Trees and Associates in Winter

Mycorrhizae and root hairs are abundant and active in winter. Our tree concept must be expanded to include these facts.

By Dr. Alex L. Shigo

Problem

With repeated observation of any part or process of a system, facts emerge that must be included in the concept of that system. Consider the cell theory, germ theory, DNA, antibiotics, and even the branch collar. In all cases, new facts made it necessary to expand our concepts for these systems.

Almost all of the studies on trees have been done on seedlings, or on aboveground parts in summer. Few studies have been done on mature trees outside. Deadwood anatomy has been and still is confused with living tree anatomy. An understanding of anatomy must precede any understanding of physiology.

Even fewer studies have been done on belowground parts of trees in winter in temperate climates.

Solution

This article discusses results of observations on belowground parts of trees in winter from 1992 to present, in New Hampshire, United States. Some philosophy is given as a plea for Modern Arboriculture. An expanded concept of a tree is given. Trees are viewed as opportunistic multiple systems. Abiotic and biotic factors are discussed as initiators of processes.

Dormancy

Trees have five major phenological stages: Start, leaves, growth, storing and rest.

Reproduction is a sub-pattern that usually starts near stage two. It is impossible to generalize these patterns because there are almost as many variations as there are species. However, every tree system must start again from a quiet period. Every tree must produce new leaves or needles for photosynthesis. Every tree must increase in mass; this is growth. Every tree must store ingredients essential for survival. Every system must rest. Most trees also have reproductive cycles. Some are extremely complex in their patterns.

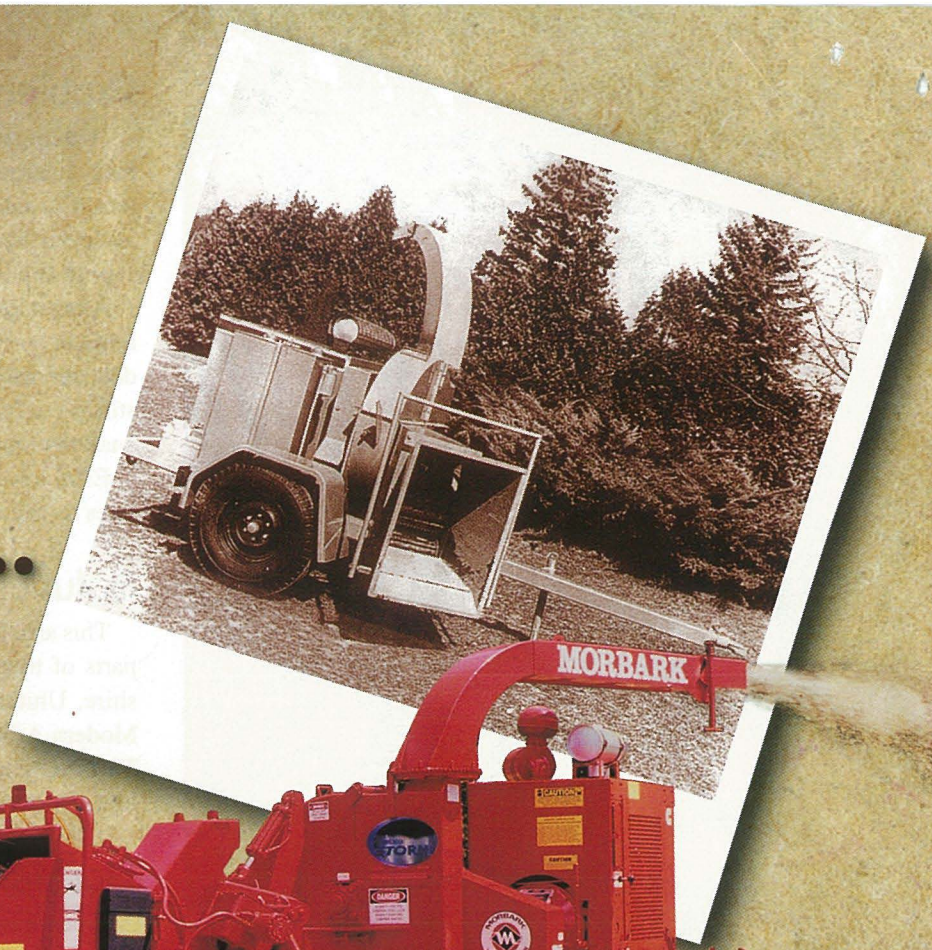
Dormancy is usually thought of as a period of rest where processes essential for life function at a minimal rate. Dormancy does not mean stopping! Stopping is death.

The second law of thermodynamics states that no system will survive unless it receives a continuous supply of energy to maintain order. In order to survive, trees must also have a supply of water and elements. These points must be remembered as the discussions go on.

Trees as business conglomerates

Trees are often referred to as living systems. Many of the problems with understanding phenological stages could be clarified if a tree was viewed not as a single system, but rather as a cluster of systems connected in highly ordered ways. Maybe a tree is more like a business conglomerate. If the business conglomerate analogy could be accepted, then many different parts of a tree could be in different phenological stages at the same time. Many aboveground stages are different from those belowground. In the sense of natural dualities, the business conglomerate analogy is a better way to view a tree.

That Was Then...



This is now!

The Evolution Continues...

With an exciting line-up of machines from the pioneer of modern brush chipping technology. Backed by Morbark's exclusive two-year warranty and supported by a world-class network of equipment dealers.

MORBARK, INC. 1957 2002 45 years

Celebrating our 45th year of uncompromising dedication to innovation and quality.

1-800-831-0042 • 989-866-2381 • www.morbark.com

Please circle 36 on Reader Service Card

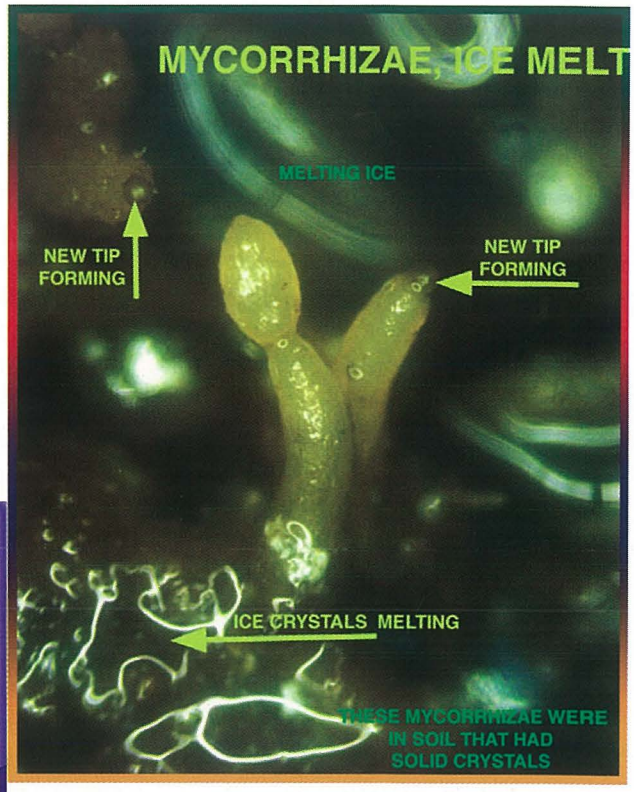
Physiology

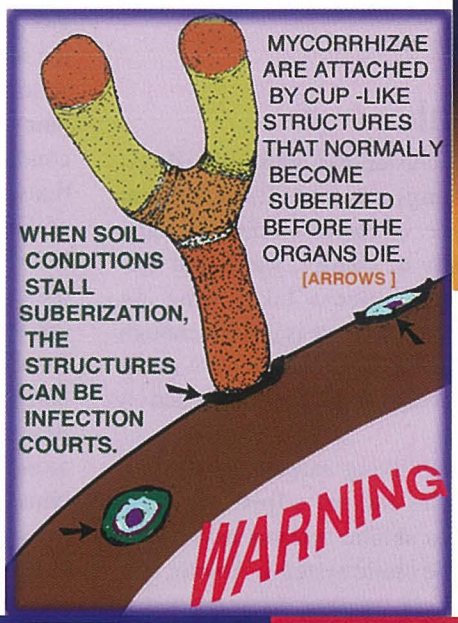
If a tree is a cluster of systems, and all systems require a continuous supply of energy to maintain order, then it appears that the different systems would require energy that came from storage. It is difficult to accept that energy from photosynthesis could supply all systems at the same time. Some timing or allocations for timing must be there, and also, a supply of energy in a stored state.

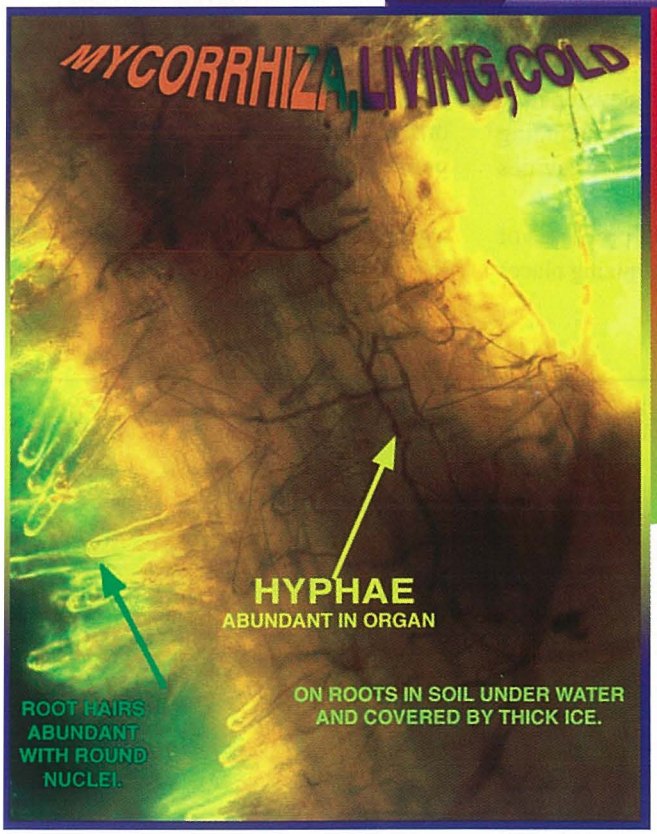
This we know is true because trees first form ATP, which is used to form glucose which then forms cellulose, starch and a great number of other substances. Still, glucose is the fuel that makes it possible for the tree to survive. Trees do have ways of storing energy reserves and for regulating the use of the energy for processes to survive.

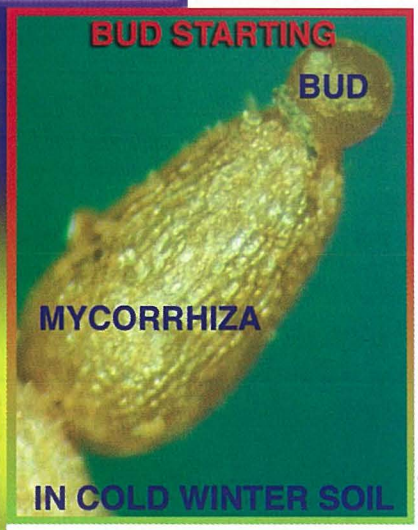
Water is another essential for life. We think of water, mostly, in its liquid form. Water molecules enzymatically removed or inserted are essential for many processes and products, from cellulose to starch and back to glucose. Trees store water as bound water on the hydroxyls on cellulose. The water is bonded to the cellulose by very weak, but significant, hydrogen bonds. When any force greater than hydrogen bonds is exerted, the bound water then moves to liquid water again.

Water can also exist as a gas or as a solid. As temperatures decrease, the constantly changing positions of the water molecules slow, and if temperature continues to decrease, all possible positions for hydrogen bonding will be occupied and molecular motion stops – ice formation.









Energy flow

Water and energy flow downhill, or from high concentrations to lower concentrations. When ice forms in the spaces between cell walls and even in cell walls, liquid water flows out of the cell and death from dehydration usually follows in plants that are not cold hardy. But if ice does not form, then dehydration may not occur. When temperatures decrease below 0 degrees Celsius, and the water is pure and quiet, ice may not form. This is called supercooling of water. When nucleators are present, the ice will form as crystals about each one.

Element storage

It seems that if energy and water are stored, and that elements are also essential for life, then there must be some way the tree stores elements. It is difficult to conceive that growth and other element-requiring processes receive elements at the time they are required. There must be a storage process for elements.

Elements in molecules often precipitate when pH increases. This we know for iron, manganese and other elements. We know also that some elements such as potassium can be bonded in many chelated-like forms. Potassium is an element that is absorbed in its pure form. When potassium is in high concentrations, the electrical resistivity (as measured by a Shigometer) of the wood is very low. In summer during the growing season, electrical resistivity in k-Ohms is low. As winter approaches, the electrical measurements increase greatly. Summer could be in the 8 k-Ohm or 10 k-Ohm range while winter could be in the range of a hundred, or even higher. If potassium is a factor in electrical resistivity, then it must be bonded in ways that prevent its action as an electrolyte.

Elements must be stored and I believe that much of the absorption of elements occurs in cold soil in temperate climates.

Photos in books

Results showed many active mycorrhizae and root hairs in soil under cold water covered by ice. Ectomycorrhizae and endomycorrhizae from cold soil are shown in color in my book, *Tree Anatomy*. On the cover of another book, *100 Tree Myths*, I have a color photo of ectomycorrhizae and root hairs from a *Pinus strobus*. There are other color photos of mycorrhizae from cold winter soil in *Tree Pithy Points*.

Life in cold soil

The mycorrhizae are not only in non-frozen soil under frozen soil, but from soil under water that was covered by ice. Further, many of the mycorrhizae and root hairs at 1,000X with a phase microscope showed abundance of hyphae inside the non-woody roots. The nucleus in a root hair is at the tip of the cell. Nuclei in all shapes were viewed. Active nuclei are round and as they age and die, they become spindle-shaped.

I had other people excavate roots and view them under my dissecting and phase microscopes. The mycorrhizae were always there. My neighbor who teaches a biology course at the University of New Hampshire routinely got samples of mycorrhizae for his class from soil under water and ice from my pond.

Survival

Trees are clusters of highly ordered systems; a conglomerate. Each system requires time, optimum conditions, and a ready supply of energy, water and elements. Each process takes time. In temperate climates there is just not enough time during warm periods to have every process of every system conduct its activities.

Survival in living natural systems depends on the rate of adjustment and adaptation to abiotic systems beyond the control of the biotic systems. Abiotic systems provide space, temperatures, elements, water and energy. The positions on Earth where these factors exist are very different, yet life forms have developed in almost every conceivable place, including ocean vents, to boiling springs, to cavities within deep ice.

It is not difficult to expect processes of some long-term systems optimizing places and conditions considered not the best for life. Absorption of elements developed or adjusted to low temperatures. This then extended the time for a larger cluster of systems to survive. Trees have always been and still are the most massive, tallest, longest living organisms on Earth. To be such superior survivors without the benefits of movement, the tree systems adapted and adjusted to every possible condition present over a period of one solar year.

Absorption

Mycorrhizae are organs made up of fungus and tree tissues. The organs facilitate the absorption of water and elements essential for healthy growth. Trees have many redundancies, some for short-term conditions and some for long-term conditions. Root hairs are finger-like extensions of single epidermal cells that contain very little lignin in their walls. The cell walls of the epidermis do have cellulose, which is not the best of boundaries or membranes for absorption of water and elements. Root hairs are usually ephemeral. They grow as new roots grow and they go or die as woody roots begin to from a bark that contains suberin. Their numbers are usually so great that even if they are poor absorbing structures, they still absorb some water and elements.

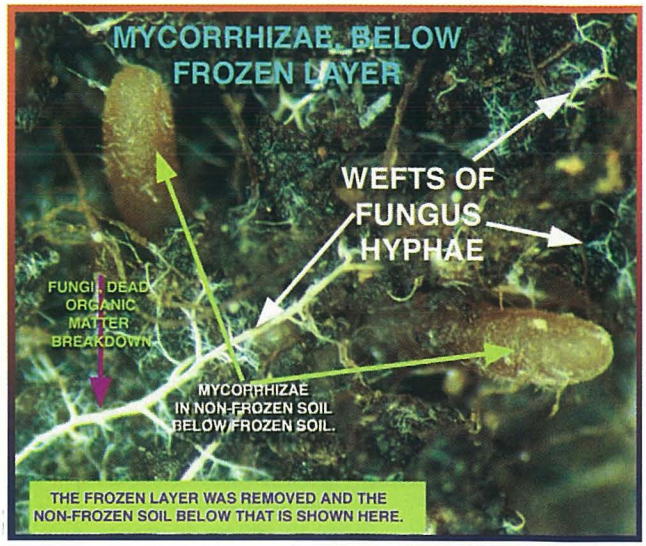
Mycorrhizae present a system of synergy. The fungi receive more and the tree receives more with this association. Mycorrhizae live for long periods; a year or more. (Note forms that bud.)

A mycorrhiza starts when a hypha from a germinating spore infects a newly forming non-woody root. When some fungi

infect a root, they control the further development of that root. Some fungi penetrate the root and hyphae spread far beyond the root. It is not uncommon to see some mycorrhizae with hyphae completely wound about the organ. Root hairs do exist on some mycorrhizae.

The question quickly arises about how fungi can exist in roots in soil under water. To make sure the roots were from neighboring trees, samples were collected from streams where only one tree species was growing. Large woody roots with smaller masses of roots were dug. The mycorrhizae were on the tree roots, mostly *Acer rubrum* and *Ulmus americana*.

The fungi in roots under water appeared typical for species close to *Glomus* – a member of the Zygomycetes. Chlamydospores of several types were abundant from the winter samples. (The organisms in the roots could be oomycetes, which are close to water molds. If this can be shown, then the organisms would be better classified as endophytes. There is so much yet to be learned.)



Membranes

Membranes are nature's discriminators. Membranes keep things in that should stay in and keep things out that should stay out. When membranes lose their ability to discriminate, the cell will die. When many cells die, the organism will die.

Membranes and bonds are extremely important. Bonds hold matter in place and the bonded matter is further kept in place by some membrane. The basic unit of life – the cells – speaks to this point.

Plant cells have vacuoles and turgor pressure. Animal cells have neither. Plant cells have a continuous symplast made possible by plasmodesmata. Animal cells have another means for intercellular communication called channels.

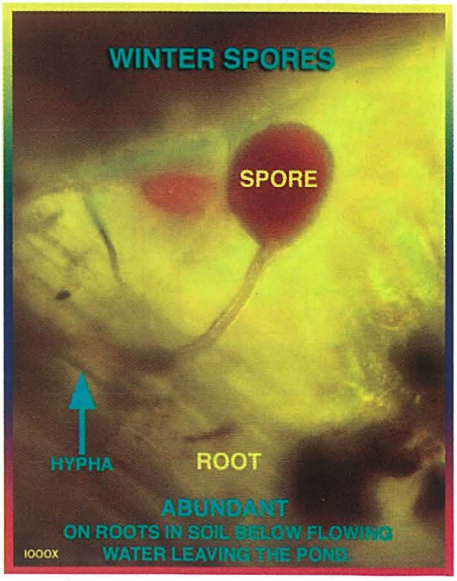
Root hairs have cellulose as the major substance in their outer membrane. Fungi have chitin, which contains nitrogen, in their outer membrane. Chitin must have unique characteristics for absorption. Fungi have hyphae that grow through a substrate. Energy-yielding substances, water, essential elements, and vitamins must be absorbed through the chitin-rich membrane of the hyphae.

The connection of fungi with trees optimizes two absorbing systems – cellulose in root hairs, and chitin-rich substances in hyphae. Mycorrhizae with root hairs have both systems.

Respiration

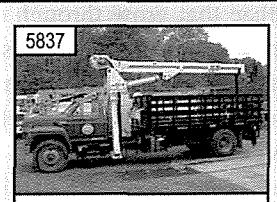
What determines what stays in and what comes in? And what drives this process of absorption? No system can start itself.

Respiration starts the absorption process and once started, concentration



150 SPECIALIZED TRUCKS AT WWW.OPDYKES.COM

5837



94 FORD F800: Cummins 8.3L diesel, 225 hp, 5 spd + 2 spd, 33,000 lb GVW, with **10 ton JLG 1000JBT CRANE**, 57 ft hook ht, 16 ft wood flatbed w/ stake sides, **50K miles. $39,500.**

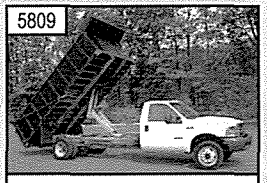
5825

(2) 99 INT 4700: DT466E, 190 hp, 6 spd + lo, 33,000 lb GVW with **55 ft ALTEC LRIII-55 BUCKET**, 12 ft split dump / chip box. **15K miles. $59,500 each.**

5769

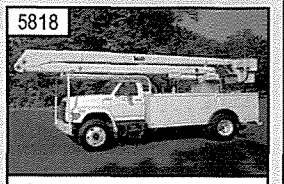
98 FORD FT9000: Cummins 8.3L diesel, 225 hp, 8 speed + lo, +lo/lo, 52,000 lb GVW, with **18 ton MANITEX 1870 CRANE**, 80 ft hook height, 20 ft steel flatbed, 41K miles. **$69,000.**

5809



2000 FORD F550 SD: 7.3L Power Stroke diesel, 235 hp, auto w/od, 4x4, 17,500 lb GVW, with **16 ft dump body w/36" sides, 13K miles. $34,500.**

5818

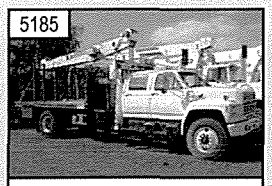


99 FORD F800: Cummins 5.9L diesel, 215 hp, 6 spd, 33,000 lb GVW, with **55 ft TECO V5A-55IP-2TFE2 BUCKET**, 2 man end hung basket, 14 ft utility body, **25K miles. $44,500.**

5735

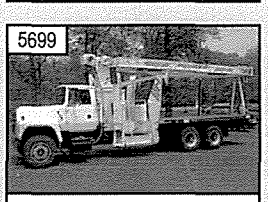
98 VOLVO WG64: 3306 CAT, 300hp, 8 spd +lo +lo/lo, 58,000 lb GVW, with **21 ton NATIONAL 800C crane**, 133 ft hook ht, 18 ft steel flatbed. **$89,500.**

5185



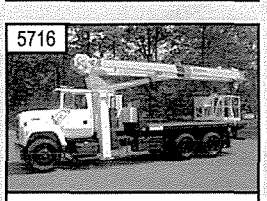
93 FORD F8000 CREW CAB: Cummins 8.3L, 5 spd + 2 spd rear with **7 ton NATIONAL 337A crane**, 47 ft hook ht, 14 ft wood flatbed with stakesides. **$19,500.**

5699



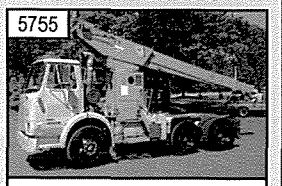
97 FORD LT8000: 8.3L Cummins, 275 hp, 8 spd +lo +lo/lo, 58,000 lb GVW, with **PIONEER 2000 crane**, 124 ft total hook ht. **$79,500.**

5716



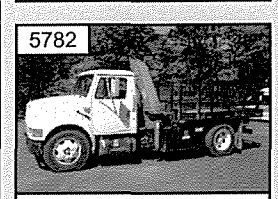
95 FORD LNT8000: 8.3L Cummins, 275 hp, 8 spd + lo, 54,400 lb GVW, **21 ton NATIONAL 800C crane**, 114½ ft hook ht, pin-on basket, 18ft flat. **$89,500.**

5755



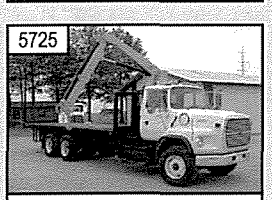
82 WHITE ROAD XPEDITION II TRACTOR: Cummins NTC300, 300 hp, 6 spd + lo, + lo/lo, with **10 ton RO TC120 CRANE**, 50 ft hook ht, overhaul ball. **$17,900.**

5782



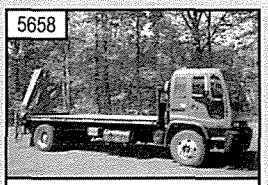
93 INT 4600: 7.3L diesel, 155 hp, 5 spd, 21,500 lb GVW, with **3½ ton HIAB 550-3 KNUCKLEBOOM**, 23ft max side reach, remote ctrl, 11ft steel flat. **$21,500.**

5725



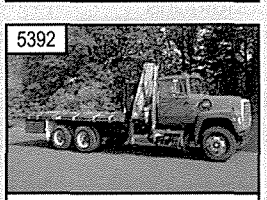
95 FORD LNT9000: L10, 260 hp, 10 speed, 22 ft flatbed, with **5½ ton IMT crane**, 25 ft side reach. **$39,500.**

5658



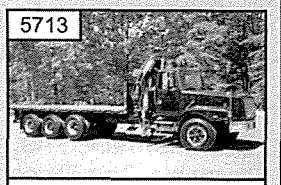
98 GMC T7500: 3116 CAT, 6 spd, **6½ ton HIAB knuckleboom**, 26 ft side reach, 19 ft steel flat. **$39,500.**

5392



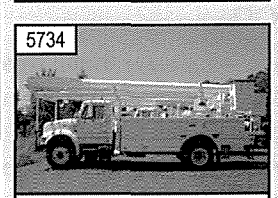
82 FORD LT8000: 3208 CAT, 210 hp, 13 speed, 64,000 lb GVW, with **6½ ton HIAB 1265 crane**, 34'5" max side reach, 20 ft steel flatbed. **$14,900.**

5713



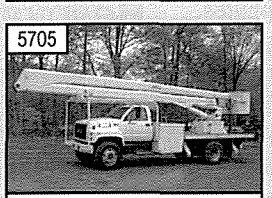
93 WHITE / GMC WG64: CAT 3306, 305 hp, 8 spd +lo, +lo/lo, 73,280 lb GVW, with **10 ton CORMACH 1900E crane**, 24'6" steel flatbed. **$47,500.**

5734



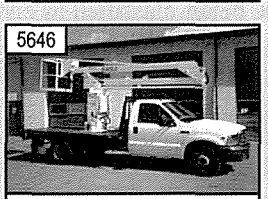
2000 INT 4900: DT466E, 215 hp, 9 spd, 33,000 lb GVW, **55 ft ALTEC AM855 bucket**, 14 ft utility body. **$79,500.**

5705



99 GMC C7500: CAT 3126, 210 hp, 7 speed, 33,000 lb GVW, with **65 ft TECO V6-65IP-4TFE2 bucket**, 2 man end-hung basket, 14 ft steel flat-bed. **$64,500.**

5646

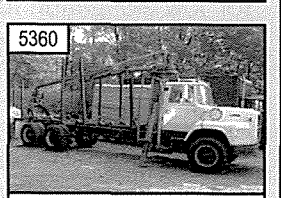


99 FORD F350: V/10, auto, with **28 ft EAGLE bucket**, 6,000 miles. ***This truck was a demo unit, in unused condition.*** **$19,500.**

5756

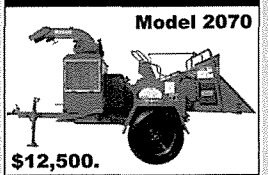
90 INT 2674: Cummins NTC315, 315 hp, 8 spd + lo, + lo/lo, 73,280 lb GVW, tandem, air tag axle, **24'6" flatbed/dump body. 86,000 miles. $32,500.**

5360



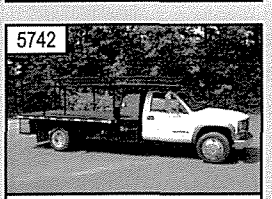
1987 FORD LTS9000: L10 Cummins, 8 speed +Lo +Lo/Lo, 18ft, 44 gears with **Barko** model 80 log loader. **$24,500.**

MORBARK BLOWOUT
BELOW DEALER INVOICE
Model 2070



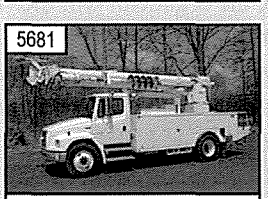
$12,500.
Wisconsin 66 hp.
Only 1 unit available.

5742



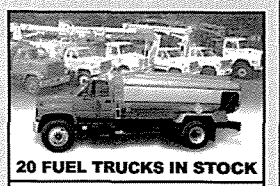
2000 GMC 3500HD: 7.4L Vortec gas engine, auto w/od, 15,000 lb GVW, with **12ft wood flatbed** w/ ladder racks, 6 ft platform above cab, tool boxes. **$19,900.**

5681



99 FREIGHTLINER FL80: 5.9L Cummins, 230 hp, Allison 5 spd auto, 36,220 lb GVW, with **15 ton ALTEC D2050TR digger**, 50 ft hook ht. **$69,500.**

KNUCKLEBOOMS
10 HIAB, IMTCO, NATIONAL, ETC...
MOUNTED OR UNMOUNTED.



20 FUEL TRUCKS IN STOCK
(40) BUCKET TRUCKS, (15) BOOM TRUCKS, (15) KNUCKLEBOOMS, (10) UNMOUNTED KNUCKLEBOOMS, (15) DIGGER DERRICKS, (5) MECHANICS TRUCKS W/CRANES.

Opdyke Inc.

Truck & Equipment Sales

Call Toll Free
866-250-8262

3123 Bethlehem Pike • Hatfield, PA 19440 • Phone 215-721-4444 • Fax 215-721-4350 • www.opdykes.com

Please circle 43 on Reader Service Card

gradients and the Le Chatelier principle keep it going.

Trees are multiple systems operating in states of dynamic equilibrium. There is the appearance of balance or the static state while really many processes are moving at equal rates in opposite directions.

Many tree processes can be explained by the Le Chatelier principle. Natural processes move toward a state of balance, but when they do reach balance, they die.

Yet, as one part decreases or leaves the equation, the process moves in that direction, again in an "attempt" to establish balance.

An understanding of dynamic equilibrium and the Le Chatelier principle are essential to an understanding of not only absorption, but many other tree processes. Remember, balance means no movement; death!

Clusters of ice crystals form in minute cavities. Soil does not freeze, but the water in soil freezes.

The ice melted when I placed this sample under the microscope. The sample came from soil that had ice crystals in the cavities. The soil came from my backyard in January. The soil surface was covered with snow. I believe that mycorrhizae and many other organisms do not freeze, but supercool.

Connections

Nitrogen is essential for growth. What pathway operates for entrance of nitrogen through a membrane into tree roots? And, how does all of this relate to mycorrhizae being abundant in cold winter soil? Here are some additional thoughts based on points of chemistry and results of observations that repeated.

Chemistry behind absorption of nitrogen

Compounds of carbon, oxygen, hydrogen, nitrogen, sulfur and phosphorus make up about 98 percent of the mass of trees. Carbon, oxygen and hydrogen come from water and carbon dioxide; but where do the others come from and how do they get in?

The elements are absorbed as ions. Ions are molecules, or elements, that have a positive or negative charge. Like charges repel, and unlike charges attract. Ions move.

Nitrogen enters as nitrate anion or as ammonium cation. Phosphorus and sulfur enter as molecules bonded with oxygen as anions. Each element enters in its pure state. Ions of sulfur, phosphorus and oxygen are big and heavy. In ways I do not understand, the fungi with chitin in their hyphal walls facilitate the absorption of these ions. The absorption of phosphorus by mycorrhizae is one of their most important functions.

Nitrate ion has a molecular weight of 62. Ammonium ion weighs 18. Now back to respiration. Energy from glucose from stored starch in living root parenchyma cells is made available for tree processes

by respiration. Respiration is an energy-releasing process. Products of the process are carbon dioxide and water. When some carbon dioxide dissolves in water, carbonic acid forms. The acid dissociates to form hydrogen ions that bond with water to form hydronium cations and bicarbonate anions. Hydronium weighs 19 and bicarbonate weighs 61. When you add 19 and 61, 80 is the sum. When you add the weights of nitrate and ammonium, you also get 80! On the tree side of the rhizoplane, the two ions weigh 80, and on the rhizosphere soil side, the ammonium of 18 and nitrate of 62 again weigh 80. Coincidence? I wonder.

Back to cold soil and cold water under ice. First, water. Cold water contains more oxygen than warm water. Oxygen is a requirement for respiration!

In soil below 0 degrees Celsius, clusters of ice crystals form in minute cavities. In a sense, soil does not freeze, but the water in soil freezes. That is not as important as the fact that cold soil will have many ice clusters. I believe the ice clusters in soil act in a way similar to the sheets of ice over water.

Plants that are not cold hardy die from dehydration because water moves out of the cell, because water moves from high concentrations to lower concentrations. As ice forms in soil, liquid water moves toward the ice clusters. The abiotic cold factor then acts as a trigger for molecules to move. It is fascinating to know that light heat from the sun triggers processes that make life possible – photosynthesis. And, low temperatures also trigger life processes.

As water moves toward ice clusters, air with oxygen fills the cavities. Many living organisms – bacteria, fungi, mites, thrips, nematodes, enchytride worms, amoebae – live in the oxygen-rich cavities. And, roots live there also. Abiotic factors trigger biotic processes!

The rhizoplane is the boundary between soil and living roots and hyphae. The mycorrhizae serve both tree and fungus. In roots in soil under water, I believe the endomycorrhizae benefit from the ready supply of carbon from the tree. In ectomycorrhizae, I believe the fungi and tree benefit from absorption through a chitin-rich boundary. I believe also that hyphae that grow out from mycorrhizae obtain some carbon from decomposing wood and leaves.

Trees, as all living things, pay taxes. Taxes are paid in the sense of exudates that contain carbon. Many soil organisms benefit from the "taxes" and in return the organisms make elements available for the trees. The words of Galileo come to mind as he was faced by his inquisitors. Galileo said God wrote two books – Nature and Scriptures. The problem, he said, was that few people have ever read or know about the book of Nature, and until Book 1 is understood, Book 2 will never be understood. They did not understand what he said. They issued his sentence! (I am now working on Book 1.)

Natural systems have developed in ways that benefit high-quality survival. Systems

in tropical climates are different from systems in temperate climates.

Back to rhizoplanes and the 80, 80 idea. Respiration and the Le Chatelier principle work to keep the processes moving. The natural "attempt" for balance keeps getting disrupted as one part of a two-part system keeps moving to a decreasing state. For example, to move or be absorbed into a root, the molecule must be in a soluble ionic state. This state is soluble in water also, and as water moves in soil, the ions move along with the water away from the target living system. To say it another way, the same ions essential for life also move "downstream" to the groundwater or on to the ocean, where new and different life forms exist. Indeed, the natural systems function to maintain life and non-life, and these processes go on, and will go on, without the intervention of humans. This is what Book One is all about.

Philosophy

"Always" is what I believe in. Where does a circle start? I believe that philosophy is a mental trip around a circle. Always.

Life forms and abiotic forms move toward balance. When balance is reached, the nature of the form changes; death. When abiotic forms become so highly ordered, we call the resulting form "living." When living forms become balanced, we call the resulting form "dead."

So long as movement is ordered, life goes on. Dynamic equilibrium gives nonmoving forms, such as trees, the appearance of balance, while actually many systems are moving.

Nature is a super, multiple system made up of what we call living and nonliving forms. Forces external to Earth – the sun – initiate processes of life and death.

When these powerful forces begin to be recognized, then many parts will come together.

In the end Modern Arboriculture will come, albeit slowly, mainly because old arboriculture is accepted by many people and organizations as it assures economic gains. A new train is coming. It is filled with students who have different ideas and values for life. This train includes the quest for solutions that can only come from biology and Book 1, chemistry.

The train is called Modern Arboriculture. It runs on the energy of connections.

The lack of knowledge of tree biology has been, and still is, the major problem for trees and tree workers worldwide! Learn about trees. Connect with nature. Touch trees.

Dr. Alex L. Shigo is the owner of Shigo & Trees, Associates in Durham, N.H. The images for this article were taken from a new CD that features more than 5,000 items taken from Shigo's research and travels worldwide over a 40-year period. The CD has more than 100 chapters with more than 4,000 color photos. To order, call 1-800-733-2622 or online at www.natlarb.com. TCI

T
BEST PERFORMING &

CHIPPERS AND WASTE REL

Hand Fed Chippers

Towable or self-propelled, with or without a loader

• 18" • Mdl 280 Disc

• 18" • Mdl 1890 Drum

• 14" • Mdl 254 Disc

• 15" • Mdl 1590 Drum

• 12" • Mdl 150 Disc

• 12" • Mdl 200 Disc

• 12" • Mdl 250 Disc

• 9" • Mdl 90 Disc

• 9" • Mdl 95 Disc

• 6" • Mdl 65 Disc

All Bandit Chippers have the most powerful feed systems available. Most are offered with the Quad Feed System — the best ever developed.

BANDIT INDUSTRIES, INC.

6750 MILLBROOK RD • REMUS, MI 49340
PH: (800) 952-0178 OR (989) 561-2270
FAX: (989) 561-2273
E-MAIL: brushbandit@eclipsetel.com
WEBSITE: www.bandichippers.com

CUSTOMIZE YOUR CHIPPERS:
HYDRAULIC WINCHES
HEIGHT ADJUSTABLE DISCHARGES: instantly adjustable
AUTO FEED PLUS: stop the feed before the engine lugs to the point of stalling and backs out of the cut
LOADERS: available for most hand fed chippers. What a back saver!