Heart rots, which are caused by fungi that attack the wood of living trees, are to blame for an estimated annual loss of 1.5 billion board feet in our commercial forests. In money, the loss lies somewhere between the approximately 10 million dollar value given the cull as stumpage and the 47 million dollar value given it as logs.

Every timber species in the United States is subject to attack by one or more species of the fungi, but fortunately a large part of the losses can be prevented by proper management.

In trees that have a clearly defined heartwood—oak, ash, and most conifers, for example—the heart rots are usually confined to the true heartwood. In many other hardwoods, normal heartwood forms irregularly, and decay of the inner sapwood is also called heart rot. The term “sap rot” is used for the decay of dead or dying sapwood.

When a fungus that is decaying the heartwood of a tree has developed for a number of years, it often produces a spore-bearing structure like a mushroom or a bracket-shaped conk. Each year one such structure can produce millions of tiny spores, which are carried about by air currents. When a spore comes to rest upon exposed wood and conditions are suitable, it germinates and sends fungus filaments into the wood. By means of these threads the fungus spreads through the tree, feeding upon and rotting the heartwood as it goes. Some fungi, which cause some of our common root and butt decays, rarely produce spores, but spread largely by growth through the soil.

Entrance points for rot fungi are usually provided by the exposure of heartwood when the trunk, top, limbs, or roots are wounded by fire, logging, or storms. Butt rot in sprout hardwoods usually is transmitted from the rotted stump to the attached sprout. Some of the most important heartwood destroyers gain entrance through branch stubs or branches killed by natural suppression.

The high decay cull in many eastern hardwoods reflects mostly fire-scarring, ice damage, and abandonment of defective trees in past logging. Decay cull in most eastern softwoods and in the southern pines now has reached a small percentage because their cutting ages have been reduced. Improved timber management probably will keep the losses from decay at a low figure for those species.

The basic problem of timber management in the West now is to bring hitherto unmanaged forest land into maximum production. The two principal problem types are forest lands that have been cut-over or burned (on them new growth is inadequate) and stagnated virgin stands of overmature old-growth timber. Heart rots are involved in the management of both types. Through good forest practices, heart rots in future timber stands of the West may be kept at a minimum if the factors leading to heart rot are fully understood.

Decay factors affect silvicultural practices throughout the country in seven important ways: In the determination of the cutting age; in the system of harvest cutting; in the choice of trees to be cut in partial-cutting systems; in requiring special salvage cuts in timber burned or otherwise damaged; in managing mistletoe-damaged stands; in requiring the early treatment of hardwood stump sprouts; and in pruning and similar operations. Each is discussed here.

In most of our eastern and southern species, the age at which the trees will be cut (based upon the rate of return from the land) will be lower than the age at which decay ordinarily becomes
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a critical factor. This is true, for example, of the southern pines, white oak, yellow-poplar, sugar maple, and many other species. But in some species decay definitely limits the desired cutting age. In aspen in the Northeast and the Lake States, stands much older than 50 years are likely to be badly decayed. Decay should limit the cutting age of balsam fir to about 70 years. Most of the oaks will pass 150 years without major decay losses but decay cull usually results in the serious break-up of scarlet oak stands over 80 years old.

In the West, the thrifty, uninjured young forest trees are generally free from heart rots. After the virgin stands have been replaced by second growth, the most profitable cutting age occurs before heart rots become serious.

Frequent light cuts in the large-crowned hardwoods result in a maximum of logging damage. Clear cutting in strips or blocks or adopting a minimum number of cuts per rotation consistent with good silviculture will cause the least logging injury and the lowest subsequent decay. Logging injuries provide good opportunities for the entrance of heart rot fungi. Careless felling and frequent cutting can cause considerable breaking of the tops and branches of residual trees. Wounds exposing only sapwood in resinous species often become covered with pitch so that fungi are largely excluded. Such wounds in nonresinous species, however, readily permit the establishment of sapwood fungi, and the subsequent checking and sloughing of the decayed sapwood exposes the heartwood beneath to heartwood destroyers.

Selective logging with heavy tractors often causes extensive wounding of residual trees unless special precaution is taken. All forms of damage, including branch and top breakage, felling scars, and butt injury from skidding and yarding, increase as the frequency of cutting in a given stand increases. Heavy partial cuts in old spruce and fir result in wind breakage to the remaining stand, because these old trees are commonly heavily butt-rotted. Under such conditions some form of clear cutting should be considered in place of partial cutting.

Where partial cuts are made, the forester always aims to retain the trees that are increasing the most in volume. He marks for cutting the heavily defective trees, particularly those that are losing more wood from decay than they are adding through growth. Aids are available for estimating internal defect from external signs in some eastern and western species. The timber marker who can estimate the decay situation in a given tree can greatly enhance the net growth in selection systems of silviculture by eliminating defective trees in the earliest cuts.

Heart rots in the overmature stands of the West present a major problem in forest management. Whether such stands are clear-cut or selectively cut, all highly defective trees should be cut whether they are merchantable or not, unless it is necessary to leave them for seed trees to restock the area. In some stands there are so many cull trees that the sound timber available will not pay for their cutting and still leave a profit for the operator. Even if all were felled, considerable damage would be done to young trees and other timber left standing on the area, new young growth would be obstructed, and a serious fire hazard would develop. If they are left standing, they occupy a large percentage of the area that should be taken over by vigorous young trees.

How to dispose of the obviously worthless trees under these circumstances is a challenging problem. This same problem arises in connection with large areas of high-graded timberland in both the East and West. On these areas only the best trees were removed, leaving a considerable stand of near-worthless timber. The systematic elimination of these trees, most of which are badly decayed, is now a prominent phase of the forest land-improvement operations in many sections of the country.
The heart rots that develop through naturally suppressed branches and branch stubs are the most prevalent in western conifers. Some fungi enter almost entirely through dead branches that contain heartwood and that are nearly always an inch or more in diameter. Others enter through branch stubs that contain heartwood. Management of forests to maintain a high density in the young stands, so that branches do not form heartwood before being shaded out, and artificial pruning in more open young stands will reduce the incidence of such decay. Ground fires, insect epidemics, and heavy partial cuts that heavily thin stands and thereby stimulate the formation of large branches on the surviving trees are important factors in providing favorable places of entrance for these fungi.

A stand of timber badly burned or damaged by wind or ice should be salvaged promptly or heavy losses from decay may ruin the merchantability of a high proportion of the volume. Prompt salvage cuts of this type require knowledge on the part of timber managers of the high toll that decays can take in badly broken or heavily fire-scarred stands.

Many timber stands have been repeatedly burned by ground fires so that practically all old trees have scars at their butts. Fungi entering through these scars account for a large proportion of the heart rot in older stands. The so-called butt rots are usually confined to the roots, stump, and basal 16-foot log, but occasionally extend much farther. Other rots known as trunk rots, which may enter through butt scars or any wound or dead stub on the trunk, usually are more extensive and often cause entire trees to be culled. The resinous pines are not so subject to butt rot following injury as the nonresinous conifers and hardwoods.

The dwarf mistletoes of western conifers cause enlarged branches and burls on the trunk that provide points of entrance for heart rot fungi in old trees. Dead areas on these burls, stubs of swollen branches, holes in the stem where enlarged branches have been pulled out, and broken tops offer major rot hazards from mistletoe infections. In western hemlock in the Northwest, heart rots established through mistletoed knots and burls account for more decay than from any other cause. Silvicultural methods to prevent serious mistletoe infections in future timber stands are now being developed.

In the East, oak stump sprouts that arise more than a couple of inches high on the parent stumps are very likely to become butt-rotted from the old stump. Ground-level sprouts seldom contract rot from a parent stump. One cleaning operation made in a sprout stand at about 15 years of age can eliminate the decay-susceptible high-origin sprouts and provide single-stemmed crop trees rather than sprout clumps. Two defects can thus be minimized by a timely cleaning. In the case of scarlet oak, a pruning at 15 to 20 years will eliminate many of the future rot pockets and holes at the bases of dead branches, so common in this poorly self-pruning species.

Decay reduction and silviculture are also linked in pruning, through decreasing decay where small branches are pruned or possibly increasing it where large branches are cut. The removal of trees with spore-shedding conks, where practicable, is good silviculture. A number of common heart rot fungi may enter the trunk through the roots, either through root wounds, root grafts, or contact with decayed roots of other trees. These rots are controllable mainly through the knowledge of the age at which they become important and arrangement of the cutting schedules accordingly.

Major losses from heart rot can definitely be prevented. A certain amount of decay is bound to occur in any timber stand, but we already have the means of keeping such losses to low levels. For many species that can be achieved by adjusting downward the cutting age when necessary, by
Breeding and Selecting Pest-Resistant Trees

The heart rots that develop through the roots, as in the case of many of the spruce, fir, and pine butt rots, will never be entirely eliminated. Where they are known to be common in a stand, however, cutting can be done early enough to minimize the loss, and in such a way that the residual stand will not suffer undue breakage or windthrow as a result of the decay.

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BREEDING AND SELECTING PEST-RESISTANT TREES

GEORGE H. HEPTING

Russell B. Clapper, John M. Miller

Epidemics of introduced parasitic fungi stimulated interest in the development of healthier trees. Forty years ago the Department of Agriculture employed Walter Van Fleet to breed chestnut trees that would resist the introduced blight fungus. Since then several agencies have taken up the work of breeding and selection, for the most part to obtain vigorous, fast-growing specimens for lumber and other products. More recently, greater emphasis has been placed on develop-