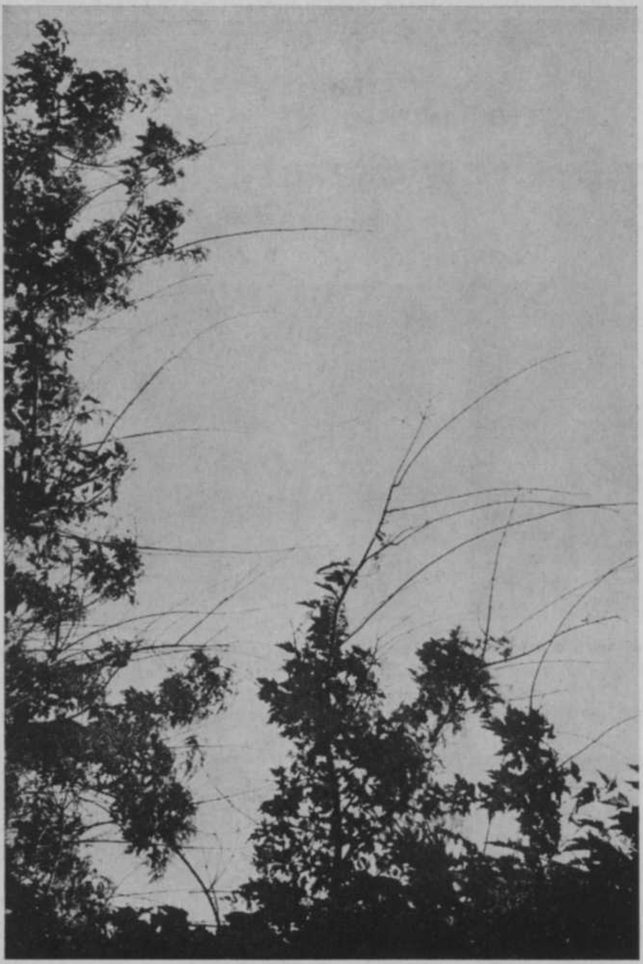

Dieback of exotic maples from winter cold in Maine. The entire subject of noninfectious tree diseases is rapidly being put into its proper importance in tree maintenance.

Conspicuous cracking of paper birch stem. Whether caused by cold, heat, or lightning, repeated opening following annual healing has already stimulated formulation of a "rib."

Noninfectious Tree Disease, Part 1

Effect of Cold Injury and Freezing

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IN SPITE of the dramatic and conspicuous destruction wrought by such well-known infectious tree diseases as Chestnut Blight, White Pine Blister Rust, Elm Phloem Necrosis, Dutch Elm Disease and Oak Wilt, it is possible that over longer periods of time, diseases of noninfectious origin may cause greater losses than infectious ones. Infectious diseases are those whose primary causal factors are bacteria, fungi, or viruses, and infection is the establishment within living tissue of such disease-causing agents. By contrast noninfectious diseases are caused independently of such pathogenic agents.

Although some noninfectious diseases are the direct or indirect result of man's activities, most of the causal factors leading to disease are the diverse and natural aspects of the environment to which a tree is exposed. Here it may be well to explain the concept of disease which we will consider.

A disease is considered to be a sustained process of physiological changes, harmful to the living organism affected. These changes are expressed in physical and/or chemical alterations of trees affected, and their outward manifestations are symptoms of internal trouble. Diseases of trees (and of men) were regarded by the ancients, as expressions of the "Anger of the Gods." Later, in Biblical times the influence of adverse weather in causing plant disease was recognized generally. So solid was this view that as late as a hundred years ago, before the germ theory of disease was accepted, most plant diseases now known to be infectious were attributed to adverse weather.

Following the knowledge that disease may be infectious and that known infectious agents are microorganisms, the concept developed that disease was essentially of infectious origin. With the ultimate discovery as infectious agents, of those self-duplicating submicroparticles, the viruses, the infectious disease acquired a new dimension that reinforced the association between disease and infection. Often the terms infection and disease were, and still are, linked together as essentially interdependent.

From that time, the concept of disease, resulting from any other cause than infections, has had but grudging acceptance by both pathologists and laymen. But the discovery that viruses and other infectious agents may be transmitted by insects, and that insects are much affected by the environmental influence of temperature and moisture, led to a reappraisal of the influence of the environment as a primary cause of disease without infection.

Later, it was discovered that certain plant vitamins are necessary to prevent certain human diseases, and that nutritional elements are needed to prevent plant disease.

With this information and the knowledge that availability and absorption of such elements are dependent on the chemistry of the soil, the concept of noninfectious disease was strengthened. More recently, a continuing series of new and troublesome tree diseases have been found for which there are no known infectious agents.

Examples of such diseases studied intensively within the past two decades are: White Pine Needle Blight, Birch Dieback, Pole Blight of Western White Pine, Sweet Gum Blight, Little Leaf Disease of Southern Pine, Ash Dieback, and Maple Blight, Dieback or Decline.

Disease Cause Twofold

Even more recently the knowledge that natural (as well as manmade) radiations may cause diseases of noninfectious origin, has emphasized the point, that a perfectly valid concept of tree disease must include the noninfectious as well as those truly infectious. The purpose of this paper is to explore some of the basic factors, which are the direct or indirect causes of noninfectious disease and how they operate. Considerations of time and space make it necessary to limit the discussion to the imbalances of temperature and water. Cold injury and freezing are discussed in this installment.

Cold Injury

Which of the natural environmental factors significant in direct plant injury is most harmful to trees in causing disease? Probably low temperature brings the most trouble, because it is known to be a limiting factor in geographic distribution of species of trees as well as other plants. In addition, temperatures damaging to trees occur over wide geographic areas and affect millions of individuals of many species. Over an extended period of time, in temperate zones, almost all species of trees may be affected, but there is much variation both between and within species and strains.

Depending on latitude and climate, freezing damage may and does occur at any time of the year. With numbers of trees affected, it is probably most significant on trees in the spring, and is rather rare in summer. After growth has begun, late spring frost may be sufficiently light, so that only thin tissues at leaf margins or between veins may be killed, or it may be severe enough to kill all leaf and stem tissue of new growth.

In the former case, leaves of deciduous trees may appear ragged with interrupted margins and uneven holes. In the latter case, all the new tissue is collapsed, is discolored brown or black, and may break off and fall within a short time. Terminal growth of the year will be lost, and the growth pattern of the tree may be distorted.

Early frost in the fall is much less serious. In its mildest form, it may cause nothing more than premature defoliation, especially to those species whose buds for the next year are set, whose growth has ceased, and whose gradual period of hardening off is well advanced. Species whose growth continues until actually stopped by frost will have succulent stem tissue killed back. With such trees this is considered to be a natural phenomenon. With early frost then, these species are little affected from normal onset of cold weather. Between these extremes, however, are trees whose growth has stopped, terminal buds having been set, but whose tissues are still succulent because hardening has not occurred to any degree. With dieback occurring on this type of species, the terminal buds for the following year often will be lost, and growth may be distorted, as with late spring frost.

For the individual tree, midwinter freezing is probably the most injurious of all cold damage. Trees so affected may suffer dieback of twigs and roots, radial cracking of trunk or branches, or killing of cambial tissue between bark and wood of stems. Since all freezing injury involves drying of tissues as water leaves the cells, such tissue collapses if soft, or contracts if hard. Some tissue is killed outright, some is weakened sufficiently to be susceptible to easy invasion by weakly parasitic fungi, and some is so altered, that it may develop abnormally when growth begins. As the name implies, "dieback" results from death of small, thin terminals, and with increased severity extends inward toward larger stems or roots. Extent of dead tissue is easily detected before new growth begins, by a line of sharp demarcation at the interface of living and dead tissue.

Cold Causes Radial Cracks

Radial cracking or "frost cracking" of stems is, of course, a well-known and conspicuous indication of excessive or sudden cold. Under such conditions a woody stem is affected in a curious way. As the outer tissues of the stem freeze, this tissue contracts faster than deeper, inner tissues. In a vertically oriented stem, such as a standing tree trunk, shrinkage of woody tissue from loss of water is greatest in a horizontal plane. Contraction, through drying of the outer shell, creates a tensile force on these outer cells. At the same time, because of their insulated location in the stem, the inner lying cells are not under such extreme tensile forces. The dynamic stresses between differential contraction of inner and outer wood, force the outer tissues of the stem to separate, and separation occurs along radial lines where cleavage is easiest mechanically. Such cracks occur suddenly with an explosive force and a sharp cracking sound. They may extend from one to

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Noninfectious Tree Disease

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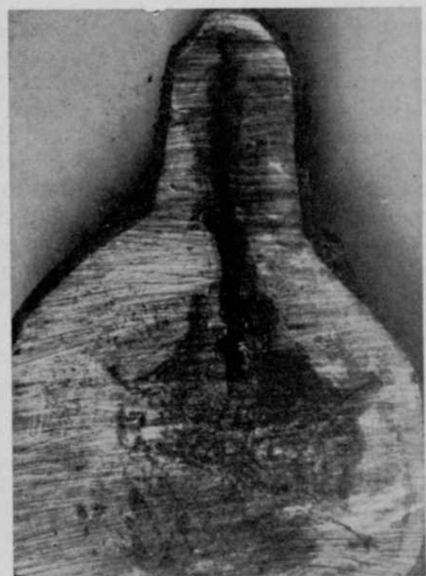
several feet in length along the trunk, and are most often within ten feet off the ground on the north side of a tree. However, they may occur at any height and on any side.

Most frequently such cracks provide openings for invasion of insects, bacteria and fungi. But apparently many heal without infection, or at least there is no evidence of any for many years. If healing is clean, fresh callus tissue in the following spring and summer will often close-over the opening. But once weakened, the stem may crack again under more mild conditions than at first. Such cracks may be repeatedly opened following successive healings, by nothing more than swaying of the tree by the wind. Since the callus tissue tends to protrude more and more with each opening, after several years a pronounced "frost rib" may develop, representing an exaggerated protrusion of vertical woody growth running up and down the trunk for several feet. In addition, many frost cracks become infected with wetwood bacteria, so that bacterial exudations themselves may predispose the stem to repeated cracking, and many frost ribs are characterized with a constant seepage of foul-smelling sap from such exudations. Wetwood infections may also predispose stems to frost cracking, but the reverse is probably most common.

Internal evidence of cold injury involves activity of cambial cells following damage. Where the cambium is not killed completely, it is stimulated to abnormal growth and the formation of frost rings. Since some of the cambial cells are killed, or some of the first cells produced from them may die, the tissue may contain, collapsed cells, and to that extent is physically distorted. For reasons not well understood, many cells produced from damaged cambial tissue fail to differentiate properly when growth first begins, so that in the early part of the growth ring there is often much undifferentiated tissue composed exclusively of parenchyma cells. One explanation may be that the separation of the bark from the wood leads to growth of excessively large new parenchyma cells. The combination of collapsed dead cells and the soft undifferentiated parenchyma cells results in excessively broadened rays, misalignment of rays in the wood with those of the previous year and generally distorted tissue.

Unless killed completely, the stem may recover its growth balance shortly after growth begins, when a solid ring of cambial tissue is established through regeneration. Then as growth becomes regular, excessive parenchyma disappears, differentiation becomes normal, and rays become straightened in the advanced areas of the growth ring.

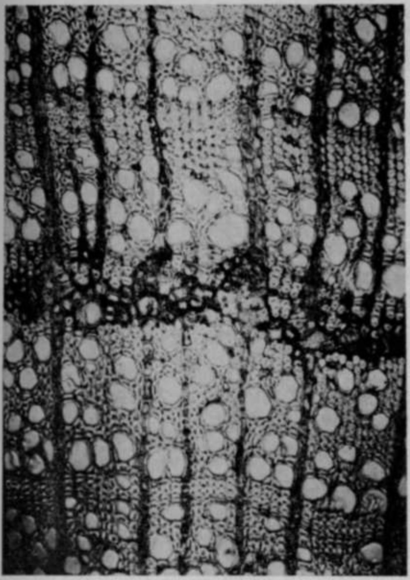
Sometimes, however, whole areas of cambium are killed outright in basal stems of trees. Because the water-conducting tissues of the previous wood are unaffected, growth above the injury may begin and advance normally for some time. Eventually, if the entire stem was girdled, the top will die. If only a portion of the stem was killed, the stem may die partially, completely, or not at all, depending on circumstances. Tissue weakened or killed by cold ordinarily will be invaded by a wide variety of insects, bacteria, and fungi. It then becomes a race between weak predators or parasites and the regenerative powers of the tree that will determine the outcome. Not the least of the determining factors influencing the situation at this point are the climatic factors involving temperature of water.



Dramatic closeup of frost ring in woody tissue of apple, showing misalignment of rays, broadened bases of rays in the early growth of the ring, and excessive number of darkly colored parenchyma cells.

Mechanics of Freezing

The phenomena of freezing injury to plant tissues is basically one of dehydration. Water in plant tissue is either between the individual cells (intercellular water) where it is pure, or within cells, (intracellular) where because of dissolved salts, sugars, minerals, proteins, and other substances it is anything but pure. Pure, intercellular water freezes at or near 32° F, whereas intracellular water freezes only at much lower temperatures. For many years it was believed that freezing expanded the water in plant cells causing them to swell and rupture, but it is now known that plant cells actually contract. The first thing to happen in the freezing of plant tissue is the formation of ice crystals between the cells. This decreases the vapor pressure around the cells, causing water within cells to diffuse out through cell walls by osmosis. As the intracellular water moves out into the intercellular spaces, it freezes, adding to the ice crystals already there. This decreases the turgor pressure within the cells, causing them to contract. With ice formation between cells and shrinkage of cells, the ensuing dynamic stresses and tensions may be sufficient to cause physical rupture of tissues. If the cells remain intact, they become less vulnerable to freezing damage, unless the temperature continues to drop; containing less water, their freezing point has decreased. Such cells may remain "undercooled" without actually being frozen, even at temperatures below freezing, because of high content of fatty substances in cell membranes and proteins in the internal water. Both of these conditions have the net physical effect of insulating the water from freezing. But if the temperature drop is extreme, and especially if it drops suddenly, ice crystals may eventually form inside cells, rupturing the cell protoplasm and membrane, thus killing the cells. According to one authority such an extreme situation has not actually been observed under natural conditions, but the



Protrusion, in this closeup of a frost rib in cross section of an elm stem, is associated with bacterial wetwood and heart-rotting fungi.

conditions making it possible are known to occur.

Following direct freezing of plant tissue without formation of intracellular ice, the affected cells may recover or not. If the contraction of the internal protoplasm has been severe, protoplasmic coagulation may occur to a degree that is irreversible, and the cells may die. The extent of recovery possible will depend on the manner of thawing, during which the cells can be injured further. On thawing, the intercellular ice melts first, causing a flow-back of water into the cells with a subsequent swelling of the protoplasm. If the rate of thaw is rapid the swelling may be so sudden that the cells may rupture. The manner in which cold-affected cells become sensitive to turgor pressures not affecting them previously, and the decreased elasticity of the cell membrane to moisture changes following injury, indicate that freezing even without intracellular ice in some way alters the permeability of the membrane.

Synthetic studies of slow freezing damage indicate, that following intercellular ice, ice forms between walls and membranes first, in cytoplasm next, and in the vacuole last of all. The nucleus is the last of the protoplasm to be affected. Within the cell then, the degree of susceptibility appears to be largely positional, since in mature cells the vacuole lies at the center of the cellular complex. For the most part, however, cellular damage results from collapse of cells alone, without internal freezing, and from tearing or bursting of tissue following freezing of intercellular water and subsequent thawing.

Although the mechanism of freezing injury is similar for plant tissues generally, all cells and tissues are not necessarily affected in the same way. Apart from heritable differences not expressed structurally, differences in susceptibility and sensitivity result primarily from differences in structure of tissue, and location and exposure of species. Some plants are affected only mildly or not at all because of their capacity to become "hardened." Hardening involves a gradual conditioning through repeated exposure to slowly increasing coldness. During this period there is time for newly formed tissues to mature fully, and the cell walls of both inner and outer tissues become impregnated with various degrees and types of exposure-resistant chemicals, such as: the cutin of shiny leaves; the suberin of corky bark; the cellulose of all plant cells; and the lignin of woody cell walls. In addition, there is a gradual loss of water, so that hardened tissues are relatively dry. Woody plants generally begin hardening off immediately after growth ceases and become progressively cold resistant with approaching frost. These species are characterized by formation of truly terminal buds on ends of branches, in contrast to "pseudoterminal" buds. The latter type are typical of species which do not cease growth until literally stopped "cold" by freezing temperatures. Interestingly, some of these same species, such as the willows, are among the first to resume growth in the spring. This practically guarantees their premature exposure to a certain degree of late frost in the spring, but such species appear to be relatively resistant to such frost, suggesting an adaptation to these conditions.

Destruction of terminal meristems by freezing changes the distribution of auxin which regulates the growth of lateral branches. As with death of terminals from any cause, dormant meristematic tissues in the living stem below the injury may be stimulated to activity. The result may be a profusion of so-called water sprouts appearing as lateral branches in an irregular pattern, or the internal formation of aggregations of tightly packed and sometimes distorted cells, whose growth is short lived. The net effect of such internal tissues may be to interfere with the normal development of food and water-conducting tissues (phloem in bark, and xylem in wood).

The net affect then of freezing may include: partial death of leaf tissue to vigorously growing plants; dieback of terminals; death of cambial tissue, abnormal cell formation, with formation of frost rings in woody plants; failure of new cells to differentiate, with the formation of excessive parenchyma; formation of callus tissue; stimulation of dormant meristematic activity; and complete death of all or parts of individual trees.

Part II will appear in a later issue—Ed.

Plans Being Completed for 12th Fla. Turf-Grass Conference

Final arrangements are now being made for the 12th Annual Florida Turf-Grass Management Conference set for Gainesville, August 25-27, on the University of Florida campus there.

In addition to details announced in W&T last month (p. 20), spokesmen now announce that speakers and turf professionals for the event will be drawn not only from Florida, but from surrounding southeastern states and the Caribbean.

Included in the annual seminar are separate sessions devoted to the specific interests of various turfgrass management groups. Included are discussion groups covering golf course turf; horticultural spraymen and lawn service agencies; retail dealers and garden supply houses; industrial sites; and nurseries.

Those who wish to attend may write for further information to: Dr. Granville C. Horn (or John C. Cabler), 401 Newell Hall, University of Florida, Gainesville; or Walter D. Anderson, Executive Secretary, Florida Turf-Grass Association, 4065 University Blvd. North, Jacksonville.