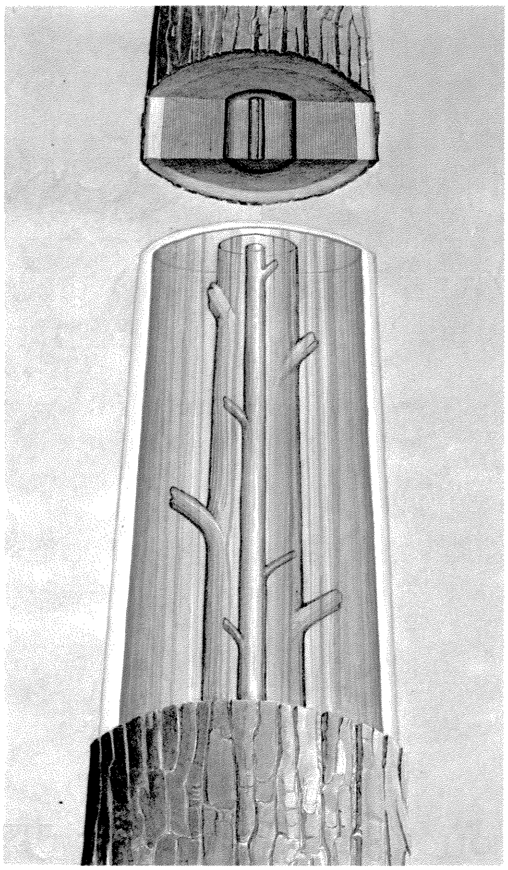
ODC 245.1 (416.5)

by Alex L. Shigo, E. Allen McGinnes, Jr.,
David T. Funk, and Nelson Rogers

Internal Defects Associated with Pruned and Nonpruned Branch Stubs in Black Walnut



FOREST SERVICE RESEARCH PAPER NE-440
1979

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

THE AUTHORS

ALEX L. SHIGO is Chief Scientist with the Northeastern Forest Experiment Station, Durham, New Hampshire 03824.

E. ALLEN McGINNES, JR. is Professor of Forestry at the University of Missouri, Columbia 65201.

DAVID T. FUNK is Principal Plant Geneticist with the North Central Forest Experiment Station, Carbondale, Illinois 62901.

NELSON ROGERS, until his retirement, was a silviculturist with the North Central Forest Experiment Station, Salem, Missouri 65560.

MANUSCRIPT RECEIVED FOR PUBLICATION 18 DECEMBER 1978

ABSTRACT

Dissections of 50 branch stubs from seven black walnut trees revealed that some discolored wood was associated with all stubs, and that ring shakes and dark bands of discolored wood were associated with 14 of 17 stubs that were "flush cut" (branch collar removed) 13 years earlier while they were living or dead. Ring shakes formed along the barrier zone tissues that separate the wood formed before wounding from wood that formed subsequently. Pruning done early in the life of the tree eliminates these problems. When pruning is done late in the life of a tree, care must be taken not to remove the branch collars that form around the bases of dying and dead branches. A pictorial description of the internal defects associated with the pruned and nonpruned stubs is presented.

BRANCH PRUNING is not a "cure all" for defects in black walnut (*Juglans nigra* L.). Proper pruning that is begun early in the life of a tree and continued as needed can be beneficial most of the time. Improper pruning at any time will cause problems. But what is proper pruning?

The high value of black walnut as timber necessitates a reevaluation of our pruning techniques. Of particular concern is the recommendation that *all* branches be *flush cut* (implies removal of branch collar). How this is interpreted and performed could make the difference between growing trees with little defect or with a great amount of defect.

With photographs of actual dissected stubs, and with diagrammatic paintings, this paper will show the defects associated with pruned and nonpruned branch stubs. This extends the information published on pruning black walnut on strip mine spoils. Because most of the introductory material and the literature cited are similar for both studies, they will not be repeated here. For these details, see Shigo et al. (1978).

BLACK WALNUT

The value of black walnut depends on many factors, but one of the most important is the amount of defect-free wood in the stem. The major defects are knots, discolored and decayed wood, and ring shakes.

Discolored and decayed wood and ring shakes can be associated with many types of wounds, including those that result from dead, broken, and pruned branches.

Black walnut, like other trees, is a highly compartmented plant that compartmentalizes injured and infected wood associated with wounds. This process confines defects within the diameter of the tree at the time of wounding. This is of benefit to tree managers and buyers because a defect is not so important if it is restricted to a small volume in the center of the tree. For example, if a tree is wounded severely when it is 3 inches in diameter, the worst that can happen is that a 3-inch core of defect will develop. The decay caused by fungi will not spread to the growth rings that form after wounding even in heartwood—because, after wounding, the cambium forms a distinctly different tissue called the barrier zone. Decay usually starts in the discolored sapwood and not in the exposed heartwood; and it does not spread progressively to the center of the tree as is implied in the classic heartrot concept. Details on compartmentalization of decay and the formation of barrier zones are published (Shigo and Marx 1977).

The barrier zone is a very strong protection against further infection, but it is also a plane of structural weakness because it has a different anatomical and chemical makeup from normal wood. When internal stresses caused by rapid temperature changes or wind occur near the barrier zone, the wood may separate tangentially and longitudinally along the barrier zone which results in a ring shake. The ring shake could trigger separations along other planes of weakness and radial separations may develop from the inside of the stem outward to the bark resulting in a radial seam or "frost crack."

THE ORIGINAL STUDY–1965

In February 1965, 77 planted black walnut trees were selected for study at the Crab Orchard National Wildlife Refuge near Carbondale, Illinois. The objective of the study was to improve the growth of pole-size trees by overstory release, understory release, and fertilization. Although pruning was not a part of the study, the sample trees were pruned to 25 feet with a pole saw when thought necessary. The trees were 25 years old. This is considerably older than the recommended age for pruning plantation-grown walnut trees. The site index has been calculated as 75 for age 50.

DISSECTION OF TREES–1977

In November 1977, six trees considered to be representative of moderate-growing specimens, and one slow-growing specimen were cut. Nonpruned stubs varied in age. Care was taken to dissect the branch stubs longitudinally through the pith. After they were cut into 2-inch-thick boards, all cut surfaces of the samples were planed. The boards were sent to the Forestry Sciences Laboratory in Durham, New Hampshire, for further study after sanding and drying. In this paper, "stub" is used to define the remaining basal portion of a cut or fallen branch, whether the portion is embeded entirely in the trunk or slightly protruding.

On six of the trees, all 13-year-old pruned stubs were closed. These 38-year-old trees were growing at a moderate rate, and the diameters at breast height (dbh) ranged from 9 to 13 inches. One tree was growing very slowly and had a dbh of 5.9 inches. Four of the five pruned wounds on this tree were still open.

OBSERVATIONS

Discolored wood was associated with all pruned and nonpruned stubs, but very little was associated with the small nonpruned stubs. Ring shakes were associated with 14 of the 17 stubs that were flush cut. Four stubs did not have their branch collars removed when pruned, and no ring shakes were associated with them. Most of the stubs without branch collars were dead at the time of pruning. In these cases, the ring shakes formed between the growth ring present at the time of pruning and the growth ring that formed the year after. The ring shake separation was along the barrier zone formed by the cambium after wounding. In some stubs, ring shakes also formed at the barrier zone formed when the branches died.

Many of the stubs had long flush pruning cuts (elliptical; long axis vertical). Some were over 8 inches long for branches recorded as 2.5 inches in diameter in 1965. The long cuts often resulted in multiple ring shakes. It was obvious that the protruding branch collars or bumps were cut along with the dying or dead branch, which resulted in large wounds. The sprouts that formed around some of these pruned branches were cut 1 year later, and some ring shakes formed along the barrier zone that formed that year.

Decayed wood was associated with the large open branch wounds on the slow-growing tree, but even then the decayed wood compartmentalized within the tissues present at the time of branch death. Small compartmentalized pockets of decayed wood were associated with many branch stubs, especially the nonpruned stubs.

Radial seams were associated with two flush-cut branch stubs. The radial seam formed deep in the tree along the pith and developed outward toward the bark.

Insect galleries made by ants were obvious in many stubs.

SUMMARY & RECOMMENDATION

Branch collars, which form rapidly as branches die, appear to be a characteristic of black walnut. Pruning cuts that remove the branch collar can cause serious internal defects in black walnut. When pruning is to be done, it should be started early in the life of the tree and continued as needed. If small branches are pruned on young trees, pruning cuts flush with the bole can be made and very little to no injury will result because the branch collars will be very small. On older trees, great care must be taken not to prune the branch collars flush with the stem because the dying and dead branches are already compartmentalized.

When a branch collar is removed, a second, more severe wound is created. Such a cut removes the protective chemical zone that formed in the branch stub as the boundary between the decay spreading inward from the dead branch and the healthy wood of the stub. When this zone is removed, the stub is vulnerable to infection. Although flush cuts may result in straight boles, a great amount of defect may result from ring shakes and bands of discolored wood. Also, the ring shakes can act as planes of weakness for radial separations. When radial separations break out to the cambium, a seam usually called a "frost crack" forms.

The patterns of dark-colored bands often seen in the heartwood of black walnut are also associated with branch stubs, and the large flush cuts initiated the longest columns of discolored wood in the samples investigated.

Great care must be taken not to interpret flush cut as the removal of the branch collars —this is especially important in chain-saw pruning and high pruning with pole saws. It is better to have shorter lengths of high quality, defect-free wood than to have long lengths of defective wood.

LITERATURE CITED

Shigo, A. L., and H. G. Marx.
1977. **Compartmentalization of decay in trees.** [CODIT] USDA, Agric. Inf. Bull. 405. 73 p.

Shigo, A. L., N. F. Rogers, E. A. McGinnes, Jr., and D. T. Funk.
1978. **Black walnut on Kansas strip mine spoils: Some observations 25 years after pruning.** USDA For. Serv. Res. Pap. NE-393. 14 p. illus.

Acknowledgments

The walnut release study was planned by John E. Krajicek and F. Bryan Clark, and is now the responsibility of Richard Schlesinger. The study area was made available by the Crab Orchard National Wildlife Refuge.

Thanks to Darrell Alley, M. S. Cook, Candy Murphy, and David Polak for field assistance, and to Robert Bodkin, Ken Gaddis, Ed Helton, and Paul Parks for dissecting the bole sections.

The authors also wish to thank Paul S. Szopa (Forestry, University of Missouri) for taking many photographs in the field and of the study group.

The watercolor illustrations are by David M. Carroll, Warner, New Hampshire.

Figure 1.—The study at Crab Orchard, near Carbondale, Illinois. The arrow shows the position of two pruned stubs. All pruning wounds (arrow) were closed on the six fast-growing trees dissected.

Figure 2.—The pruning wounds on one slow-growing tree were still open after 13 years. Wound closure is directly related to the increment of growth after wounding. Wounds on fast-growing trees close more quickly than those on slow-growing trees.

Figure 3.—A decayed branch stub on a black walnut tree. As the stem tissues grow around the stub, a bump or bulge forms as a collar. The large arrow shows the position of the barrier zone, which is the tissue formed by the tree after the branch died. Any discolored or decayed wood associated with the stub will be confined to the inner side of the barrier zone. The small arrows indicate bud traces.

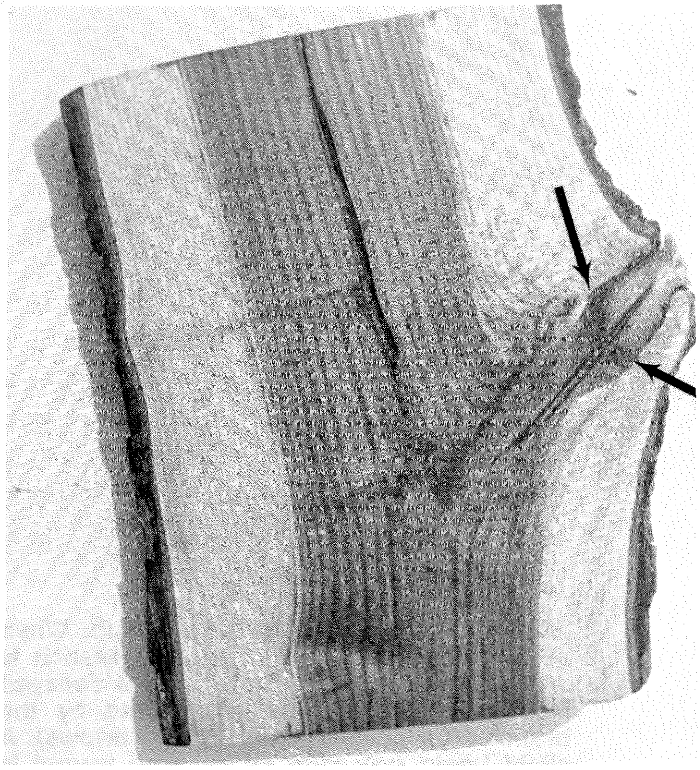


Figure 4.—A pinched-off decayed branch. The microorganisms that cause decay are beneficial because they aid in the breakdown of dead organic matter that is essential for new life. As the decay process develops, the tree begins to form a chemical protection zone within the stub, as shown here by the arrows. Normally, the branch will be decayed back to this zone. Here, a plane of great strength and a plane of great weakness meet, and stress from wind, ice, snow, etc. can cause the branch to break at this point. The tissues around the stub then close the wound.

Figure 5.—A well-closed branch stub. When all systems function properly, the branch is enclosed in the stem. Even if some decayed wood develops, it will be confined by the branch stub chemical zone (large arrows). A slight bump may form as the stub wound is closed. The barrier zone, which formed after the branch died (small arrows), usually—but not always—results in a darker growth ring. Should microorganisms invade the tree through the stub, they would be confined to the inner side of the barrier zone.

Figure 6.—A long stub associated with a large bump. The dead branch remained on the tree for a long period, and decayed to the boundary of the chemical zone (large arrows). Note the almost horizontal angle of the stub. This may have prevented early abscission. The small arrows show the position of the barrier zone that formed after the branch died. Note the dark band of wood on the inside of this zone.

Figure 7.—An enclosed small stub. This stub broke before it fell from the tree, and the arrow shows the extent of the decayed wood and the cracked base of an old branch. The broken stub, even on this very small branch, greatly increased the time required for closure.

Figure 8.—Compartmentalization of decayed wood associated with a large branch stub (large arrows). The branch broke and aparently stayed attached for a long time (open arrow), preventing rapid closure. But, even though decayed wood developed, it was compartmentalized within the tissues present at the time of branch death. Note also that the decayed wood is surrounded by nondecayed heartwood. A dark band separates the compartmentalized decayed wood from the sound heartwood. Multiple ring shakes were associated with the stub (small arrows).

Figure 9.—Proper pruning cut of a large dead branch. When pruning is done late in the life of a tree, great care must be taken not to remove the branch collar or bump that developed around the branch.

Figure 10.—Large bump associated with an old dead branch. A proper pruning cut was made. A flush cut would follow the dark solid line. This would create a new, more serious wound. The barrier zone associated with the branch has been formed (large arrows). Any further development of discolored or decayed wood would stay on the inner side of this zone. If the flush cut were made, the decayed wood (open arrow) would spread rapidly beyond the old barrier zone.

Figure 11.—A flush cut of a dead branch. Improper pruning removes the large bump or branch collar. The barrier zone associated with the dead branch is shown by the open arrow. A new barrier zone would develop at the position shown here by the large arrows. The small arrows show the boundary of the heartwood. A large flush cut of this type would give the tree a straighter form at the expense of potential ring shakes and dark bands of discolored wood.

Figure 12.—A large flush cut similar to that shown in Figure 11, but 13 years later. The distance between the open arrows is 7 inches. The branch at the time of the cut was less than 2 inches in diameter. The large arrows show the large ring shakes that developed between the growth ring present at the time of wounding and the one that formed subsequently. Also, the heartwood on the inner side of the ring shake was discolored. The small arrows point out a dark band associated with an older dead stub.

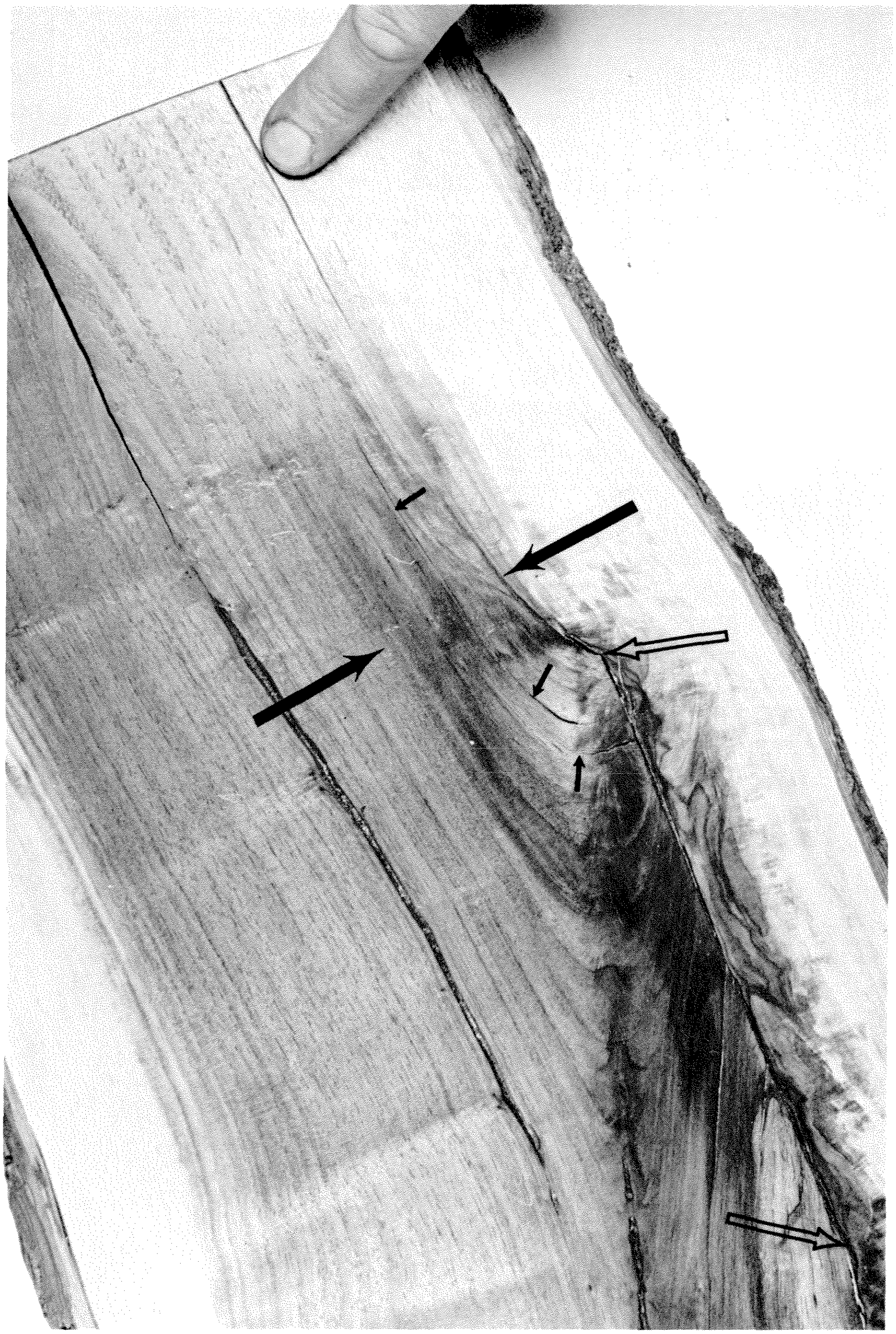


Figure 13.—A 7-inch, 13-year-old flush cut (open arrows). Note decayed wood beginning to form at the upper and lower limits. The large arrows show the dark band of discolored heartwood associated with the flush pruning wounds. The finger points to a large ring shake associated with the wound. The shakes usually opened more at the ends of the sample boards. The large open shake was between the growth ring that was present at the time of the wound and the ring that formed the following year. The small arrows show smaller ring shakes within the band of discolored heartwood. Bacteria, nondecay fungi, and decay fungi are commonly associated with the discolored and decayed bands of defective heartwood.

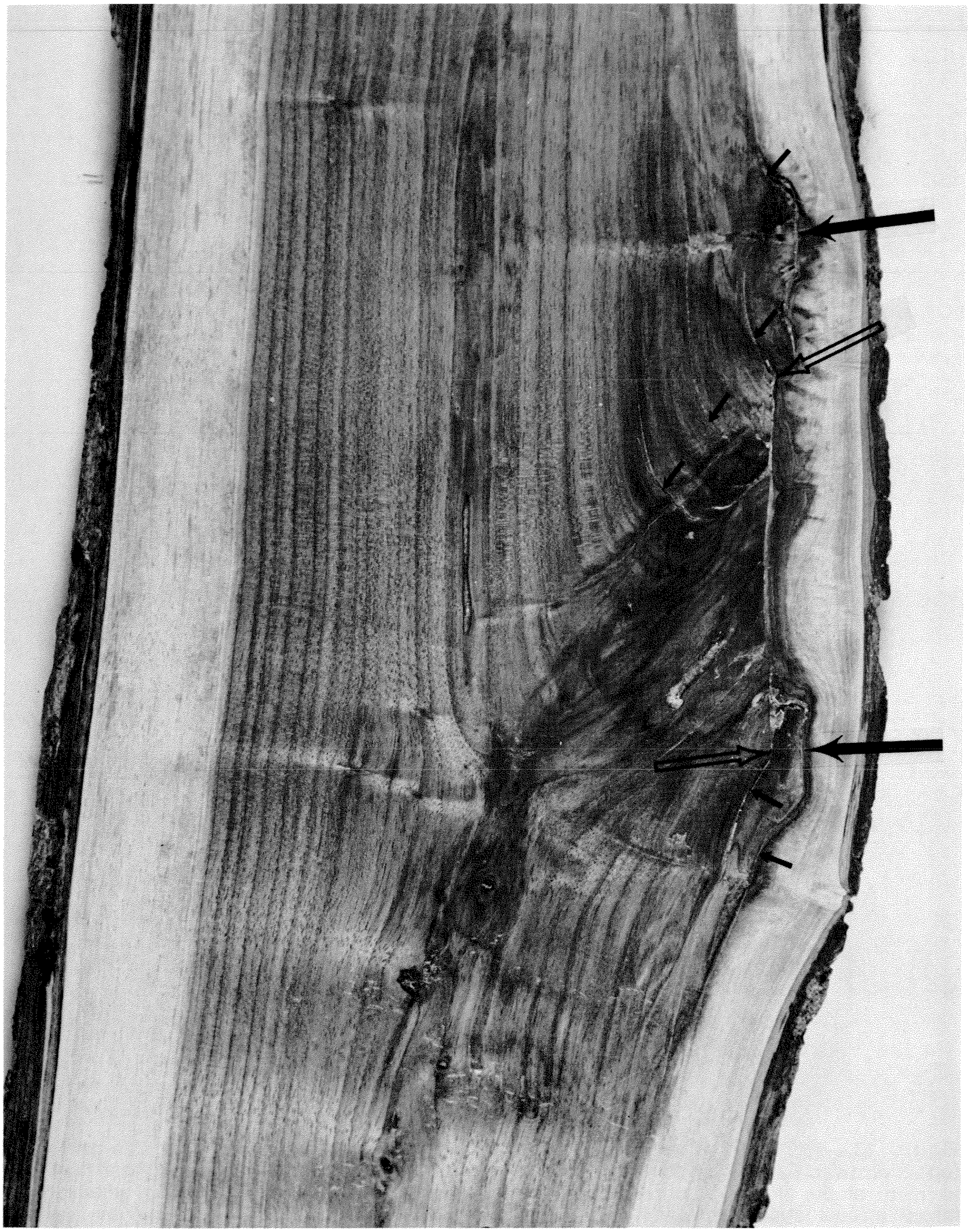


Figure 14.—Multiple ring shakes (small arrows) associated with a large flush cut and the subsequent removal of sprouts (large arrows). A thick band of discolored heartwood was also associated with the wounds. The original flush cut was 5 inches long (open arrows).

Figure 15.—A 2½-inch flush cut (open arrows) that did not remove the V-shaped chemical protection zone in the stub (small arrows). A dark streak developed (large arrows), but no ring shakes.

Figure 16.—Pockets of decay starting in discolored sapwood in a dead stub (large arrows). When decay develops in a stub it usually starts in the discolored sapwood and not the exposed heartwood, as is stated in the heartrot concept. Note that the heartwood in the stub is sound (open arrows). The small arrows show the barrier zone associated with the stub. The decay would be confined to the inner side of this zone. The discolored zone is longest along the heartwood-sapwood boundary in the stub.

Figure 17.—Most of the time the tree's defense systems function properly, and even when decay develops in the discolored sapwood of the branch, it does not continue to spread into the tree after the branch falls. The large arrows show the old decay pockets that were in the dead branch before it fell. The open arrow shows the position of the barrier zone. The flat, straight closure of the stub wound suggests that the old decaying stub was forced off by the pruning saw blade.

Figure 18.—Advanced decay (large arrows) associated with a flush cut dead branch on a very slow-growing tree. Note the position of the decay—it did not spread to the center of the tree as implied by the heartrot concept. The decay is advancing through discolored wood and is not spreading inward through nonaltered or nondiscolored heartwood. The open arrows show the advanced discolored wood that would later become decayed. The indentations shown by the small arrows indicate that decay was well established in the sapwood before the branch was cut. Insect galleries are obvious in the decayed wood above the stub.

Figure 19.—Advanced decay associated with a large open 13-year-old pruning wound on a very slow-growing tree. Note that the outer portion of the stub is decayed, but the inner core of the stub and the tree are still sound. The large arrows show the inner compartment of sound wood. Yet, the heartrot concept would lead you to believe that the center of the tree would be decayed before the outer core. The decay did not penetrate this inner core of heartwood because it was already walled off by a barrier zone from some previous injury or loss of a branch. Decay-causing fungi *do not* grow indiscriminately through heartwood or sapwood in a living tree. The large open arrows show large ring shakes in the discolored heartwood.

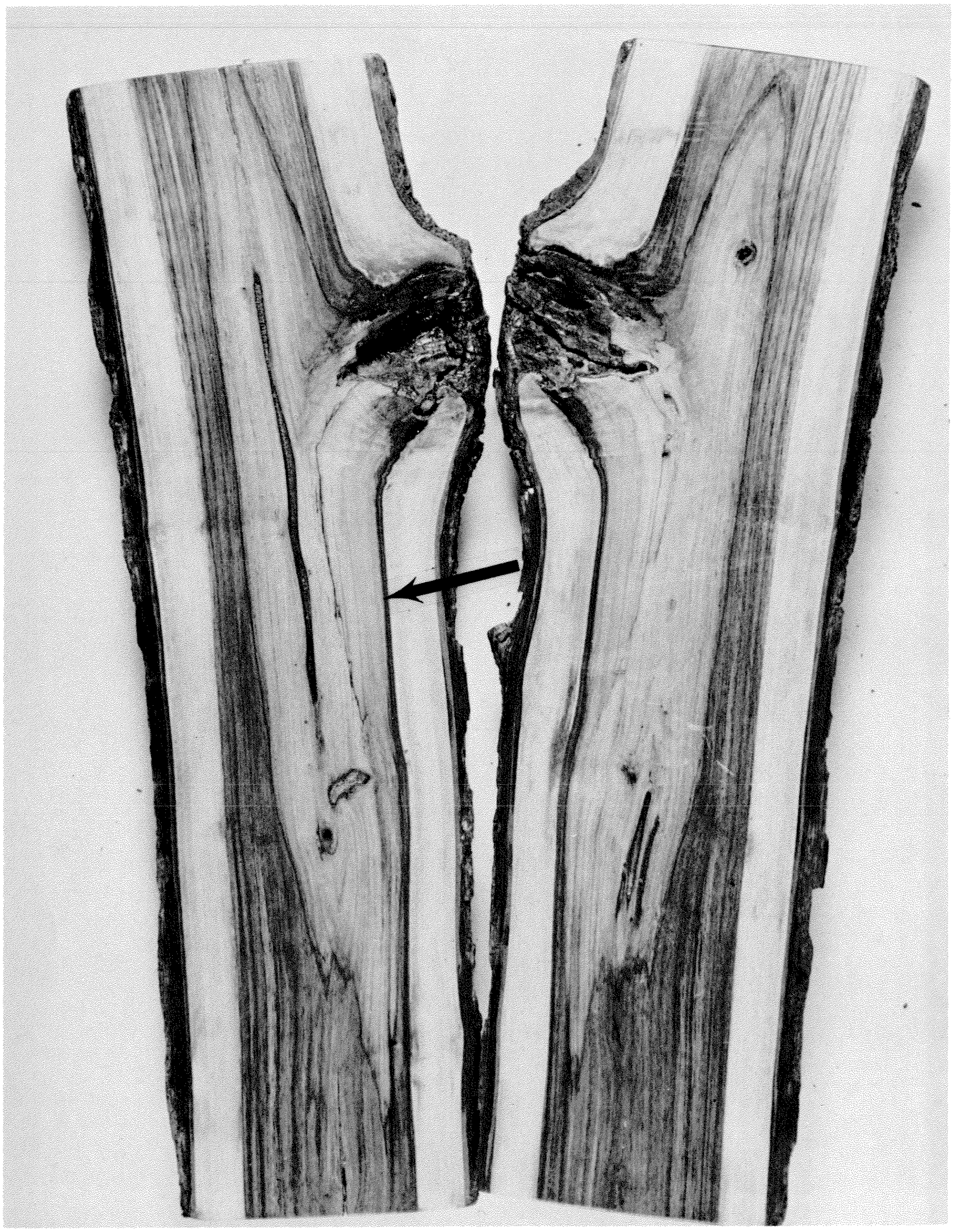
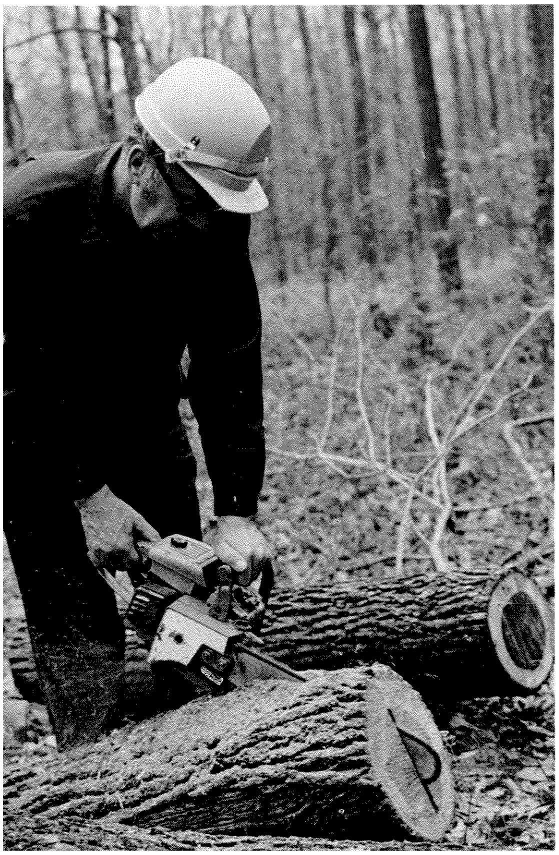
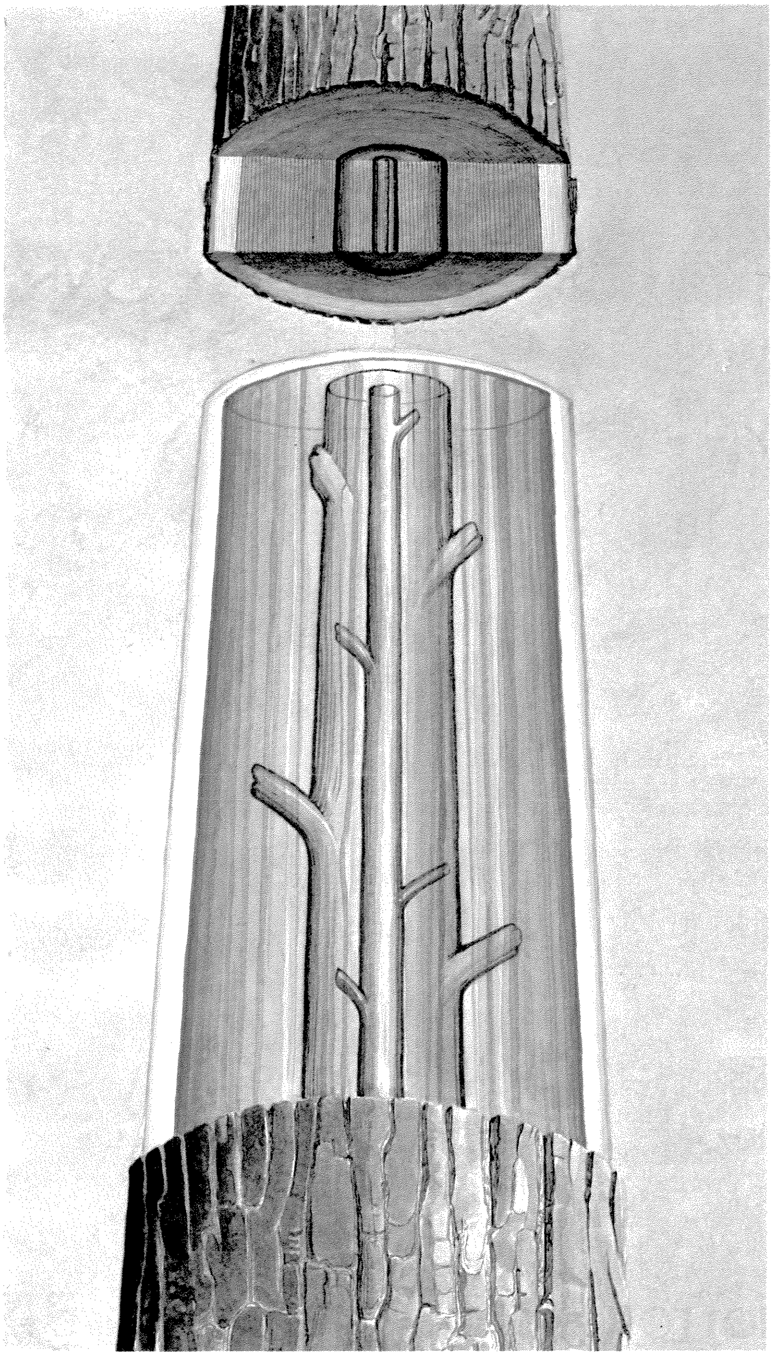


Figure 20.—Large pockets of advanced decay associated with an open nonpruned stub in a very slow-growing tree. The arrow indicates the diameter of the tree when the branch died. Heartwood formation was stalled because at this point there are over 25 rings of sapwood. The decay did not spread outward into the tissues that formed after the death of the branch. Many factors contributed to this advanced column of defect, but the two major ones were the slow growth of the tree and the insect infestation deep into the stub beyond the chemical protection zone. Stubs should be pruned before insects infest beyond this zone.

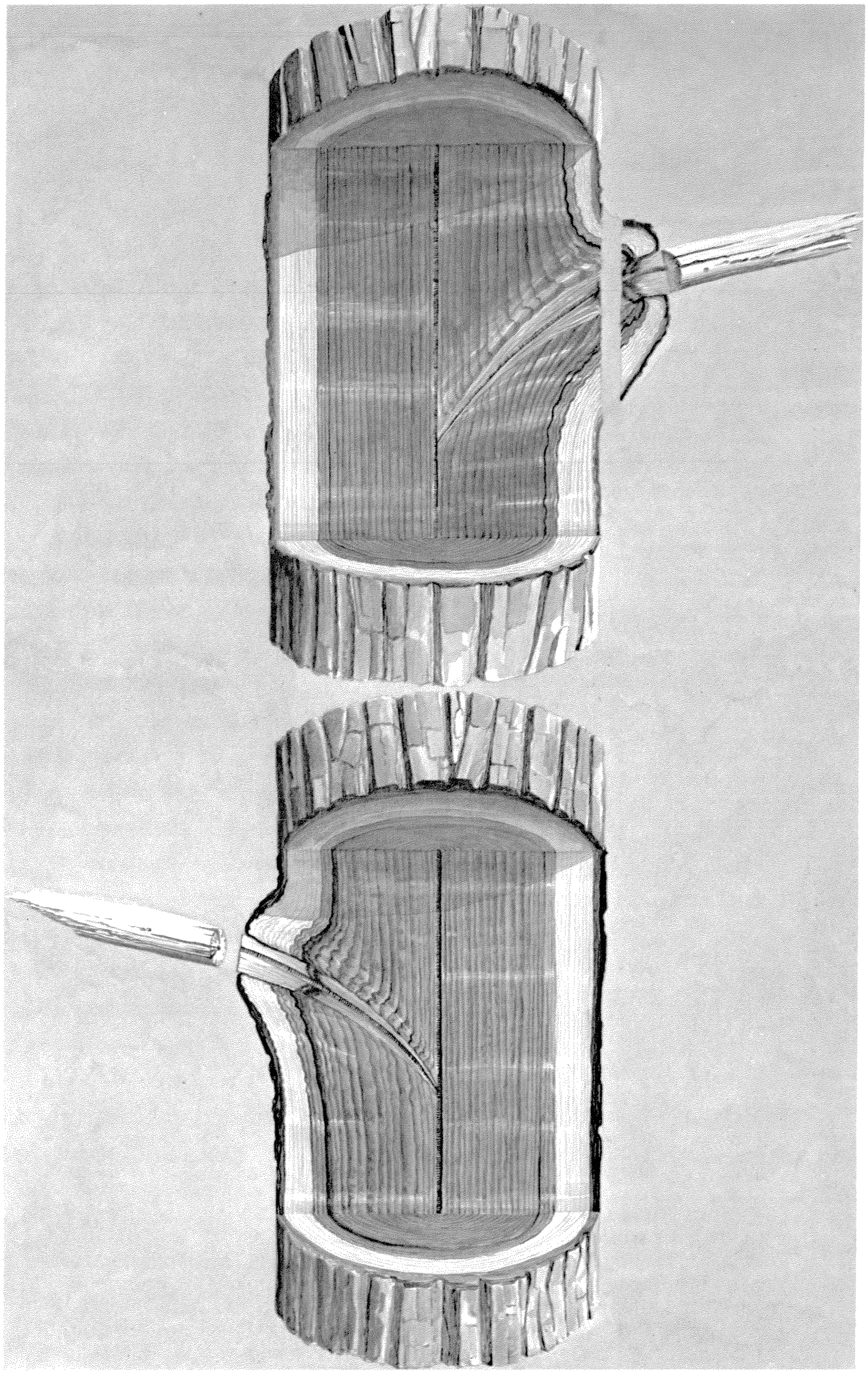
Figure 21.—A large radial seam was associated with this pruned stub (large arrow). Insects had infested deep into the stub (open arrow). Ring shakes were also present (small arrows). As wind or temperature extremes stress the tree, the radial seam may split from the inside outward. A typical "frost crack" would then form. Such cracks are usually to the sides of branch stubs.

THE STUDY GROUP

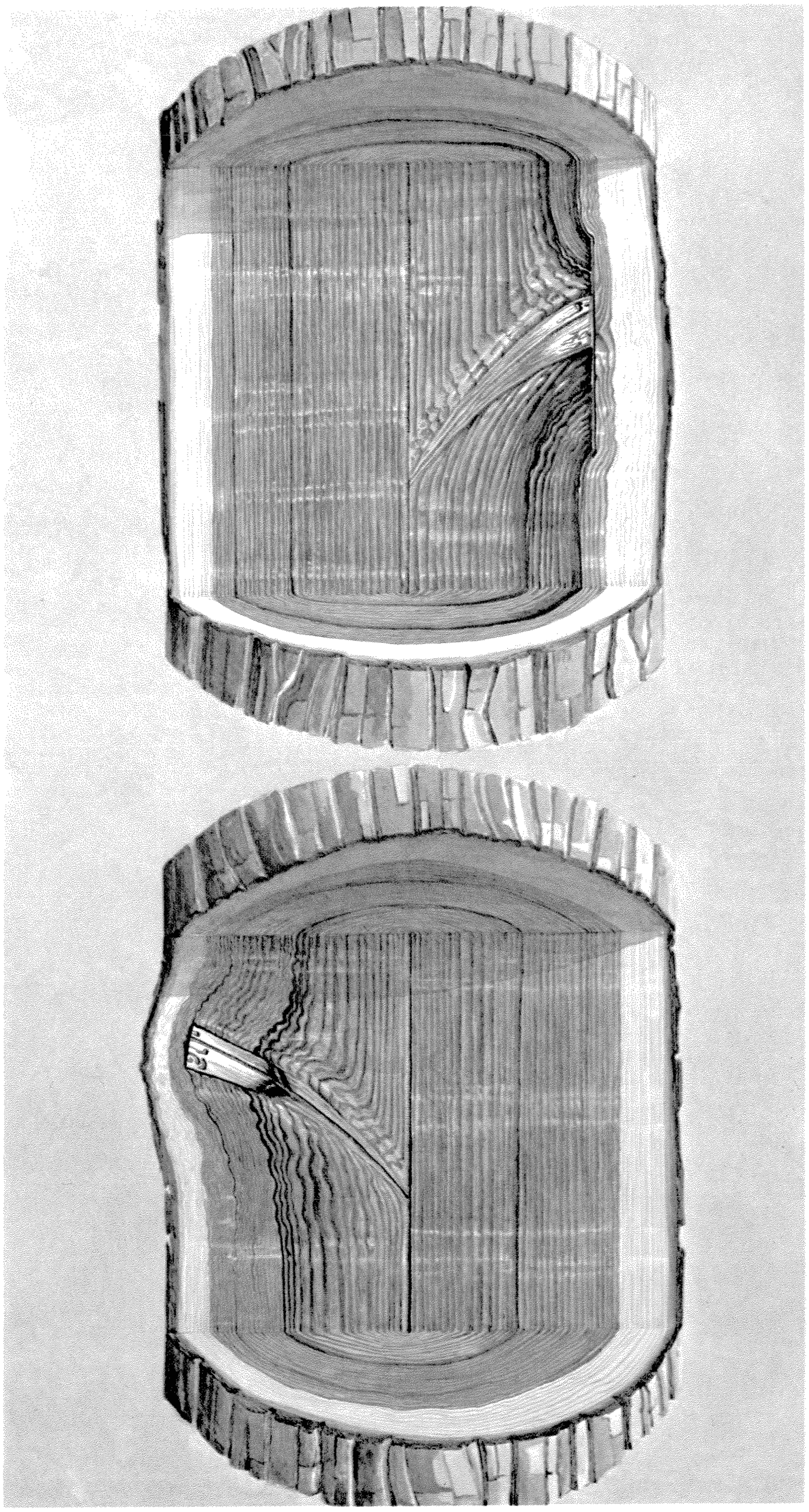




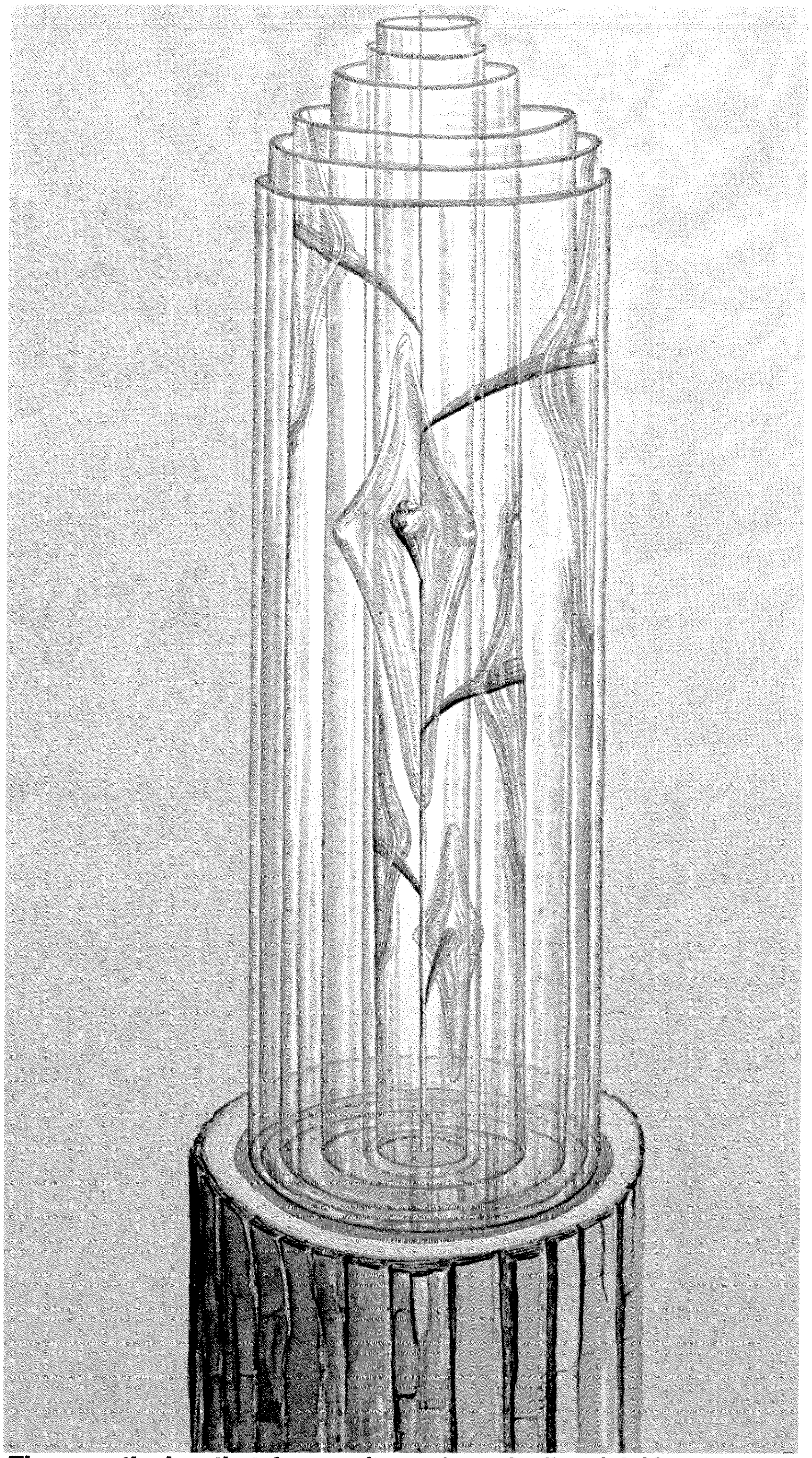
Different types and conditions of wood in black walnut: sapwood (yellow), heartwood (orange), discolored heartwood (green), and decayed wood (brown). When several wounds are inflicted at about the same time or when several branches die at about the same time, the associated altered wood will be compartmentalized within the cylinder of wood present at the time of wounding or branch death. Decayed wood is usually obvious after a tree is cut, but identifying discolored heartwood could be a problem. It may go unnoticed until veneer is made or until the wood is made into a product.



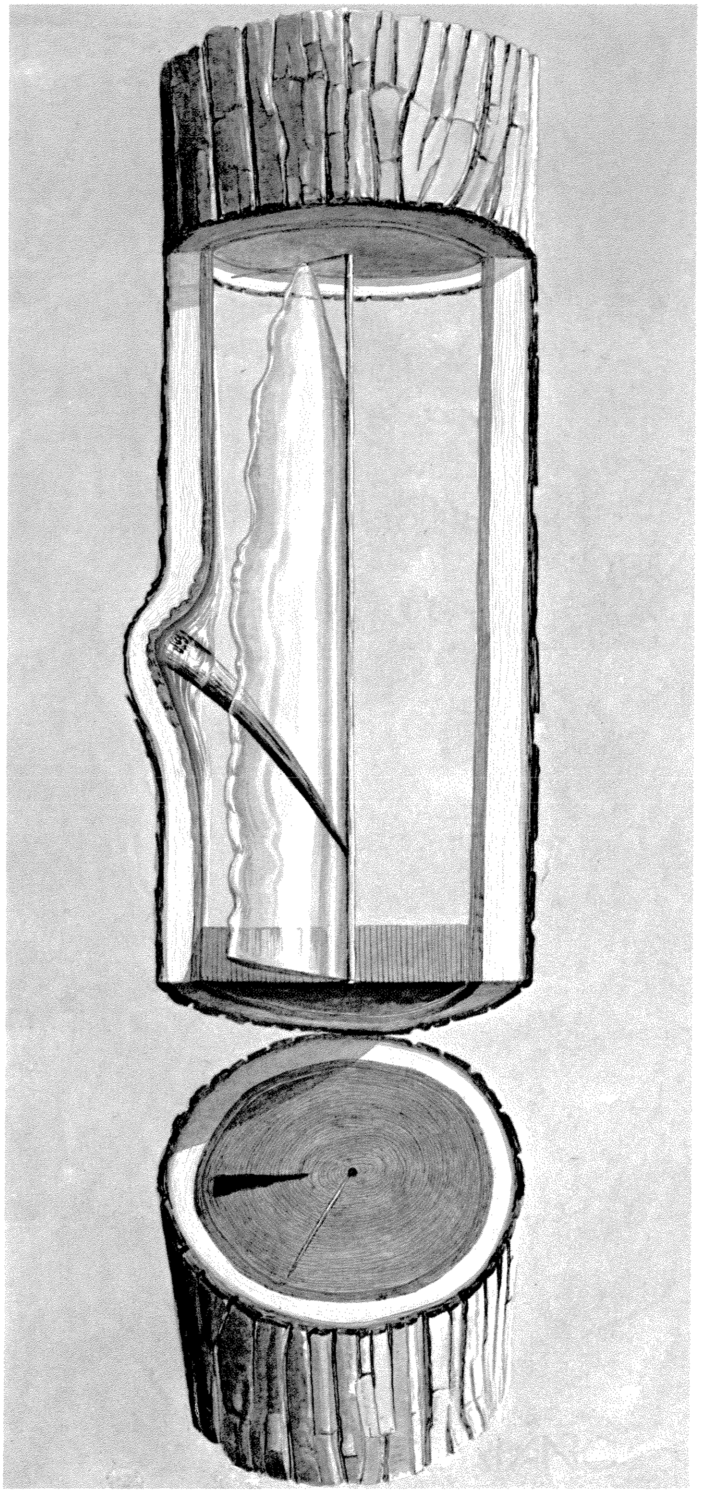
Improper (above) and proper (below) pruning cuts for dead branches that have large collars.



Internal condition of wood associated with closed wounds after improper (above) and proper (below) pruning of dead branches.



The growth ring that forms after a branch dies (pink) will often have an area that is slightly darker above and below the stub (blue). These bands of darker wood are seen commonly in black walnut.



Radial separations sometime develop off to the side of a stub (green). They may break out to the bark and become visible radial seams. After a branch is pruned, a barrier zone forms (red). It may cover a small area around the stub or it may go entirely around the trunk. The barrier zone is both a chemical and an anatomical zone. It is not always visible.

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania.
- Warren, Pennsylvania.