INFORMATION ABOUT THE TREE SURGERY LICENSE EXAMINATION

Exam Content

The Tree Surgery license examination consists of 100 True/False and Multiple Choice questions covering topics listed below:

- Tree biology
- General knowledge of nomenclature
- Soils
- Pruning
- Care
- Cabling
- Bracing
- Topping
- Trimming
- Fertilizing
- Cavity work
- Removal of trees
- Tree Surgery regulations

Exam Information

The examination starts at 8:30 a.m. and all exams must be completed and turned in by 3:00 p.m. The exam will be graded usually within a couple of days and your test results will be emailed to you. This exam typically requires approximately one hour to complete.

YOU MUST MAKE A PASSING GRADE OF 70% OR ABOVE TO MOVE ONE STEP CLOSER TO OBTAINING A LICENSE.

STUDY GUIDELINES FOR LICENSE EXAM (TREE SURGEON) TSL

CATEGORY TSL: TREE SURGEON EXAMINATION

SOME INFORMATION YOU SHOULD HAVE KNOWLEDGE OF BEFORE TAKING LICENSE EXAMINATION FOR TREE SURGEON.

This outline may be used as a study guide for the license (Category TSL) Tree Surgeon. The Mississippi Bureau of Plant Industry is providing a list of suggested references and this outline as aids in studying for the license examination. The use of the World Wide Web can provide a wealth of information and may be helpful in increasing your knowledge of the listed topics. Web sites from universities, extension, and sites devoted to specific tree surgeon topics may provide detailed information. A copy of the Regulations Governing Tree Surgeons can be found at The Mississippi Department of Agriculture and Commerce, Bureau of Plant Industry website, http://www.mdac.ms.gov/wp-content/uploads/11-Regulation-of-Professional-Services.pdf. **Please note that you should be familiar with the topics in this outline, but there is no guarantee that all of the topics listed, or only the topics listed will be included on any Licensing examination.**

1. You should be thoroughly familiar with Bureau of Plant Industry Regulations Governing Tree Surgeons. Topics include, but are not limited to:

   Definitions
   Licensing requirements
   Licensing renewal requirements
   Violations
   Record keeping requirements
   Insurance requirements
   Licensed operators
   Employees
   Equipment
   Waiver

2. Basic terminology:

   Photosynthesis
   Branch bark ridge
   Scaffold limbs
   Hedge
   Xylem
   Phloem
   Heading
   Stomata
   Drop-crotching
   Wound
   Decay
   Heartwood
   Strong compartmentalizer
   Vascular cambium

3. Be familiar with monocotyledons vs. dicotyledon.

4. Why is it important to know the scientific name instead of the common name?

5. What function(s) does heartwood serve?

6. Why are urban soils unfavorable to tree growth?

7. Does soil pH affect the availability of plant nutrients?

8. What percentage of pruning is suitable for a mature tree?

9. Why do Excurrent trees (*Pinus spp.*) require less structural pruning?

10. Be familiar with pros and cons of trees with a round shaped crown.

11. Where would you find a branch protection zone?

12. Be familiar with pruning such as but not limited to:
    - Each step required when pruning a tree branch
    - Minimizing sap leakage from pruning cuts
    - Structural pruning
    - What would happen to deviate from the pruning standard?
    - Use of wound dressing when pruning
    - Appropriate time of year to prune
    - How often should trees be pruned?
    - Use of flush cuts

13. Pros and cons of fertilizing trees before and after construction.

14. Be familiar with cabling and/or bracing.
    - Use of lag screws and how tight is “tight” to minimize tree injury?
    - Use of triangular washers on the ends of rods?
    - What angle (degrees) should be present when cabling/bracing a weak horizontal branch?

15. Pros and cons of injuring or removing the branch collar.

16. Be familiar with the function(s) of tree roots.

17. Pros and cons of fertilizing trees by tree injection.

18. What can the presence of suckers or waterspouts be an indication of?

19. What is the function(s) of a stem or tree trunk?

20. Use of climbing spurs when pruning oaks during the dormant season.

21. Purpose(s) of removing branches on young trees during the first 2-4 years in the landscape.

Created May 2, 2018

Subpart 3-Bureau of Plant Industry
Chapter 11-Regulation of Professional Services
Subchapter 05-Regulations Governing Tree Surgeons

Definitions

500 For the purpose of these regulations, the following words, names and terms shall be construed within the meaning and purpose of *Miss. Code Ann* Sections 69-19-1 through 69-19-11.

1. "Act" shall mean *Miss. Code Ann.* Sections 69-19-1 through 69-19-11.
2. "Bonafide Employee" shall be a person who receives all or part of his salary, pay or commission from a licensee or the company employing a licensee and whose salary, pay or commission is regularly reported by the licensee or the company employing a licensee under the Federal Social Security and/or income tax laws. A bonafide employee must be under the direct supervision of a license holder.
3. "Bureau" shall mean the Bureau of Plant Industry of the Mississippi Department of Agriculture and Commerce created under the provision of *Miss. Code Ann* Section 69-25-3.
4. "Executive Secretary and/or State Entomologist" shall mean the executive secretary and director and/or state entomologist of the Bureau of Plant Industry, Mississippi Department of Agriculture and Commerce, as set forth in *Miss. Code Ann* Section 69-25-5.
5. "Licensed Operator" shall mean the person who shall be responsible for fulfillment of all services to be rendered by a company licensed to perform any or all of the professional services covered by these regulations.
6. "Ornamental Trees and Shrubs" shall mean a plant grown for the beauty of its form, foliage, flowers or fruit, rather than for food, fiber or other uses.
7. "Person" shall mean any individual, partnership, corporation, association, company or organized group of persons whether incorporated or not.
8. "Professional Services" shall mean the professional services performed as designated by the category listed under Subsection 503.02 of this chapter.
9. "Registered Technician" shall mean a bona fide employee of a license holder as described in subsection 509.02 of this chapter and who has obtained a registered technician identification card from the Bureau.
10. "Tree Surgeon" shall mean a person who advertises in a local phone book, newspaper, newsletter, bulletin, the internet or other prominently displayed sign as a licensed or insured tree surgeon and receives compensation for any work or consultation relative to the care, pruning, cabling, bracing, topping, trimming, fertilizing, cavity work and removal of ornamental trees and shrubs in any manner. Nothing shall prevent any person from performing such services as long as their advertising does not include the description licensed or insured.
11. "Status" shall mean death, retirement, prolonged illness, merger of companies, sale, change of ownership, etc. of a license holder.

Source: *Miss. Code Ann.* §69-19-1.

Persons Required to Secure License

501 Tree surgeons must secure a license from the Bureau of Plant Industry, Mississippi Department of Agriculture and Commerce, only if they advertise as licensed or insured in accordance with *Miss. Code Ann.* Sections 69-19-1 through 69-19-11.

Source: *Miss. Code Ann.* §69-19-1.

License Application; Qualifications

502 Application for license shall be submitted on a regular form furnished by the Bureau in time to be approved ten (10) days prior to regularly scheduled examinations. No application for a license shall be accepted unless the applicant shall furnish written proof that he meets one (1) of the following requirements:

1. Must be graduated from an accredited college or university with at least 15 semester hours or the equivalent in the field for which he is requesting a license,
2. Must have not less than two years college or university training with special training in the field for which he is requesting a license,
3. Must be at least a high school graduate and have had, in addition, at least one year's experience with a licensed operator within the past two years,
4. Holds a valid arborist certification issued by the International Society of Arboriculture, and
5. If the applicant does not have a high school education or its equivalency, he must be able to furnish proof that he has at least two year's experience with a licensed operator within the past three years.

Source: *Miss. Code Ann.* §69-19-1.

Examinations; License Categories

503.01 Each person required to secure a license in accordance with the Act shall be examined as follows: When the firm is under the control of one (1) person who is solely responsible for the work, this person alone shall be required to pass the examination. When more than one person is responsible, then each shall be required to pass the examination. A person may designate an employee who is regularly and actively in charge to take the examination, and the license will be issued naming the employee as supervisor. Both the employer and the person to whom the license is issued will be held responsible for the professional services rendered.

503.02 The applicant shall take an examination which shall be written and, in general, cover the subject of the professional services designated in the application. The

examination may be waived if the applicant is already licensed to perform the same professional services in a state with standards equal to those of Mississippi and, provided further, that said state recognizes such examinations given by Mississippi.

503.03 Examination dates: Examinations shall be given once each quarter at Mississippi State, Mississippi. The dates for written examinations shall be the second Tuesday in each quarter of the calendar year. Applicants not passing the examination may take it on the next regularly scheduled examination date.

503.04 Category in which the examination is to be given and for which a license will be issued:
Tree Surgery – This category includes a person who advertises in a local phone book, newspaper, newsletter, bulletin, the internet or other prominently displayed sign as a licensed or insured tree surgeon and receives compensation for any work or consultation relative to the care, pruning, cabling, bracing, topping, trimming, fertilizing, cavity work and removal of ornamental trees and shrubs in any manner. Nothing shall prevent any person from performing such services as long as their advertising does not include the description licensed or insured.

Source: *Miss. Code Ann.* §69-19-1.

Issuance of License

504.01 After all qualifications and requirements have been met, said applicant must furnish proof of insurance in the proper amount as set forth in Section 507 of this chapter in conformity to *Miss. Code Ann* Section 69-19-9. The Bureau shall then issue a license which shall be valid for an indefinite period unless suspended or revoked for cause.

504.02 A license is not transferable. When there is a change in the status of a license holder due to uncontrollable circumstances, a reasonable period of time shall be allowed for a qualified person to meet the requirements of Section 501 of this chapter. Failure of the licensee to notify the Bureau of an address change will invalidate the license.

504.03 A person requesting a license must have passed the required examination within the past year or have been actively engaged in the work since passing the examination or be reexamined before his license can be issued.

Source: *Miss. Code Ann.* §69-19-1.

Denial, Suspension or Cancellation of a License; Refusal to Issue or Renew Same

505.01 Where the holder of a license, permit or identification card commits any of the following acts or omissions, it shall be grounds to suspend, modify, deny, cancel

or revoke such license, permit or identification card, in addition to those grounds set forth in *Miss. Code Ann.* §69-19-9, §69-25-51, to wit:

1. Made false or fraudulent claims through any media misrepresenting the effect of materials or methods to be used;
2. Operated in a faulty, careless or negligent manner or knowingly operated faulty or unsafe equipment in a manner as to cause damage to property or person;
3. Refused or, after notice, neglected to comply with the provisions of the Act, the regulations adopted thereunder or any lawful order of the commissioner;
4. Refused or neglected to keep and maintain records required by the Act or to make reports when required;
5. Made false or fraudulent records, invoices or reports;
6. Used fraud or misrepresentation in making application for a license or renewal of a license;
7. Aided or abetted any person in evading the provisions of the Act;
8. Allowed one's license to be used by an unlicensed person;
9 Impersonated any state or federal official;
10. Misrepresented for the purpose of deceiving or defrauding;
11. Made a false statement with knowledge of its falsity for the purpose of inducing others to act thereon to their detriment;
12. Performed work in a category covered by the Act for which the licensee does not hold a license;
13. When repeated inspections by Inspectors of the Bureau of Plant Industry reveal that the licensee is not performing services in a satisfactory manner;
14. Failed to register agents or solicitors;
15. Convicted in any of the courts of this state of a violation of the Act or these rules and regulations;
16. Failed to correct substandard work; or
17. Failed to renew the insurance that is required in Section 507 of this chapter.

505.02 When a license has been canceled, the insurance company shall be notified in writing.

Source: *Miss. Code Ann.* §69-19-1.

Insurance

506 Before a license shall be issued or reissued to engage in tree surgery, proof of insurance must be furnished on a form provided by the Bureau. This insurance shall be conditioned as to insure against negligent or careless acts. This insurance shall not be less than $100,000.00. No insurance shall be accepted except from companies admitted to do business in Mississippi, companies that are non-admitted but approved to do business in Mississippi, or risk retention and purchasing groups registered by the Commissioner of Insurance of Mississippi.

Those currently licensed to perform tree surgery must obtain the required insurance not to exceed twelve months.

Source: *Miss. Code Ann.* §69-19-1.

Inspections; Records; Reporting; Contracts

507 Licensed operators shall keep complete and accurate records of all work performed including copies of contracts issued for at least two (2) years. Such records shall be available for examination by employees of the Bureau during reasonable business hours. Such records shall include location, kind of services performed, date performed, materials used if there be any, and other information as may be necessary for a complete record.

Source: *Miss. Code Ann.* §69-19-1.

Identification; Licensed Operators; Employees; Equipment

508.01 Licensed Operators - All licensed operators or owners of firms engaged in tree surgery soliciting work or dealing with the public must be provided with an identification card to be obtained from the Bureau. The licensee shall submit an I.D. card application provided by the Bureau.

508.02 Employees -

1. All employees of licensed operators who solicit business or otherwise represent the licensed operator in dealings with the public must be provided with a registered technician identification card to be obtained from the Bureau. An employee of a licensed operator considered as a laborer shall have a registered technician identification card or be accompanied by an employee who holds a valid registered technician identification card.
2. The licensed operator shall submit a registered technician identification card application provided by the Bureau requesting registered technician identification cards for his employees.
3. When a licensed operator or an employee resigns or is discharged, the licensee shall return the license or registered technician identification card to the Bureau for cancellation.
4. The registered technician identification card shall be in the possession of the licensed operator and his employees at all times when performing work or soliciting business and will be presented on request to the person or persons for whom business is performed or solicited.
5. The registered technician identification card will not be issued to any person who has been employed by another licensed operator until his previous card has been returned to the Bureau for cancellation.

508.03 Equipment - All vehicles used by persons engaged in professional services covered by the Act and these regulations shall be marked for easy identification to include the company name and license number.

Source: *Miss. Code Ann.* §69-19-1.

Bonafide Employee

509 Services or work performed under any section of these regulations must be performed only by the licensee or his bonafide employees.

Source: *Miss. Code Ann.* §69-19-1.

Effective Date

510 These changes will become effective after adoption by the Commissioner, approval of the Advisory Board and appropriate filing with the Secretary of State.

Source: *Miss. Code Ann.* §69-19-1.

Waiver

511 The Bureau, in cases of natural disaster, may waive any and all provisions of this chapter.

(Subchapter 05 amended August 12, 1994 and May 12, 1995; Amended Aug. 12, 2010)

Source: *Miss. Code Ann.* §69-19-1.

STUDY REFERENCES FOR TREE SURGERY LICENSE EXAMINATION

1. Regulations Governing Tree Surgeons (enclosed)

2. Harris, Richard W. *Arboriculture: care of trees, shrubs, and vines in the landscape*. Englewood Cliffs: Prentice-Hall, Inc., 1983. Print.

3. Pirone, P.P., J.R. Hartman, M.A. Sall, and T.P. Pirone. *Tree Maintenance*. 6th ed. New York: Oxford University Press, Inc., 1988. Print.

4. Shigo, Dr. Alex L., Homeowner's Guide for Beautiful, Safe, and Healthy Trees. Durham: Northeastern Forest Experiment Station, 6th Reprint.

5. Shortle, Walter C. "TREE CARE: A NEW LOOK, 1979." *Journal of Arboriculture* 5.12 (1979): 281-84. Print.

6. Shigo, Dr. Alex L., Tree Decay in Our Urban Forests: What Can Be Done About It? Durham: Northeastern Forest Experiment Station, 1982. Print.

7. Lilly, S.J. *Arborists' Certification Study Guide*. 4th ed., 2022. Print. https://wwv.isa-arbor.com/store/product/7/.

Homeowner's Guide for Beautiful, Safe, and Healthy Trees



United States Department of Agriculture

PREPARED BY Forest Service (6th Reprint)

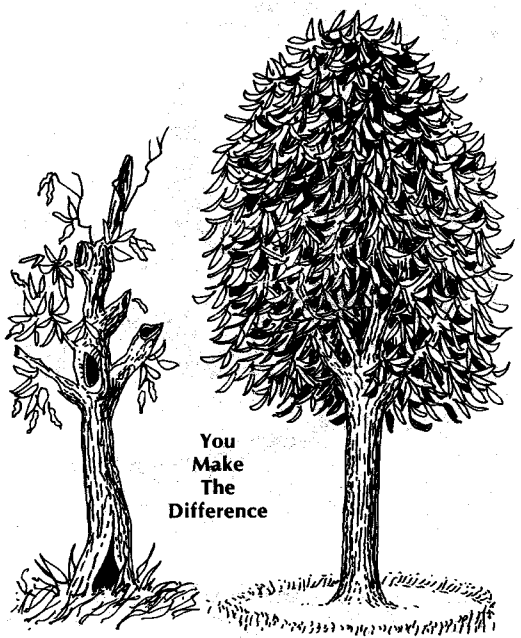
Northeastern Forest Experiment Station NE-INF-58-96

The Real Cause of Many Tree Problems

Insects and microorganisms are not the real cause or starting point of many tree problems. These organisms are often secondary agents that attack weakened, wounded, improperly treated, neglected, and generally unhealthy trees. Poor tree health is a major worldwide problem. Fighting the secondary agents that are often very obvious, or the symptoms of poor health, will not solve the basic problem. We must start now to attack the real causes: the starting points of poor health. The major organisms responsible are PEOPLE!

Once we recognize that we are often the problem, we can do much to solve it. Here are some brief guidelines for you, the homeowner, that will help you keep your trees beautiful, safe, and healthy.

"We have met the enemy; and he is us!"
Pogo



Give Trees a Good Start

Plant the right tree in the right place.

Do not plant:

- ☐ pin oaks in alkaline soils
- ☐ trees in old alkaline building rubble
- ☐ willows in dry soils, pines in wet soils
- ☐ birches in shade, dogwoods in unprotected open sites

Learn the biological requirements of your trees. Do not plant unless you plan to maintain.

Plant properly

Do not:

- ☐ crowd trees in small holes with compacted soil
- ☐ over-amend the soil with humus
- ☐ fertilize at planting time

Do prune dead and dying branches and roots.

Keep grass away

Do not:

- ☐ water grass heavily near trees that normally grow on dry sites
- ☐ lime grass heavily near trees that grow best in acid soils
- ☐ wound trees with lawnmowers and other machines

Heavy use of herbicides may harm trees.

Brace, but not too tightly.

Do not:

- ☐ tie young trees so tightly that they do not move
- ☐ leave braces on after tree is established
- ☐ kill bark with cords, wires, bands, etc.

Prevent wounds

Do not:

- ☐ allow anyone to climb your tree with spikes
- ☐ allow heavy construction machines near your tree
- ☐ park cars near trees

PRUNE CORRECTLY.
Correct pruning is the best thing you can do for your tree.
Here are the guidelines:

Natural target pruning

1. Locate the branch bark ridge (BBR).
2. Find target A—outside BBR.
3. Find target B—where branch meets collar.
4. If B cannot be found, drop an imaginary line at AX. Angle XAC equals XAB.
5. Stub cut the branch.
6. Make final cut at line AB (with powersaws make final cut on upstroke).

Do not:

- ☐ make flush cuts behind the BBR
- ☐ leave living or dead stubs
- ☐ injure or remove the branch collar
- ☐ paint cuts

The best time to prune living branches is late in the dormant season or very early in spring before leaves form. Dead and dying branches can be pruned anytime. Use sharp tools! Make clean cuts. Be careful with all tools. Safety first!

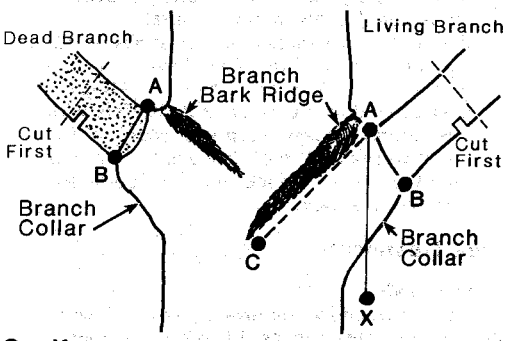
Topping

Topping trees is a serious injury regardless how it is done. Avoid it if possible by starting to prune early in the life of the tree to regulate its size and shape. If you must top cut, follow these guidelines:

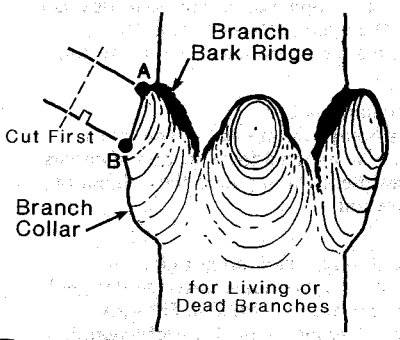
Cut line DE at an angle approximately the same angle as the angle of the BBR. Do not leave a stem stub. Do not paint the cut. Know your safety limits—call professionals when the job is too big for you.

Natural Target Pruning

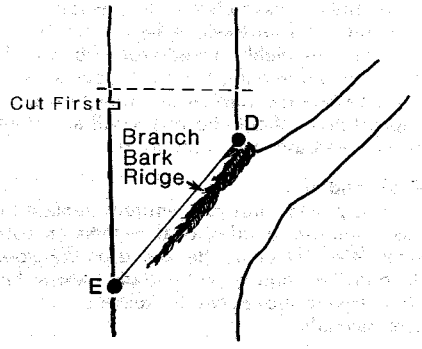
Hardwoods



Conifers



Topping



Wound Dressings

Wound dressings do not stop rot.

Do not:

- ☐ apply house paints or wood preservatives
- ☐ apply heavy coats of any material.

Research shows that wound dressings do not stop decay or stall rot. Trees have been responding effectively to their wounds for over 200 million years. Do not interfere with this natural process. Keep your tree healthy and it will take care of its wounds. In a short time the wound surface will blend perfectly with the tree bark.

Tree Treatments

Treat wounds

If trees are wounded, remove injured bark with a sharp knife. Make cuts as shallow as possible. Forming an elongated ellipse is not necessary. Make all margins rounded; do not point tips. Do not enlarge the wound. Do not paint. Do everything possible to maintain health—water, fertilize, prune.

Holes for draining water

Do not bore holes to drain water from cavities. Drain tubes may be used for wetwood materials, but such treatment will increase the column of internal wetwood.

Cavities

If cavities are to be filled, do not clean so thoroughly that the boundary between decayed wood and sound wood is broken. Fill with nonabrasive materials. Leave for professionals.

Injections and implants

If you plan to have chemicals injected or implanted in your trees, make certain that it is done only by highly skilled professionals. Check injection and implant holes after one season to make certain they are closed. Injection and implant holes should be very small and shallow at the tree base, not in the roots.

Cable and brace

If rot is present, put rods entirely through the stem, and use round or oval washers on both sides. Washers should be seated on the wood, not deep in the wood or on the bark. Cables should allow tree to move slightly. Leave to professionals.

Help Trees Stay Healthy

Before you fertilize or consider treatments for microelement problems, have a soil test done. Your tree may require soil acidification before fertilization, or treatment for microelement problems. Fertilizers add elements essential for healthy growth. Fertilizers are not tree food!

Trees get their energy from the sun. Leaves and needles trap energy in a molecule of sugar. Sugar is tree food. Keep leaves and needles healthy by timely treatments so trees can get their food. Keep soils free of compaction so roots can get water and essential elements. Do not over fertilize.

Some insects and microorganisms DO start tree problems. When in doubt about what to do, contact the extension agents from your county, state, or university, or ask the United States Forest Service or professional arborists.

Check for potential hazards:

- ☐ large dying and dead branches
- ☐ rot in roots and base (fruit bodies of fungi are signs of rot)
- ☐ large deep vertical cracks on opposite sides of trunk

Be on the alert 5 to 10 years after construction. Have hazardous tree crowns reduced by professionals.

DON'T FORGET WILDLIFE. They need living and dead trees for survival. Consider them in your plans.

Learn about trees.

Dr. Alex L. Shigo, plant pathologist (retired)

For further information: contact Communications Office, USDA Forest Service, Northeastern Research Station, 11 Campus Boulevard, Ste 200, Newtown Square Corporate Campus, Newtown Square, PA 19073 or call (610) 557-4253.

Northeastern Research Station
http://www.fs.fed.us/ne/

*U.S. GPO: 1996 - 705-713

TREE CARE: A NEW LOOK, 1979[1]

by Walter C. Shortle

Abstract. This paper provides an update of new ideas in tree care that have been developed as a result of research on discoloration and decay in living trees. Highlights of the CODIT model system, which shows how trees compartmentalize after being wounded, are presented along with specific recommendations about how to prevent, diagnose, and treat decay in trees. A list of useful publications about new ideas in tree care, the expanded concept of decay in trees, information packages and models, diagnosis of the internal condition of trees, wound dressings, tree injections, the use of bolts and rods, and new research is provided.

Trees have been around longer than mankind. Trees have strong survival systems that allow trees to live longer and grow larger than any other living creature on earth. The best way to better tree care is to learn how to work with the tree's own natural defense systems.

Decay is a major cause of damage to trees. Decay makes trees hazardous to people and property. Decay begins with a wound to the branches, trunk, or roots, and is caused by decay fungi acting in a succession of microorganisms. This disease goes on for many years inside the tree and unseen. Strength is lost as wood is decomposed by microorganisms for food. Finally, the results are seen as a big, old tree with a hollow core comes crashing down in a storm. How can such incidents be prevented?

Over the past 20 years, an expanded concept of decay has been developed. Old ideas about heartrot and wound healing must be set aside. New ideas, based on hundreds of research papers which are based in turn on thousands of dissected trees and hundreds of thousands of careful observations, have been brought together in a model system called CODIT — **C**ompartmentalization **O**f **D**ecay **I**n **T**rees. New methods of treating trees to reduce the impact of decay are being developed from new knowledge. The tree-care professional needs to learn how to make the defense system of a tree work at peak efficiency.

Highlights of CODIT

Color booklets, slide/tape presentations, posters, journal articles, and meetings are all available to help professionals learn about compartmentalization. Some study is necessary. But here are a few highlights before we discuss some specific recommendations for tree care.

Trees do not really heal wounds, because to heal means to replace, repair, or restore to a healthy state. What trees do is to wall-off, confine, or compartmentalize injured and infected wood.

Whenever a tree is wounded, three processes begin: wound closure, compartmentalization, and succession of microorganisms in injured and infected wood. A wound is a break in the bark that exposes injured wood. The amount of damage resulting from any given wound will depend in part on the kind of wound, how large it is, where it occurred on the stem, and the season of wounding; in part on the genes of the tree which regulate compartmentalizing; and in part on the microorganisms that begin to grow on the exposed, injured wood.

Wound closure, the external part of the defense system, is accomplished by callus formation. The rate of callus formation depends on how fast the tree is growing.

Compartmentalization, the internal part of the defense system, is accomplished by anatomical and chemical changes in new wood formed after wounding, and in the wood already present at wounding. The first wood formed by the cambium after wounding has a different anatomy from normal wood as well as a different chemical composition. This tissue is called a barrier zone and varies in size depending on the severity of the wound. The barrier zone prevents the spread of discoloration, decay, and microorganisms into normal wood formed after the barrier zone.

In wood present at wounding, the small, live

[1]Presented at the annual meeting of the Penn-Del Chapter, ISA in King of Prussia, Pennsylvania in February 1979.

parenchyma cells convert food reserves into plugging and wood preserving materials. These materials are most effective where the woody tissue is most dense. These zones of plugged, preserved, and dense tissues are called compartment "walls"; they retard the spread of discoloration, decay, and microorganisms.

In summary, when a tree is wounded, closure begins to seal off injured and infected wood on the outside by callus formation. Compartmentalization begins to wall off injured and infected wood on the inside by forming a barrier zone and compartment walls. The spread of discoloration, decay, and microorganisms is limited to as small a volume as possible.

Prevention

As in medicine, prevention is better than cure. Many wounds to trees can be prevented by careful planning. People need to be aware that wounds start the decay process.

Diagnosis

Not all wounds can be prevented. Damage in wounded trees can vary from slight discoloration to a hollow stem. How can you tell how much damage has occurred? Looking for external indicators of internal decay helps. Fruit bodies of fungi indicate the presence of decay. The size, shape, position, and depth of wounds on trees give indications of the severity of the decay. A lot of experience and judgment are needed to diagnose the internal condition of a tree from such indicators. A knowledge of the CODIT system helps the mind's eye predict what might be inside. But, often there are no obvious external indicators of serious problems.

A new electronic tool is now available to help determine the internal condition of trees. It is called a Shigometer® [1]. Used properly as a part of a three-part process, it will indicate whether a tree is sound, decayed, or beginning to decay. The first part of the method is to know the patterns of discoloration and decay in trees described by the CODIT system.

The second part is to locate "voids" (hollows or zones of punky wood) with a battery-operated drill and a fine drill bit. Finally, an electrode is inserted into the drill holes without voids, and changes in electrical resistance indicate the position of sound, discolored, and decaying wood. This method can help a tree-care professional decide whether a tree is a hazard, requiring removal, or a tree needing treatment. The meter will not make a decision for you.

Another use for the meter is determining the relative vitality of trees, by taking readings in the inner bark and outer wood. Better growing trees often have a lower electrical resistance than poorer growing trees. Although there is too much variation in readings among trees to say much about individual trees, groups of relatively high vitality trees can be separated from low vitality trees.

Treating the wound

Two kinds of wounds require treatment: *stub wounds,* in which dead wood protrudes beyond the callus and prevents wound closure, and *trunk wounds,* in which injured wood is exposed by areas of broken bark. To treat a stub wound, prune the dead wood protruding beyond the callus collar, but NEVER cut off the callus. This not only disrupts wound closure externally, but breaks the barrier zone and compartment walls internally.

To treat a trunk wound, cut away the dead and dying bark to form a healthy bark-wood interface. Be sure to round the top and bottom ends when scribing and cleaning a trunk wound. This reduces splitting of the bark above and below the wound. As with stub wounds, NEVER cut away callus if it has already begun to form. Do not paint the surface of the treated wound with a wound dressing, unless painting is required to show the job has been done, or for cosmetic reasons. Commonly used wound dressings do not stop decay. If a dressing is required for cosmetics, apply only a thin coat.

As in medicine, treating only the wound but not the patient can have serious consequences. To promote tree vitality, prune dead and dying

[1] The use of trade, firm, or corporation names in this publication is for the convenience of the reader. Such use does not constitute endorsement or approval by the U.S. Department of Agriculture or the Forest Service.

branches, water and fertilize, remove less valuable trees that are competing with the treated tree, and practice sanitation by removing dead trees and wood debris that harbor wood-degrading microorganisms. Establish a tree maintenance program.

When pruning branches, do not cut through the branch collar where the branch meets the stem. Flush cutting in this manner, which has become common practice with the use of chain saws, makes a larger wound than necessary and retards wound closure. Proper pruning requires that no stub should be left, and that the branch collar should not be cut to optimize wound closure and compartmentalization.

Treatments that cause wounds

Pruning branches has already been discussed, but there are several other practices in which wounds are made as part of a treatment to help the tree.

Boring holes to let water out of cavities is poor practice because it breaks compartment walls and causes decay to spread. It is only because the hollow is walled off from healthy wood that water remains trapped.

The use of drain pipes to help with a wetwood and fluxing problem is not the same as boring a hole to release trapped water. Conditions that favor wetwood where bleeding occurs do not favor decay fungi, thus less damage is likely to occur.

The various kinds of bolts and rods for cabling and bracing must be used with care. A bolt placed properly into sound, healthy wood does little damage. However, bolts that are "dead-ended" in decayed wood can cause the decay to spread outward and the bolt may not hold. When decay is detected, a rod placed through the stem is recommended. Washers should be put on both ends of the rod.

Injection of fungicides, insecticides, fertilizers, and other substances into trees is becoming popular. Such injections cause wounds which may or may not lead to serious problems. Repeated wounds, even small wounds, can have cumulative effects that increase the likelihood of decay-related problems. Some materials can have adverse effects on compartmentalization. Consequences of injections to the tree's natural defense systems need to be evaluated.

Drill wounds made to use the Shigometer are quickly compartmentalized because of their small size. However, even such small wounds, if repeated many times could have adverse effects.

Arborists need to be conscious of what wounds can do to trees. Think CODIT. When cleaning out a cavity before filling, be sure not to break through compartment walls and allow decay to spread. When thinning sprouts, do it early and select the best, low on stump, vigorous stems. If decay occurs, it will be limited to the diameter of the sprout when cut.

What's new

Recent work has shown that compartmentalization is under genetic control. By proper selection and breeding, it seems possible to have decay-resistant planting stock in the future.

Recent work has also shown that microorganisms that develop in injured wood can be manipulated to reduce damage. One method is bio-regulation, in which a harmless fungus, such as the mold *Trichoderma harzianum* can be used to stall establishment of decay fungi. Another method is using black plastic to alter the processes initiated by wounding. New methods are continually being tested so that better therapeutic treatments will someday be available to the arborist.

Keep informed

Keep in contact with researchers studying tree problems. Read their publications. Encourage them to write for magazines and journals read by arborists.

Useful references on tree care

Earlier summaries

Shigo, A.L. 1975. *Some new ideas in tree care.* J. Arboric. 1:234-237.

Shortle, W.C. 1976. *Tree care: a new look.* Proc. Int. Shade Tree Conf. 31:33-35.

Shigo, A.L. and W.C. Shortle. 1977. *"New" ideas in tree care.* J. Arboric. 3:1-6.

Shigo, A.L. 1977. *A new look at tree care.* Arboric. J. 3:157-164.

Expanded Concept

Shigo, A.L. and W.E. Hillis. 1973. *Heartwood, discolored wood,and microorganisms in living trees.* Phytopathology 11:197-222.

Wilson, C.L. and A.L. Shigo. 1973. *Dispelling myths in arboriculture today.* Am. Nurseryman 127:24-28.

Shigo, A.L. 1974. *A new look at tree decay.* North. Logger 23:10-11. Reprinted in New Horizons, Hort. Res. Inst. 1975. p. 10-12.

Shigo, A.L. and E. vH. Larson. 1975. *Anatomy of a wound: how city trees react — how they can be helped.* Weeds, Trees, & Turf 14:20-22.

Shigo, A.L. 1976. *Decay: a problem in young and old trees.* Am. Nurseryman 144:24-25.

Packages and Models

Shigo, A.L. and E. vH. Larson. 1969. A photo guide to the patterns of discoloration and decay in living northern hardwood trees. U.S. Dep. Agric. For. Serv. Res. Pap. NE-127. 100 p.

Shigo, A.L. 1973. A tree hurts, too. U.S. Dep. Agric. For. Serv. NE-Inf. 16, 28 p. Slide tape series available from Audio Visual Communications, Box 85, Radnor PA 19087 (215-272-8500).

Shigo, A.L. 1976. RX for wounded trees. U.S. Dep. Agric. For. Serv. Inf. Bull. 387. 37 p. Slide tape series available from Audio Visual Communications, Box 85, Radnor PA 19087.

Shigo, A.L. and H. Marx. 1977. CODIT: Compartmentalization Of Decay In Trees. U.S. Dep. Agric. For. Serv. Inf. Bull. 405. 73 p. Slide tape series available from Audio Visual Communications, Box 85, Radnor PA 19087.

Shigo, A.L. 1976. How to prune trees. U.S. Dep. Agric. For. Serv. NE-Inf. 25 (Poster)

Shigo, A.L. 1976. How to have healthy trees in parks and campgrounds. U.S. Dep. Agric. For. Serv. NE-Inf. 26 (Poster)

Shigo, A.L. 1976. How to recognize and prevent hazard trees. U.S. Dep. Agric. For. Serv. NE-Inf. 27 (Poster).

Shigo, A.L. 1976. How to treat wounds to prevent decay. U.S. Dep. Agric. For. Serv. NE-Inf. 32 (Poster).

Shigo, A.L. 1976. How to kill your tree. U.S. Dep. Agric. For. Serv. NE-Inf. 33 (Poster).

Shigo, A.L. 1976. How to keep your trees healthy. U.S. Dep. Agric. For. Serv. NE-Inf. 34 (Poster).

Shigo, A.L. 1976. *Communication of knowledge and needs between researcher and arboriculturist.* J. Arboric. 2: 206-208.

Diagnosis

Skutt, H.R., A.L. Shigo, and R.A. Lessard. 1972. *Detection of discolored and decayed wood in living trees using a pulsed electric current.* Can. J. For. Res. 2:54-56.

Shigo, A.L. and A. Shigo. 1974. Detection of discoloration and decay in living trees and utility poles. U.S. Dep. Agric. For. Serv. Res. Pap. NE-294. 11 p.

Shortle, W.C., A.L. Shigo, and J. Ochrymowych. 1978. *Patterns of resistance to a pulsed electric current in sound and decayed utility poles.* For. Prod. J. 28:48-51.

Shigo, A.L., W.C. Shortle, and J. Ochrymowych. 1977. Detection of active decay at groundline in utility poles. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-35. 26 p.

Shortle, W.C. 1977. *Decay in trees: evaluating the hazard tree.* Park Maint. 30:17-18.

Shortle, W.C. 1979. *Detection of decay in trees.* J. Arboric. (in press)

Shortle, W.C., A.L. Shigo, P. Berry, and J. Abusamra. 1977. *Electrical resistance in tree cambium zone: relationship to rates of growth and wound closure.* For. Sci. 23:326-329.

Shortle, W.C., J. Abusamra, F.M. Laing, and M.F. Morselli. 1979. *Electical resistance method as a guide to thinning sugar maples.* Can. J. For. Res. (in press).

Wound dressings

Shigo, A.L. and C.L. Wilson. 1971. *Are tree wound dressings beneficial?* Arborists News 36:85-88.

Shigo, A.L. and C.L. Wilson. 1972. *Discoloration associated with wounds one year after application of wound dressings.* Arborists News 37:121-124.

Shigo, A.L. and C.L. Wilson. 1977. *Wound dressings on red maple and American elm: effectiveness after five years.* J. Arboric. 3:81-87.

Injections

Shigo, A.L., W.C. Shortle, and P.W. Garrett. 1977. *Compartmentalization of discolored and decayed wood associated with injection-type wounds in hybrid poplar.* J. Arboric. 3:114-118.

Shigo, A.L. and R. Campana. 1977. *Discolored and decayed wood associated with injection wounds in American elm.* J. Arboric. 3:230-235.

Shigo, A.L., W.E. Money, and D. Dodds. 1977. *Some internal effects of Mauget tree injections.* J. Arboric. 3:213-220.

Bolts and rods

Felix, R. and A.L. Shigo. 1977. *Rots and rods.* J. Arboric. 3:187-190.

What's new

Shigo, A.L., W.C. Shortle, and P.W. Garrett. 1977. *Genetic control suggested in compartmentalization of discolored wood associated with tree wounds.* For. Sci. 23:179-182.

Shigo, A.L. 1977. *Superior tree production fights against wound fatalities.* Am. Nurseryman 146:10-11.

Garrett, P.W. and A.L. Shigo. 1978. *Selecting trees for their response to wounding.* Metrop. Tree Improv. Alliance (METRIA) Proc. 1:69-72.

Garrett, P.W., W.K. Randall, A.L. Shigo, and W.C. Shortle. 1979. *Inheritance of wound healing in sweetgum (Liquidambar styraciflua L.) and eastern cottonwood (Populus deltoides Bartr.)* Silvae Genetica (in press).

Shortle, W.C. and A.L. Shigo. 1978. *Effect of plastic wrap on wound closure and internal compartmentalization of discolored and decayed wood in red maple.* Plant Dis. Rep. 62:999-1002.

Pottle, H.W. and A.L. Shigo. 1977. *Treatment of wounds on Acer rubrum with Trichoderma viride.* Eur. J. For. Pathol. 5:274-279.

Pottle, H.W., A.L. Shigo, and R.O. Blanchard. 1977. *Biological control of wound hymenomycetes by Trichoderma harzianum.* Plant Dis. Rep. 61:687-690.

Research Plant Pathologist
USDA Forest Service
NE Forest Experiment Station
Durham, New Hampshire

Alex L. Shigo
USDA Northeastern Forest Experiment Station, Durham, NH

Tree Decay in Our Urban Forests: What Can Be Done About It?

Walk along almost any city street in the world and you will eventually see some trees. Some appear fine. Most do not. Pollution, soil compaction, gas leakage, salt, diseases, and insects have all taken their toll. You will not look long before you see many wounds. Mechanical injuries and those resulting from improper pruning are everywhere. Such injuries are the major problems man has inflicted on trees, worldwide. But how can decay cause trees problems when decay is the breakdown of the dead, unresponsive, central core of trees—the heartwood? Here the confusion starts.

First a Quiz

How much do you know about trees, tree decay, and some commonly used tree care practices? Are the following statements true or false:

- Trees regenerate or restore injured and infected tissues.
- Trees heal infected and injured wood.
- Callus growth is associated with decay development.
- Heartwood is a dead, unresponsive tissue in all trees.
- Wound heartwood and pathological heartwood are types of heartwood.
- Given enough time, discolored wood will be the same as heartwood.
- When wounds expose heartwood and sapwood, heartwood will decay first.
- After wounding, the central portion of the heartwood core will decay first.
- Once "heartwood-rotting" fungi infect heartwood they will continue to attack the new heartwood as it forms.
- Hollows result when all the heartwood is digested.
- Frost causes "frost cracks."
- Wind causes "wind shakes."
- Minerals absorbed from the soil cause "mineral streaks."
- To stop the development of decay in water-filled cavities, holes should be bored to drain the water.
- Before a cavity is filled, thorough cleaning beyond the rot, deep into the surrounding healthy wood, should be done.
- When pruned, all branches should be cut as close as possible to the trunk.
- Pruning cuts should be painted with wound dressing to prevent decay.
- When a fresh mechanical wound is scribed or traced, the vertical ends should be pointed.
- When a tree is braced, triangular washers should be used on the ends of rods.
- Decay is a problem only on old trees; decay affects only dead heartwood, therefore decay does not affect tree vitality.
- Decay is not a disease.
- Because of the many microorganisms involved in the decay process, it is impossible to select decay-resistant trees.
- It is not possible to detect decay nondestructively in living trees.

And the list goes on and on. All these statements are false—and all are in textbooks, are being taught, or are in common practice. Indeed, we have some problems.

Time for Some Changes

The original concept of tree decay, developed mainly by Robert Hartig, has existed with little change for over a century. The same can be said for many tree care practices based on the decay concept and old gardening practices. In brief, the original decay concept states that wounds expose heartwood, Hymenomycetes infect the heartwood, and decay results. Heartwood is defined as the dead, unresponsive central core of trees.

Early researchers could not systematically dissect large trees with the equipment available to them. As a result, the early view of tree decay was from the crosscut sections of trees. Studies of fruit bodies were possible; studies of decay as viewed from small wood sections were possible; laboratory studies on dead wood were also possible; large-scale dissections were not possible.

Some of the first systematic dissections of trees were done by George H. Hepting during his studies in the Mississippi Delta in the 1930s. Hepting was the first to observe compartmentalization of decay in trees (3).

It was not until 1950 that the powerful one-man chain saw, capable of dissecting large trees, came on the market. In 1959, I started dissecting trees, not only by crosscuts but also with full-length longitudinal cuts to expose the wood associated with external wounds and branch stubs. From these observations and the results of studies by many other investigators, an expanded concept of decay emerged. Then the CODIT model was developed, and with the help of many other researchers, a new method was developed to detect decayed wood in living trees and utility poles.

As the quiz indicates, there are many myths and misconceptions about what a tree is and about how trees respond to injury and infection. Once we begin to clarify some of these basic points, it will become obvious what adjustments must be made in tree care practices to maintain healthy, safe, and beautiful trees in our urban forests.

What Is a Tree?

Trees are highly compartmented, shedding, perennial woody plants. Wood has four functions: storage, transport, protection, and support. Sapwood has all of these; heartwood maintains a strong protective and support function. The confusion between heartwood and wood altered as a result of injury and infection is at the center of a century of problems.

This article is in the public domain and not copyrightable. It may be freely reprinted with customary crediting of the source. The American Phytopathological Society, 1982.

After a tree is wounded and infected, it responds—first in an electrical way, then in a chemical way, and, in the growing season, in an anatomical way. The wound-altered wood goes by so many confusing terms that it would be impossible to mention them all here.

In the early stages, wound-altered wood, which may contain pioneer microorganisms, has a stronger protective function than the contiguous wood, whether the contiguous wood is sapwood or heartwood. Under some conditions that we do not understand, this wood will maintain its highly protective capacity for long periods. Under other conditions, the wound-altered wood becomes less protective than the contiguous wood. Wound-altered wood can be either more protective or less protective. Wound-altered wood is a wood in transition. Many microorganisms, bacteria, nondecay-causing fungi, and decay-causing fungi may all inhabit the wound-altered wood (4).

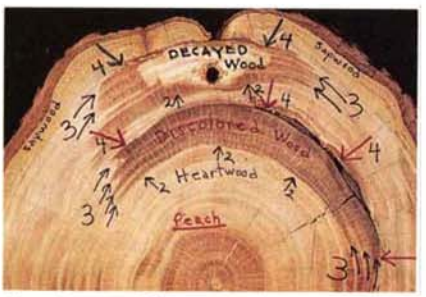


Fig. 1. In the CODIT model, 1s (not shown here) represent resistance to vertical spread of infection after injury, 2s show resistance to inward spread, 3s show resistance to lateral spread, and 4s show the separation between wood present at the time of infection and new wood.

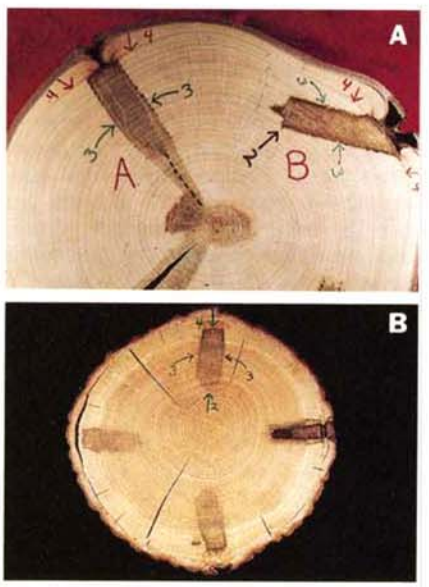


Fig. 2. (A) Discolored wood associated with drill wounds in red maple, which does not have heartwood. In wound A, the drill tip ended so close to the already discolored center that the wood between the drill tip and the center (dotted line) died and discolored; 2s of the CODIT model did not hold. In wound B, 2s resisted inward spread, mainly because of a large amount of living cells; 3s resisted lateral spread; and 4s separated wood present at wounding from new wood. Barrier zones (4s) continued beyond the wounds. (B) Patterns of discolored wood associated with drill wounds are the same in oak, which has heartwood.

Compartmentalization and CODIT

Trees survive after injury and infection by compartmentalizing injured and infected wood. Trees are generating, not regenerating, systems. Trees generate tissues in new positions every growing period. When branches or woody roots begin to die from injuries and infections, the tree begins to shed them. When trunk wood or wood in large branches and roots is injured or infected, the tree cannot shed it. The microorganisms may spread so rapidly that the branch, root, or entire tree is killed. Or the tree recognizes the infection and interacts with the microorganisms. The tree begins to compartmentalize the infected wood. The technical parts of compartmentalization are very complex, and we still only have a slight understanding of the mechanisms (10).

To make the compartmentalization process more understandable, we have developed a model called CODIT, an acronym for Compartmentalization Of Decay In Trees (5) (Fig. 1). CODIT is a model and should not be identified too closely with actual biochemical and anatomical features. The model has two parts. Part one is represented by three walls: Wall 1 resists—not stops—vertical spread, wall 2 resists inward spread, and wall 3 resists lateral spread. Walls 1, 2, and 3 are in the tree ready to go before injury and infection. After injury and infection, part two starts when the tree forms wall 4. This wall separates wood present at the time of injury from new wood. Wall 4 is a representation of the barrier zone that forms in response to injury and infection (11) (Fig. 2). The zone contains a large amount of axial parenchyma and, in conifers, many resin ducts. It is a nonconducting tissue and forms in roots as well as in trunks. It also forms in response to vascular pathogens, such as *Ceratocystis ulmi*, and to root-rotting pathogens, such as *Fomes annosus* and *Armillaria mellea* (8).

Some trees of a species can activate walls 1, 2, and 3 so rapidly and hold them so effectively that when infection takes place, the volume it occupies is small. Other trees of the same species may respond very weakly with walls 1, 2, and 3. Then the infection damages a large volume of wood. The CODIT model has made it possible to select trees that have a high resistance to the spread of decay-causing microorganisms. We can now begin selecting, and soon breeding, trees resistant to the spread of decay (2).

Compartmentalization is an effective and essential survival process, but it can also be self-defeating and destructive when it goes too far or too fast. In compartmentalization, a tree gives up a small portion of itself to save the larger whole. Every time tissues that normally function for storage and transport are walled off, the vitality of the tree is reduced. Energy is required for compartmentalization. As demands for protection through compartmentalization increase, the amount of tissue present to supply the energy decreases. When the tree has



Fig. 3. (A) A pruning cut should be made on the outer side of the branch-bark ridge that separates the branch from the main stem (black line), not behind the ridge (red line); a stub should not be left. (B) When a cut is made behind the branch-bark ridge (pencil point), the trunk is wounded, and infection develops rapidly into the trunk.

enough energy and enough time between injuries and infections to wall off and to generate tissues, the tree will continue to live in a healthy state (8).

Survival of a tree depends on energy, and the energy reserves are held in the living cells. Storage of energy-releasing materials is a major function of sapwood. As wounds decrease the volume of wood that can be used for storage, the tree becomes more susceptible to infection by other microorganisms. A tree can live for long periods on a minimum of energy reserves as long as it is not injured or infected again and there is no call for added energy.

Decay caused by wounds can reduce the vitality of trees and open the way for other microorganisms, such as those associated with cankers and root rots. But how can this be so if "heartrot" affects only the dead, unresponsive heartwood? This point keeps coming up and must be clarified because it is at the heart of over a century of confusion about trees and tree decay.

Wound the heartwood and it compartmentalizes (7). Is this a characteristic of an unresponsive tissue? The so-called heartwood-rotting fungi *do not, cannot* infect heartwood in a living tree that has not been first altered by wounding or by the death of branches. A common sight on oak, pine, or locust, all of which have a large heartwood core, is a hollow. Why do not the so-called heartwood-rotting fungi continue to attack the surrounding heartwood? They do not do it even when hundreds of growth rings surround the hollow. The diameter of the hollow is the diameter of the tree at the time of wounding. A hollow forms when walls 1, 2, and 3 all fall to the microorganisms. Experiments on living trees show this.

Pruning—Beneficial or Destructive?

The CODIT model has helped us to reexamine many tree care procedures. The most important is pruning. Proper pruning is the best thing that can be done *for* a tree; improper pruning is the worst thing that can be done *to* a tree.

For centuries the recommended pruning method has been to cut branches flush with the trunk and then coat the cut with some dressing. Now we know that branches—living, dying, or dead—should be cut as close as possible to the branch collar at the branch base, but the collar should not be injured or removed (6). Every branch has a branch-bark ridge that separates the branch from the main stem. The cut should be on the outer side of the ridge; if the cut is made on the inner side, a trunk wound will result that provides easy entry for microorganisms (Fig. 3). A flush cut will remove the protective chemical layer that is in the branch collar. And there is more. When a flush cut is made, the trunk is injured and it responds by forming a barrier zone, which is highly protective but very weak structurally (Fig. 4). When other pressures or strains are put on the trunk, the tissues along the barrier zone may split to form a circumferential crack called a ring shake.

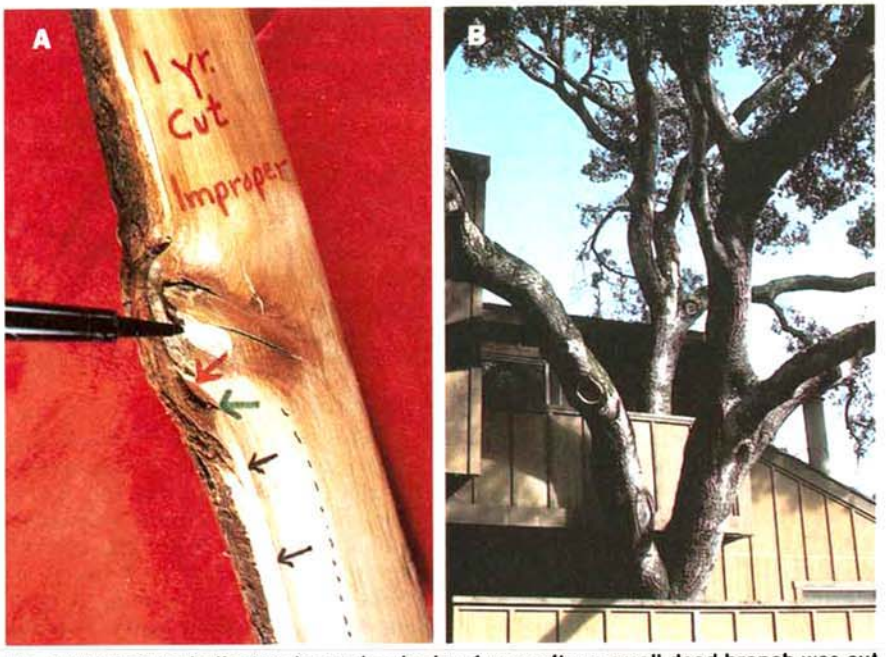


Fig. 4. (A) Pointer indicates decay developing 1 year after a small dead branch was cut flush with the trunk of a cherry tree. Red arrow shows limit of cut, green arrow shows limit of dieback after cut, black arrows show discolored sapwood on inner side of wall 4, and dotted line represents the sapwood-heartwood boundary before the cut. Sapwood above and below the cut died and discolored. (B) This live oak has many columns of decayed wood associated with large flush cuts made for aesthetic reasons (the tree died).



Fig. 5. So-called frost cracks start from wounds, especially on small trees. The large internal crack forms as the callus ridges close the wound. The secondary cracks (pencil point) form at the ends of the wound. Stress could cause the tree to split out along the three internal cracks.

There are two types of vertical cracks: those that start from the outside and move inward and those that start from old wounds and move outward. The first type are usually shallow and confined to the bark, causing little injury. They still start where some wound, branch stub, or other type of interruption occurred on the trunk. Dead roots also are common starting points for seams.

The second type of crack is very injurious. The large seams moving outward from wounds are often called frost cracks. Frost does not start these; wounds do (1). After wounding, especially on small, rapidly growing trees, wall 4 forms. In addition to this, the callus begins to close the wounds. When the callus ridges meet, a seam forms that could break out later when pressure is applied (Fig. 5). Also, small secondary cracks form where the callus begins to form.



Fig. 6. Four wounds from the same tree show that dressings do not prevent discolored and decayed wood from developing.

Wound Dressings

There are many types of wound dressings. The common treatment for

wounds has been to cover them with shellac or some asphalt or bituminous material. Why paint or dress a tree wound? The rationale has been to block out microorganisms; or to keep moisture in; or to keep moisture out; or to apply chemicals in the dressing that will kill the wood-inhabiting microorganisms. Anyone who knows anything about microorganisms and their size knows the wound cannot be shielded from them. The moisture-in or moisture-out rationale is also unrealistic because dressings coat the surface of the wound. Experiments in which trees were dissected and microorganisms isolated revealed that treated wounds did no better than untreated ones (9) (Fig. 6). To be worthwhile, a dressing would have to do better than the controls to justify the time it takes to treat the wounds and the cost of the dressing.

In the past, callus formation or "wound healing" was taken as a measure of success of the dressing. Many materials stimulate callus formation, but callus formation is not associated with prevention of decay. Decay goes on in the wood present at the time of wounding; callus forms *after* wounding. Callus formation is associated with current growth rate: A fast-growing tree will form large callus ridges. In theory, decay would stop if the wound closed rapidly and completely. But this happens rarely. Even when wounds close rapidly, microorganisms still have time to infect the injured wood. An almost-closed wound gives most wood-inhabiting microorganisms the best environment for their growth. Many fungi, such as the canker rots, even form wedges of fungus material that keep the wounds slightly open. The constant death of other branches keeps wood open to infections. We do know that some trees can wall off the injured and infected wood to small volumes. We should be more concerned with selecting and planting decay-resistant trees than with trying to treat trees like humans.

Injections

There are other reasons why we must have strongly compartmentalizing trees in the city. The recent interest in injections is one reason. Injections properly done can help trees; injection improperly done can harm trees. All types of chemicals are being injected, infused, or implanted into trees with little regard for the injury caused by the treatment. If the tree may die, then the risk of added wounding is justified. But when many deep, large holes are bored into healthy trees year after year, and all types of chemicals are introduced, trouble will begin. *A tree can survive after many severe wounds as long as the tree has energy and time to wall off the injured and infected tissues and more time to generate tissues of the type injured in a new position.* But when severe wounds occur faster than the walling-off process and faster than the generation of tissues, then the storage and transport capacity of the wood begins to decrease. When this happens, many weakly parasitic or opportunistic microorganisms quickly infect. Thus even if the wounds and chemicals of injections and implants cause injury, the tree will recover, given enough time. But if wounds are repeated year after year, the tree will be in trouble (Fig. 7).

Proper injections require skill. For the safest injections, holes should be made as small and as shallow as possible at the base of the tree, never in the roots. The holes should not be plugged or painted. After injection, everything possible should be done to maintain or increase the vitality of the tree.

Adjustments in Other Practices

The responsibility of the professional arborist is not only to help trees stay attractive and healthy but to do so in such a way that the tree is not a hazard to property and people. One way to do this is to use cables, rods, or other types of hardware to brace branches and trunks. All bracing procedures involve some wounding; there is a trade-off where some wounding is better than a hazard tree.

When holes are bored through stems that have decayed wood, wall 4 will be

broken. Decay will spread rapidly into the wood along the hole. Because of this, it is best to use large washers on the ends of the rods. The washers should be seated, when possible, on the wood—not in the wood or on the bark. The washers should be rounded or oval; washers with sharp points cut into the bark and make it difficult for the tree to wall off the wound. Cambium will die back around sharp-pointed washers. When lag screws are used, they should be placed only in sound wood. If the screw penetrates decayed wood, the decay will spread outward around the screw, decreasing its holding power.

Open ends of lag screws should not be turned so tightly into the bark that the cambium is wounded; dead area will result. Often, the wood that forms after the hardware is put into a tree gives most of the holding power to the bracing (Fig. 8). A wall 4 may form in the growth ring that develops after the hardware is inserted. This is good because it limits the development of decay, but it may be bad because the wood may later crack along wall 4, which is a strongly protective but structurally weak tissue.

When fresh wounds are traced or scribed, the dead and dying bark should be cut back to healthy wood. There is no need to scribe in the shape of an ellipse. The scribe should be as shallow as possible into the wood, and the margins or perimeter should be rounded. When the scribe has pointed ends, the cambium beyond the pointed ends may die back and callus will not form there. If the cambium remains alive directly above and below the wound, callus will form at these positions as well as from the sides.

When a cavity is being filled, only the decayed wood that comes out easily should be removed. The hard rim of tissue—wall 4—that surrounds the decayed wood must not be broken; if wall 4 is broken from the inside, the decay will spread rapidly into the newly exposed wood. Cavities can be filled with any type of material except abrasives. The filling may give the callus ridges a place to seat, thus stopping the inroll of callus. There are no data to show that fillings add strength to the trunk, but the hardware used in the cavity may add strength.

Holes should not be drilled to drain water from a cavity. The holes will break wall 4 and open new wood to infection. Tubes may be used to drain the liquid from wetwood areas. This, again, is a trade-off. The tube will break wall 4 and the wetwood column will develop out to the bark. A new wall 4 will form as a result of the new wound. But wetwood is not decayed wood; further development of the wetwood will not decrease the strength of the tree.

Construction jobs near trees result not only in wounds to trunks and roots but also in changes in soil grade that can cause trees problems. Tree owners should



Fig. 7. This elm received many deep injections and died from Dutch elm disease.

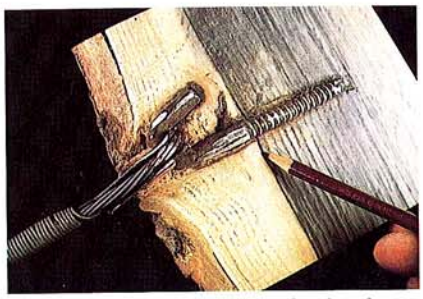


Fig. 8. The wood that forms after hardware is put into a tree does most of the holding. The pencil points to a crack that developed along the growth ring that formed after the screw was inserted. When a screw touches decayed wood, new decay will develop rapidly in the wood around the screw.

develop plans for tree protection before the job begins. Trees injured by construction jobs usually show signs of decline 5 or even 10 years later. Trees can compartmentalize, but there are limits to this process.

The city tree has many more problems than its forest relatives. In an open forest only the toughest trees survive to maturity. The millions of seeds that fall in a small area of a forest may result in only a few mature trees. The city tree comes from seeds and seedlings that would probably never survive in a forest. They are weaklings. This is why we must start selecting and planting strongly compartmentalizing trees in our cities. It can be done now. Genetic studies have been done on several tree species; they suggest that the capacity to compartmentalize effectively may be under strong genetic control.

Hazard Trees

Trees with decayed trunks, roots, and branches are hazards to property and people. External indicators of decayed wood are often present, such as fruit bodies, cavities, cracks, and fluxing material. But trees may contain a large amount of decayed wood without having obvious external indicators. This is most common with root rots. It is possible now to use a pulsed electric current to detect decay in trunks and roots. A special wire probe attached to a pulsed current meter is inserted into a small hole made by a battery-powered drill. As the tip of the probe goes inward, the electrical resistance of the wood is measured in ohms on the meter. Sudden decreases in resistance indicate changes in the wood.

The same electrical device can be used to determine the relative vitality of trees. Needle probes attached to the meter are inserted into the cambial zone. The electrical resistance of the cambial zone is shown in ohms on the meter. The lower the resistance, the higher the vitality. To use the method, many trees of the same species must be measured first and a mean reading determined. Trees of that species with electrical resistance readings below the mean are more vital than trees with electrical resistance readings above the mean. This information can be very helpful when a tree is a suspect hazard. The professional arborist needs all the information possible when a decision must be made on the fate of a tree.

What Now?

How can this information help our trees, especially those in an urban environment? Help will come in two ways. First, we must take PROPER care of the tree now growing. Second, we must use the new information now available as we plant new trees.

Maintenance programs must be developed to make certain that trees receive proper care long after they are planted. Tree care takes time and money, and the best possible procedures should be used to get the most for our time and money.

Proper pruning is still the best thing we can do for our trees. Dead and dying wood should be removed before a hazard tree harms property or people. We must make more people AWARE of what a tree is and how it survives. Wounds must be prevented. Research results must get into use. We must start selecting, then start planting, decay-resistant trees. Indeed, there is much that can be done to help our trees stay safe, healthy, and beautiful.

Literature Cited

1. Butin, H., and Shigo, A. L. 1981. Radial shakes and "frost cracks" in living oak trees. U.S. For. Serv. Res. Pap. NE-478. 21 pp.
2. Garrett, P. W., Randall, W. K., Shigo, A. L., and Shortle, W. C. 1979. Inheritance of compartmentalization of wounds in sweetgum (*Liquidambar styraciflua* L.) and eastern cottonwood (*Populus deltoides* Bartr.). U.S. For. Serv. Res. Pap. NE-443. 4 pp.
3. Hepting, G. H. 1935. Decay following fire in young Mississippi Delta hardwoods. U.S. Dep. Agric. Tech. Bull. 494. 32 pp.
4. Shigo, A. L. 1979. Tree decay: An expanded concept. U.S. Dep. Agric. Agric. Inf. Bull. 419. 73 pp.
5. Shigo, A. L., and Marx, H. 1977. CODIT (Compartmentalization Of Decay In Trees). U.S. Dep. Agric. Agric. Inf. Bull. 405. 73 pp.
6. Shigo, A. L., McGinnes, E. A., Funk, D., and Rogers, N. 1979. Internal defects associated with pruned and nonpruned branch stubs in black walnut. U.S. For. Serv. Res. Pap. NE-440. 27 pp.
7. Shigo, A. L., and Shortle, W. C. 1979. Compartmentalization of discolored wood in heartwood of red oak. Phytopathology 69:710-711.
8. Shigo, A. L., and Tippett, J. T. 1981. Compartmentalization of decayed wood associated with *Armillaria mellea* in several tree species. U.S. For. Serv. Res. Pap. NE-488. 20 pp.
9. Shigo, A. L., and Wilson, C. L. 1977. Wound dressings on red maple and American elm: Effectiveness after five years. J. Arboric. 3:81-87.
10. Shortle, W. C. 1979. Mechanisms of compartmentalization of decay in living trees. Phytopathology 69:1147-1151.
11. Tippett, J. T., and Shigo, A. L. 1980. Barrier zones anatomy in red pine roots invaded by *Heterobasidion annosum*. Can. J. For. Res. 10(2):224-232.



Alex L. Shigo

Dr. Shigo is the leader of a USDA Forest Service Pioneering Project on discoloration and decay in living trees. He is also an adjunct professor of plant pathology at the University of New Hampshire and a lecturer at the University of Maine. He joined the Forest Service in 1959 after completing his Ph.D. in plant pathology at West Virginia University. All his research has been on wound response in trees, and he has packaged portions to reach many audiences worldwide.