solutions to your stump cutter needs. These affordable machines couple the ruggedness of a Carlton with field-proven Wisconsin gasoline engines. Carlton machines are an unmatched value, offering a quick return on your investment and the solid construction to make them one of your best profit centers.

FOR MORE INFORMATION OR TO ARRANGE A DEMONSTRATION: 800-243-9335

J.P. Carlton Company Div. D.A.F., Inc.

121 John Dodd Road · Spartanburg, South Carolina 29303

800-243-9335 · 803-578-9335 · FAX 803-578-0210

Carlton X
PROFESSIONAL STUMP GRINDERS

Competitive Financing Available

Please circle 31 on Reader Service Card

trees, multiple basal cracks with wetwood are common. Forest trees rarely have large low branches. City trees that have been topped and mutilated have cracks forming in higher positions on the trunk. Large low branches often have cracks at the point where the branches bend downward. The architecture of city trees and the mistreatments they receive often leads to cracks and failures. Also, when long, hot, dry periods dry the wetwood in the cracks, failures often result.

Summary

Trees are living systems. They are unique living systems because they have the capacity to add strength to their structure at exactly the most effective places. This capacity is built into their genetic code. As generating systems, they are always building in front of themselves. When any part of the structural framework is weakened to the point where survival is threatened, the new parts that form in new positions form in ways that add strength to the weakened place.

Having the capacity to respond effectively to survive is dependent on having the energy, conditions and other ingredients necessary to turn the capacity into an ability.

Both capacity as a vigor ingredient and ability as a vitality ingredient are necessary for long-term, high-quality survival. Vigor without vitality, or vitality without vigor will not support long-term, high-quality survival.

The vigor codes for trees have met the test of time in forests. Many trees in many cities of the world are having great difficulties in expressing their vigor codes because human activities and treatments have affected their vitality.

There are no absolutes. No system, or its parts, will survive when stress goes to strain.

It is time to reexamine the tree system. It is time to start basing tree treatments on tree biology.

It is time for modern arboriculture! TCI

Dr. Alex Shigo is a noted authority in the field of arboriculture. An author, lecturer and consultant, he is the owner of Shigo, Trees & Associates in Durham, New Hampshire.

The World's Quickest Tree Injection system

- Injections are quick. Most take 10-40 seconds. No waiting to remove capsules. Most trees take 2 minutes or less.
- Least wounding of any injection method. No drilling is needed. Makes a 1/16" slit in the bark.
- Can inject at an easy work height. No need to always inject near the ground.
- No extra equipment is needed. No drill, hammer, or waste container for empty capsules.
- Efficient and rapid use of the chemical. Effective with 85% less chemical than other methods. Chemical is placed in the most active layer of the wood. No need to wait for a sunny day — works even in the rain.

The Wedgle™

ArborSystems, Inc.

P.O. Box 34645 • Omaha, NE 68134 • (402) 339-4459 • Fax (402) 339-5011

Please circle 7 on Reader Service Card