# Diseases of Pacific Coast Conifers

Agriculture Handbook No. 521

Forest Service
U.S. Department of Agriculture

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July 1978

Forest Service
U.S. Department of Agriculture

Library of Congress Catalog Card No. 77-600044

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 001-000-03727-7

Bega, Robert V., technical coordinator
1978 Diseases of Pacific Coast conifers. U.S. Dep. Agric., Agric. Handb. 521, 204p., illus.

This handbook provides basic information needed to identify the common diseases of Pacific Coast conifers. Hosts, distribution, damage, disease cycle, and identifying characteristics are described for 31 needle diseases; 17 canker, dieback, and gall diseases; 23 rusts; 8 root diseases; 15 forms of mistletoe; and 18 forms of rot. Diseases in which abiotic agents are contributory factors are also described. Also included are: color and black-and-white illustrations; a descriptive key to field identification for each major group of diseases; a glossary; and host plant and disease causal agent indexes.

Oxford: 44/45 — 1747 Coniferae (79)
Keywords: Diagnosis, abiotic diseases, needle diseases, cankers, dieback, galls, rusts, mistletoes, root diseases, rots.

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## Acknowledgments

We thank our many colleagues in the Forest Service, U.S. Department of Agriculture; Canadian Forestry Service; California, Colorado, Oregon and Washington Departments of Forestry; Oregon, Washington, and Colorado State Universities; Universities of Arizona, California, Idaho, Montana, Utah and Washington; St. Johns College, New Mexico; and the Los Angeles County Fire Department, who gave unsparingly of their time by providing photographs, critically reviewing the manuscript for technical accuracy, suggesting improvements, and testing its suitability for use by field personnel.

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# DISEASES OF PACIFIC COAST CONIFERS

## INTRODUCTION

by

ROBERT V. BEGA*

This handbook was designed to bring under one cover the basic information needed to identify some of the common diseases of Pacific Coast conifers. Although written primarily to help identify conifer diseases of the Pacific Coast States, it should be useful throughout Western North America, where most of these diseases also occur.

The information contained in this handbook is intended to serve a comparatively broad group that is interested in such activities as resource management, conservation, forestry, tree farms, outdoor recreation, and growing ornamental trees. Except for a number of texts written on forest and plant pathology, most of the available literature is in the form of bulletins, monographs, articles, and shorter contributions issued from time to time through a variety of publication outlets.

A tree disease is primarily a disturbance of the normal functions of a tree or the deterioration of its parts. Therefore, it is fundamental to recognize the parts of the tree that are attacked by disease-producing agents and the kinds of disease common to them. When attempting to diagnose a particular conifer disorder, the ability of some disease-causing agents to adapt and successfully attack must be kept in mind. The roots of a tree, for example, require infection and establishment of an organism under conditions widely differing from those to be found surrounding the leaves of the same tree. An organism causing a disease of living tissues may possess a different mode of attack than one which produces a heart rot in the dead tissues of the heartwood.

## Agents of Tree Disease

Agents of disease can readily be classified as (a) abiotic, non-organic, non-living agents, such as air and soil pollutants, ice, snow, wind, frost; and (b) biotic or living organisms, such as mistletoes, bacteria, and fungi. Viruses are not included in either of these classes simply because there have been, as yet, no proven virus diseases of western conifers.

Climate, soils, and vegetation vary greatly from the Pacific Coast to the Rocky Mountains. The cool, humid conditions of the Northwest contrast with the arid conditions of southern California. Aside from host specificity and biologic competition, the important factors in-

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fluencing the prevalence and vigor of disease pests are environmental, including the duration of critical levels of temperature and moisture, the type and aeration of soils, and human influence on these factors.

The same disease may, and usually does, have different degrees of intensity depending on the locale of the host. For example, the canker fungus *Botryophaeria ribis* has never been found attacking the giant redwood in its natural habitat. However, when the host is moved outside its natural zone, this fungus and several others (e.g., A. mellea) attack the redwood not only readily but quite destructively.

Human influence is a definite factor affecting most of the diseases being considered in this publication and must be considered in diagnosing a disease and evaluating the damage it caused. In work where trees are growing, every effort should be made to keep environmental changes to a minimum. Construction work — particularly road making, land leveling for housing development, campgrounds, and picnic sites — are frequently a source of injury to trees. Apart from mechanical damage by construction machinery, roots can be injured if they are severed or if they are covered with excessive amounts of soil. Overdevelopment in previously undeveloped areas may damage trees in an even more indirect way, such as ground water pollution or depletion.

Conversely, humans must also be protected from trees in recreation sites — particularly campgrounds, picnic areas, and summer home sites. Control of hazardous trees is of prime importance in both existing and planned recreational sites. Trees that fail because of disease or other agents can destroy lives and property.

The proper understanding of both host and disease-causing agent involves consideration of the surroundings. The effect of most abiotic agents is to some extent relative. One tree might grow quite healthfully under conditions that would cause disease or even death in another tree, even of the same species. In many cases, the degree and rate of change in the environment are more important than the actual level which conditions of the environment reach. For example, a tree planted in a hole in a pavement may grow quite well, but an established tree may die for lack of soil oxygen when a pavement is laid over its roots. This question of degree and rate of environmental change must be kept in mind in all considerations of injuries due to abiotic agencies. Many examples are cited in this publication in which abiotic factors of the environment greatly influence the origin and subsequent development of biotic-caused diseases.

This publication is organized primarily for use in field diagnosis and, except for the chapters on rusts and mistletoes, it describes symptoms based on the part of the tree attacked. Even the descriptive keys in the Rust and Mistletoe chapters, however, have been designed to focus first on specific parts of the tree. A cross index lists terms relating hosts to pathogens.

Control recommendations are not discussed in this publication except in special instances because of the continued change in control methods and changes in materials approved for control. As the environment undergoes changes, and as tree values continue to change from timber to recreation and esthetic values, specific control recommendations will also change. Many disease control methods can now be applied because the growth in value of trees permits more costly control measures to be adopted.

## Tree Disease Diagnosis

Diagnosis of plant diseases is the art of identifying a disease from its symptoms, signs, and patterns. The symptoms (expressions of the diseased host), signs (evidences of the cause), and patterns of occurrence provide the clues on which the investigator bases his diagnosis.

The following guide may be helpful in diagnosing tree disease:

1. Determine as accurately as possible the part of the plant that is actually affected. The death of only 1 year's needles indicates a needle disease; of scattered whole branches — a canker disease; of the whole tree — a root disease, drought, or fire. Note the pattern of the disease in the trees. Is the damage limited to the south side, to the lower, or to the upper crown?
2. Note what species are affected. Are there any individuals that are affected less or which are free from the problem? Also note the condition of other adjacent plants.
3. Note the pattern of occurrence. What areas show the problem worse? How do these areas differ from those areas free from the problem? Are these problem areas in any particular environmental zone or related to a particular cultural activity?
4. If the cause of the disease is not immediately evident, look first for the simplest effects, such as animal damage, frost, lightning, other climatic influences, simple injuries, fire, or other obvious causes of the problem.
5. Look for the presence of fungi, insects, or other parasites. Observe accurately, and try to judge whether the organisms found are the main cause of the trouble or just secondary. For example, insects will frequently move in as secondaries on trees weakened by disease.
6. If the whole tree is dead or suffering and nothing is found above ground to indicate the cause of the disease, expose the roots and root crown for examination.
7. If you are still unsure, learn about the recent history of the problem and the area. Is the problem of recent origin and when was it first noted? What cultural practices have been carried on in the area, such as the use of herbicides, fertilizers, irrigation or flooding, road salting, and air pollution? Do the environmental records indicate the recent occurrence of any unusually severe conditions?

## Descriptive Keys

The descriptive keys found in each chapter are based on the host and the causal agent. In each key, letters are followed by either a letter for alternatives or for the causal agent that fits the specimen. Thus, each step leads to another step and its alternatives, until a name is reached.

Success in diagnosing a specimen by these keys depends largely on an understanding of the characteristic used. In many cases, this publication illustrates the key characteristics. If at any point in the key you are undecided about the way to proceed, follow through on the alternatives and compare the specimen with illustrations and descriptions found in the text or in the references cited.

An example is the key on rots:

A[1] on incense-cedar, juniper, or redwood ............................ B

B[1] on incense-cedar ............................................................ C

C[1] A brown pocket dry rot. (Pocket dry rot) *Polyporus amarus*

C[2] A white stringy root or butt rot. (Fomes root and butt rot) *Fomes annosus*

# 1. ABIOTIC DISEASES

by

PAUL R. MILLER*

Each tree that is a subject for disease diagnosis has an environmental history. Certain factors in that history may be an individual cause of abiotic or noninfectious disease. Some injuries caused by abiotic agents may predispose the tree to certain infectious diseases. The environmental history of trees at a given location is the result of the varying influences of solar radiation, temperature, water, atmospheric gasses, chemicals, wind, fire, topography, geologic substratum, and soil. The almost instantaneous events like lightning and fire, the extremes of such dynamic factors as temperature and water, and the relatively persistent influences of geologic substratum and soils show the wide range in the time spans during which the individual causes of abiotic disease may have an active influence on trees. For example, frost injury develops suddenly, accumulation of chloride salts near roadways occurs continuously in several consecutive seasons, and the dwarfing of trees due to toxic serpentine soils is an influence which is always present. Abiotic factors may exert direct effects singly, simultaneously, or sequentially with respect to one another.

Most of the record of events or circumstances causing abiotic tree diseases is present at the site as symptoms on needles, twigs, branches, and main stems and roots, or in terms of the immediate surroundings of the subject trees. In some situations, it may be useful to consult past weather records. The following key to abiotic diseases uses several characteristics of the main stem, branches, twigs, and needles in the upper and lower halves of the crown and also the inner and outer (branch tips) portions of the crown. The four major sections ($A^1$, $A^2$, $A^3$, $A^4$) in the key each start with stylized descriptions of a tree crown and use the gross appearance of the tree as a means for selecting an entry point into the key. The key identifies animal damage and provides a cross reference to the appropriate chapter when the symptoms encountered could also be caused by an infectious disease.

The most important abiotic diseases included in the key are discussed in greater detail in the remainder of this chapter.

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# Key to Abiotic Diseases

A¹ Main stem erect, leaning or prostrate, sometimes broken. Injuries to top, middle, or lower sections of main stem and sometimes branches, usually 4 to 10 annual needle whorls retained, needles of all ages not abnormally shortened.......B

B¹ Tree leaning or prostrate.......C

C¹ Main stem sometimes bent or broken. Excessive snow or avalanche, logging activities, and failure at a rust canker or beaver girdle.

C² Main stem prostrate, large roots torn from the soil. Windthrow and butt rot.

B² Tree erect, damage to main stem.......D

D¹ Only top section of main stem affected.......E

E¹ Top broken.......F

F¹ Top has uneven, splintered break and upper branches broken, fallen to ground, tree dead or often after several years multiple leaders develop: Excessive ice or snow accumulation.

F² Top and upper branches broken, prominent furrow in bark or sapwood spiraling from top to bottom; lower portion of stem sometimes shattered lower down: Lightning damage.

E² Top not broken.......G

G¹ Top of crown has dead needles and branches with lower limit a complete girdle on the main stem: Porcupine or occasional squirrel damage; sometimes a rust canker (Chapter 4) or *Phomopsis* canker (Chapter 3).

G² Top of crown has dead needles and branches with a variable lower limit, no visible mechanical injury.......H

H¹ Investigate for bark beetle infestation.

H² Very low winter temperatures or sun scorch.

H³ Drought or high water table.

D² Mainly basal section of main stem affected.......I

I¹ Tree severely debarked, and deeply gouged, usually on one side: Mechanical damage, e.g., earth moving, logging, or snow removal equipment; sometimes struck by a falling tree.

I² A narrow circumferential strip debarked with girdle extending into heartwood, tooth marks visible: Beaver activity.

I³ Slightly debarked, smooth area 1 to 2 feet long on one side of main stem often up to 20 feet above the ground: Blasting by ice crystals where surface of the snowpack and stem intersect.

I⁴ Partially debarked, mostly one side, usually extends from 3 to 8 feet above the ground, claw marks evident:

Bear damage. Small patches debarked no higher than snow level, tooth marks evident: Ground squirrel or rabbit damage.

$I^5$ Cracks in the lower stem, larger trees, especially true firs: Frost cracks.

$I^6$ Large, calloused lesion or canker, widest just above ground level and tapering upward mostly on the uphill or leeward side of stem, heartwood exposed, sometimes charred: Fire damage.

$I^7$ Same as $I^6$, but no charring: *Armillaria* rot.

$I^8$ Lesion on south side, small thin barked tree, often Douglas-fir: Heat canker or bark scorch.

$D^3$ Damage occuring anywhere on main stem ..................J

$J^1$ Swellings or hip cankers anywhere on main stem. Investigate for dwarf mistletoes, (Chapter 5), or rust canker (Chapter 4). If not present, then stem may have been formerly cracked by wind but not broken or girdled by a cable or wire, often remaining under the bark.

$J^2$ Resin bleeding at any level. No obvious wound: Bark beetle pitch tubes, bullet holes, *Armillaria* (if base of tree).

$J^3$ Resin blisters on stems of white fir or Douglas-fir: Nonpathological.

$A^2$ Main stem usually erect, may or may not be injured, usually 4 to 10 annual needle whorls, needle lengths of all ages usually not abnormally shortened. All or restricted portions of the crown exhibit needles uniformly brown or reddish brown ..................K

$K^1$ Generally all of the tree crown has damage to all ages of needles; sometimes buds, and small stems may also be dead ..........................................................................................L

$L^1$ Affected trees often occur in distinct horizontal belts along slopes, but current-year needles eventually fall off, alternate cold and warm temperatures: Red belt.

$L^2$ Affected trees occur singly or in definite small groups ..........................................................................................M

$M^1$ Exposure of roots by excavation.

$M^2$ Burial of roots, silting, or asphalting.

$M^3$ High water table, beaver ponds or new stream channels.

$M^4$ Fire; heat-killed foliage, minimal burning.

$M^5$ Make inspection for major root rot infection or bark beetle infestation (Chapter 6).

$M^6$ Accumulation of chloride salts along roadways.

$M^7$ Borate or chlorate soil sterilants.

$M^8$ Drought (severe).

$M^9$ Trees very close to industrial site or rail siding: Chlorine, hydrogen chloride, or ammonia gas; accidental release.

$M^{10}$ Only needles of pines (often Jeffrey) show tip dieback, mainly older needle whorls: Needle miners.

L³ Affected trees uniformly distributed over landscape ...N

N¹ In spring, buds, new shoots, and full length of emerging needles are dead or brown. In fall, succulent shoots and needles still growing are affected. Damage most intense in low spots or depressions: Frost damage.

N² Damage in late winter or early spring, needles of all ages are brown or intensely brown flecked: Winter kill.

K² Mainly the upper portion of the crown exhibits brown needles ........................................................................O

O¹ Only upper crown was in the lower part of the belt on a slope where warm and cold temperature alternate in winter: Red belt.

O² Condition visible usually in late summer, often continuing into next spring: Drought.

K³ Mainly the lower portion of the crown exhibits brown needles........................................................................P

P¹ Cold air accumulation in very shallow layer near the ground in winter, site usually flat or slight depression: Winter kill.

P² Only the lower crown was in the upper part of a belt on a slope where warm and cold temperatures alternate in winter: Red belt.

P³ Ground fire, scorched needles on lower crown, bark near ground charred.

P⁴ Herbicide damage, only lower crown sprayed.

K⁴ Mainly one side of crown, upper or full length shows brown needles; sometimes needles and smaller branches are absent ...................................................................Q

Q¹ Trees isolated or on edge of stand, usually midwinter: Sun scorch.

Q² Windward side of tree affected, usually early spring: Parch blight.

Q³ Trees exposed to salt spray up to 100 m inland along the coastline after gale.

Q⁴ Flagform tree: Branches, and needles blasted by ice and snow particles or salts.

Q⁵ Trees along roadside with injury only to needles: Drift of contact herbicides, deicing salt, or injury to needles, and smaller branches removed: Impact of snow plume from rotary snow plow.

K⁵ Mainly the outer portions of the entire crown or the youngest (current-year) needles are normal length, or sometimes shorter ..........................................................R

R¹ Partial brown tip dieback, symptoms most severe in late summer progressing from the current year to older needles and from top to bottom of crown: Soil drought.

R² Complete brown dieback of current-year needles: Frost injury or high temperature.

R³ Complete brown dieback of current-year needles, also evidence of insect mines, usually white fir: Defoliator insects.

A³ Main stem usually erect, may or may not be injured, usually 4 to 10 needle whorls, needle lengths of all ages usually not abnormally shortened. All or restricted portions of the crown exhibit needles with general chlorosis, chlorotic mottle, discrete brown flecks, partial brown tip dieback, bands of brown, fading green, white bleaching or purple discoloration. Needles may droop or needles and shoots may be twisted........................................S

S¹ Chlorosis or yellowing of needles........................................T

T¹ Destruction of chlorophyll by normal low winter temperatures imparts a brassy yellow-green color to conifers: Winter yellows.

T² Exposure of needles to low concentration spray of contact herbicide.

T³ Chronic exposure to ozone with 0.10 to 0.15 ppm daily peaks.

T⁴ Chronic exposure to sulfur dioxide.

T⁵ Exposure to low concentrations of borate or chlorate applied to soil.

T⁶ High water table (greenish-yellow).

T⁷ Nitrogen deficiency.

S² Chlorotic mottle of needles........................................U

U¹ Older needle whorls exhibit most mottle; mottle most intense at needle tip and progresses to the base of the needle: Caused by chronic exposure to ozone with daily peaks greater than 0.12 ppm.

U² Mottle present at basal portions in all ages of needles: Usually is associated with insect punctures or scale infestation.

S³ Discrete necrotic flecks on needle surfaces facing skyward, with or without chlorotic mottle or tip dieback: Winter fleck, associated with exposure to snow and low temperatures.

S⁴ Brown tip dieback, "tipburn," extent on needles variable ..V

V¹ Narrow chlorotic margin delimiting necrotic and healthy tissue: Soil drought.

V² Sharp boundary between necrotic and healthy tissue ........................................W

W¹ Injury by high concentrations of air pollutants: Hydrogen fluoride, hydrogen chloride, chlorine, ammonia, sulfur dioxide, or ozone.

W² Potassium deficiency — rare.

W³ Rapid chloride salt accumulation near roadway, both tip and banded necrosis.

W⁴ Low temperature or frost injury.

W⁵ Current-year foliage most affected: Severe injury by borate or chlorate soil sterilants.

W⁶ High temperature injury; Douglas-fir or white fir.

W[7] Needle miners, typically Jeffrey pine or Rocky Mountain ponderosa pine.

S[5] Brown tip dieback with darker bands evident at 1 to 2 cm intervals within the brown tissue: Gradual accumulation of chloride salts.

S[6] Whole needle fading from green to tan ............................... X

X[1] All of tree crown involved. Inspect for bark beetle infestation or for root infection by *Fomes annosus* or *Armillaria mellea* (Chapter 6).

X[2] Random needles involving all or parts of crown — inspect for infection by needle cast fungi, e.g., *Lophodermium, Elytroderma, Rhabdocline* (Chapter 2).

S[7] Needles bleached yellow-white: Foliar application of aminotriazol.

S[8] Purple discoloration of older foliage followed by withering: Phosphorus deficiency.

S[9] Purple discoloration of younger foliage and tops of smaller trees and seedlings: Prolonged exposure to moderately cold temperatures.

S[10] Drooping or curved needles: Associated with rapid transpiration in the absence of available soil moisture.

S[11] Severely twisted needles and shoots: Foliar application of hormone weed killers, lightning.

A[4] Main stem usually erect and uninjured, top surfaces or upper branches may be injured and needles of all ages reduced in number, more frequently one to three annual whorls present; needles normal or more often, shortened with chlorosis, chlorotic mottle or tip dieback ................................................................ Y

Y[1] Affected trees uniformly distributed over landscape, sometimes in a strip, but not related to similar sites. Upper crown has fewer needles of all ages than lower crown, upper surface of branches has wounds or scars, numerous terminal buds missing, green foliage on ground: Hail damage.

Y[2] Affected trees are dwarfed, occur uniformly over the landscape and are often separated from normal appearing vegetation by a sharp boundary: Serpentine soil toxicity.

Y[3] Affected trees randomly distributed over landscape, not related to particular site conditions ........................................ Z

Z[1] Tree is large, over-mature, low vigor results in fewer annual whorls retained and shorter needles throughout the crown with no pronounced foliage discoloration: Natural senescence.

Z[2] Trees of all ages, most frequently ponderosa, Jeffrey, Coulter, or Monterey pines, and big-cone Douglas-fir, retain one or two needle whorls in upper crown and one in lower crown; needles have intense chlorotic mottle and sometimes tip necrosis, needles often shortened and in late summer fall easily from the stem. Branches of lower crown dead or dying: Chronic ozone injury.

Z[3] Chronic damage by defoliator insects, e.g., Douglas-fir tussock moth.

$Y^4$ Affected trees distributed individually or grouped in recognizable patterns .......................................................... $A^0$

$A^{01}$ Pole-sized western white pine on dry sites; leaders and needles shortened, needles yellow, symptoms progress downward and inward; resin bleeding associated with flat or depressed area in bark: Pole blight.

$A^{02}$ Trees recently damaged by red belt or summer drought, after older needles have fallen off and before a sufficient number of seasons have elapsed to allow recovery.

$A^{03}$ Trees infected by a root disease fungus, e.g., *Fomes annosus* or *Armillaria mellea* (Chapter 6).

$A^{04}$ Trees damaged by salt accumulation.

# Effects of Low Winter Temperatures

## Winter Killing, Winter Injury

Extremely low temperatures can kill the needles, buds, twigs, and the inner bark of conifers. Needles are usually completely brown regardless of age (fig. 1-1), however, irregular brown and green tissues may result in less severe cases of injury. Discrete brown flecks mainly on the upper needle surface commonly occur with greatest intensity on the older needles which are exposed to the sky and snow deposition (fig. 1-2, lower). Minima ranging from -31 to -45° F caused extensive damage to ponderosa and Jeffrey pine east of the Sierra Nevada crest. Affected trees recovered unless the inner bark tissues of the main stem had been injured.

The severity of low temperature injury varies between and within a species; for example, differences in winter injury have been observed among white fir seedlings depending on seed source. In eastern Washington, ponderosa pine receives greater injury than Douglas-fir during midwinter low temperature episodes. Injury to needles of coast redwood seedlings resulted during an 8-day period when the temperature remained between -5 and -1° C. Inland plantings of Monterey pine especially above 1,500 feet elevation in southern California are badly damaged when temperatures remain below freezing for several hours during 1 or 2 consecutive days.

*Top kill* — Top kill of Coulter pines in southern California results from freezing of inner bark tissue down to about 5 inches in diameter when a quick drop in temperature to approximately 20°F followed an abnormally warm period of 11 days; this particular damage is called spiketop. Similar injury has been observed on ponderosa pine in northern California. Spiketop may also be caused by drought, lightning, bark beetle attack, defoliator insects, or the mistletoes (fig. 1-3).

*Frost crack* — Frost cracks are frequent in older white fir trees, particularly those on the east slope of the Sierra Nevada, and on grand fir in northern Idaho and Montana. During periods of sudden cooling the wood cylinder shrinks more in a tangential than a radial direction, resulting in cracks that usually do not extend more than 20 feet above

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Figure 1-1. A Monterey x knobcone pine hybrid severely injured by below-freezing temperature in midwinter.

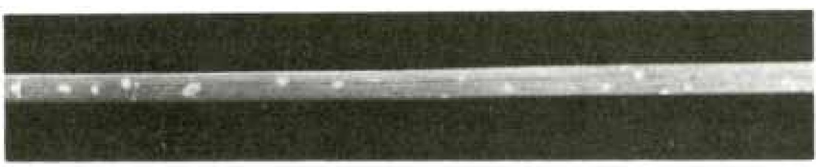

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Figure 1-2. Discrete necrotic flecks on a ponderosa pine needle associated with winter conditions only, particularly snow deposition.

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**Figure 1-3. Top kill of Jeffrey pine associated with drought. Similar "spiketop" appearance may be caused by cold temperature, lightning, insects, or mistletoe.**

the ground. Callus tissue forms over the surface of the crack in the first year. The crack is split and healed again successively through the seasons until it heals completely. Frost cracks are often the source of a watery exudation from the bole of white fir. This exudate is often called "slime flux." Large callus growths that project some distance out from the normal circumference of the trunk are called "frost ribs."

## Frosts in Spring and Autumn

Tolerance of foliage, small branches, and main stems to cold temperature depends on "hardiness", which in turn is closely correlated with the time of year. Low temperatures above freezing and short photoperiods induce frost hardiness. The changes in plant cells which are associated with frost hardiness include increases in both osmotic pressure and cell protein content. Freezing injury is most often caused by ice crystal formation within the cell and less frequently by dehydration of tissue by extracellular ice crystal formation. Increases in osmotic pressure and cell protein content may inhibit intracellular formation of ice crystals. The sudden occurrence of below freezing temperatures (frosts) in spring or early autumn can severely damage unhardened tissues, actually killing young shoots and needles.

*Autumn frost injury* — Any succulent shoot tips and current-year needles will be injured if growth is still in progress. A partial list of conifers in order of increasing frost sensitivity includes lodgepole pine, Jeffrey pine, ponderosa pine, incense-cedar, sugar pine, and white fir in California. Recovery can be expected the following spring.

Frost lesions form on the main stems of small Douglas-firs as a result of a sudden drop in temperature before tissues have hardened off. Later the sapwood is exposed when the dead bark tissue cracks and falls off. Eventually the lesion is calloused over, but in the meantime decay fungi may enter the area.

*Spring frost injury* — Spring frost causes differing amounts of damage to conifers depending on the stage of growth and development at the time of injury. Before bud break, some buds may be killed. After bud break, there is damage to the new leaves and soft succulent shoots. The brown, dead portions usually remain on the tree and a new shoot is produced (fig. 1-4). Trees that are repeatedly injured by frosts are characterized by long, dead main stems with a dense growth of needles developing at the base forming a bushy appearance (fig. 1-5). Frost injury that is not severe enough to cause death of succulent tissue often results in crooked shoots. Spring frost damage may vary considerably on the same species because it is dependent on the stage of development of the new tissue. For example, the more advanced growth at the lower elevational range of a species would result in greater injury than at the upper limits where the stage of development is in an earlier phase.

After an abrupt temperature drop to -10° C in mid-April in New Mexico, the order of increasing sensitivity in several species was alligator juniper, Douglas-fir, ponderosa pine, white fir, and limber pine. Limber pine was the most severely damaged because its growth was the most advanced in its lower elevational range.

Both spring and autumn frost injury is likely to be localized where topographic conditions cause the pooling of cold air. These depressions are referred to as "frost pockets."

## Winter Temperature, Sunlight, and Wind Interactions

*Red belt* — The occurrence of trees with variable lengths of their crowns from the tip downward that display dead, reddish-colored needles and that are distributed in well-defined bands varying from less than 20 and up to 1,000 yards wide on slopes and benches is a condition called "red belt." Extensive damage may develop when an unseasonably warm spell in winter is followed by a sudden drop in temperature.

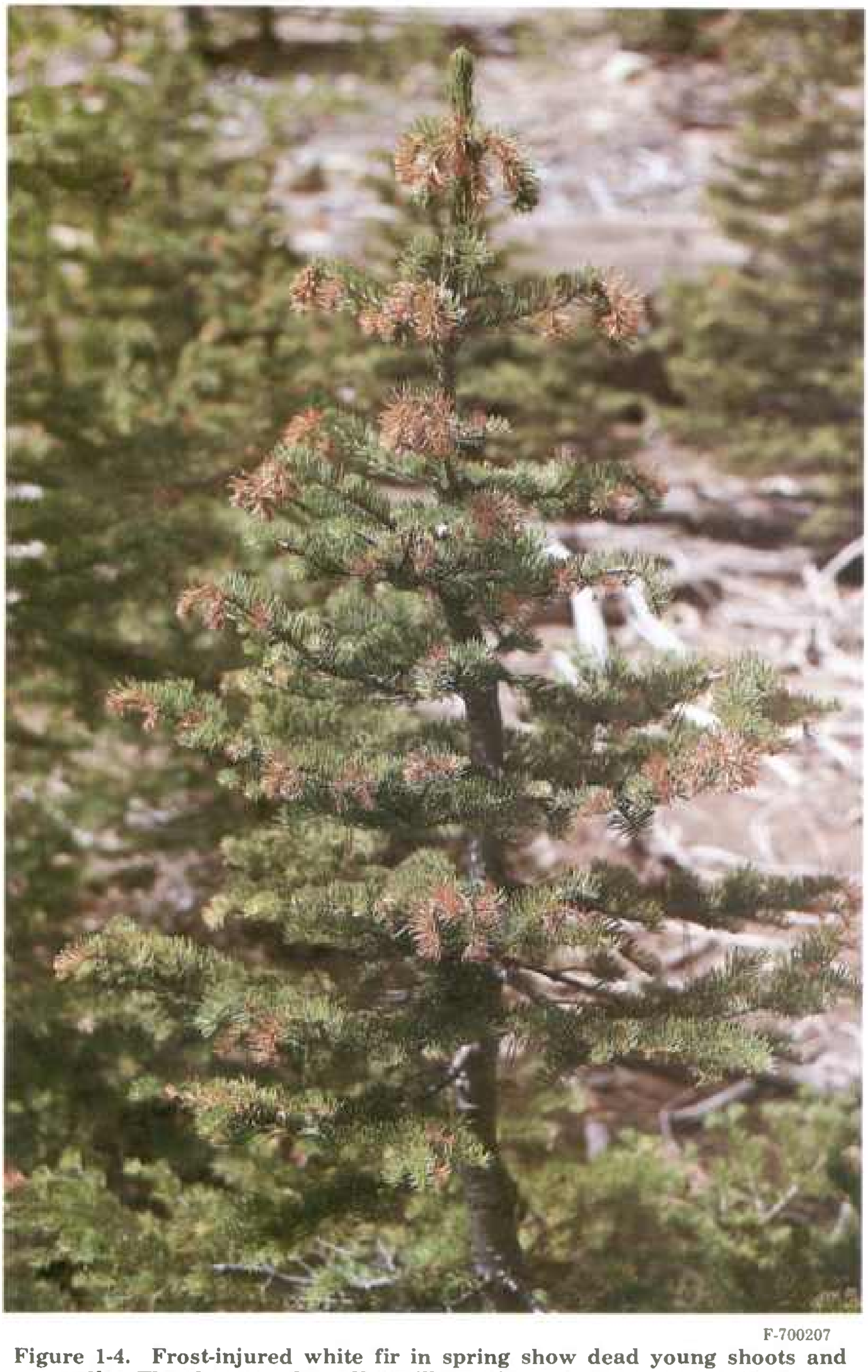

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Figure 1-4. Frost-injured white fir in spring show dead young shoots and needles. The shoots and needles will remain on the tree through summer.

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**Figure 1-5. Repeated frost injury to bishop pine planted out of its natural range results in numerous dead branches and ragged tree crowns.**

The belt is formed because of a warm temperature inversion layer that impinges at varying elevations along the slope, depending on time of day. The valley bottoms are constantly filled with cold air, but the sudden occurrence of warm dry foehn winds (Chinook or Mono winds) form a relatively thin layer of warm air on top that does not mix downward. At night, normal cold air drainage down the slopes fills the valley to a greater depth and raises the warm air layer above its daytime level. Trees exposed to unseasonably warm air by day receive cold air at night. This alternation of warm and cold air exposure with the soil usually frozen causes injury because daytime transpiration removes moisture from the needles more rapidly than it can be replaced by roots in frozen soil. Older needles fall off, leaving only current-year needles on living branches.

*Winter drying or sun scorch* — When bright sunny days follow a period of below freezing temperatures, several western conifer species — typically western red cedar — experience conditions causing the leader and several of the youngest branch whorls to die. Usually the south, southeast, or southwest sides of mostly small trees on the border

F-700209

**Figure 1-6. Young shoots and needles of Jeffrey pine, particularly those on the sunny side, have been desiccated. This occurred during sunny, warm winter days when roots and stems were too cold for adequate water transport.**

of denser stands, or sometimes the entire exposed crown of isolated trees show reddish-brown needles (fig. 1-6). Lower portions of the crown where needles are covered with snow never show injury.

The localization of injury on the sunny side of the trees suggests that rapid thawing in the bright sun and transpiration without replacement of water because roots and bole are very cold or frozen causes irreversible desiccation of the needles. After repeated incidents, the more sensitive species such as lowland grand fir and incense cedar will develop a bushy appearance (fig. 1-7). Limber pine native to high elevation sites near timberline has a permanent prostrate form because of continuous injury to new growth (fig. 1-8).

*Parch blight* – Brief episodes of dry winter (Chinook) winds occur occasionally in western Washington and Oregon. The winds originate east of the Cascades. During these episodes the needles of Douglas-fir on the eastern edge of single exposed trees, and particularly trees on the eastern edge of stands, become brown. Even last year's shoots may be killed. The soil is not frozen at the time but apparently transpira-

F-700210

**Figure 1-7. An incense-cedar has an unusual bushy form because of repeated desiccation of the top not protected by snow.**

tion losses exceed the rate of water absorption possible by roots in a cold soil. Injured trees recover almost completely by the following summer.

## Minor Effects of Low Winter Temperatures

*Winter yellows* — One of the least harmful effects of cool winter temperatures is the winter yellowing or chlorosis of conifer needles. A breakdown of chlorophyll begins with the first frost; foliage exposed to direct sunlight shows the most severe symptoms, namely, a brassy yellow-green. Giant sequoia often turns to a bronze color. The chlorophyll content is restored and the needles become green after the first weeks of warm weather in spring.

*Purple top* — Ponderosa pines and western white pines grown in exposed nursery beds show a purple discoloration of the youngest

F-7002110

**Figure 1-8. Prostrate growth of this limber pine near timberline was caused by repeated freezing and desiccation of upper needles and branches not protected by snow.**

foliage. The tops may eventually become brown and die; surviving seedlings have a bushy appearance.

*Necrotic fleck* — Discreet tan flecks only on needle surfaces facing skyward are a common occurrence on conifers throughout the West (fig. 1-2, lower). Histological evidence has eliminated fungi as a cause and implicated low temperatures. Circumstantial evidence suggests that exposure to snow is a prerequisite for injury to develop. Flecks are most numerous on the oldest needles, but do not seem to contribute to early senescence.

## High Temperature and Radiation Injury

*Needle scorch* — Leaves or needles that have developed under cool conditions may be injured by sudden temperature increases. For example, needle tip browning results in the latter part of a generally cool spring on coast redwood, Monterey pine, and juniper when temperatures suddenly reach 100° F.

F-700212

**Figure 1-9. Needles of this ponderosa pine have bent at the end of the fascicle wrap where tissue is soft and immature.**

*Shoot tip dieback* — The new developing shoots of Douglas-fir and white fir are particularly sensitive to a sudden rise in temperature in May and early June. This injury may be confused with spring frost damage because the shoot tips droop, turn red-brown, and later break off.

The effects of prolonged high temperatures during spring, summer and fall in conjunction with soil moisture deficiency and dry winds may result in extensive top dieback in large trees of several species (fig. 1-3). This condition resembles bark beetle damage, but lack of beetle galleries and the involvement of firs, incense-cedar, and pines together appear to disqualify insects as the cause.

*Needle droop* — Sudden and excessively rapid transpiration may result in abrupt needle droop caused by collapse of the tissue near the base of young succulent needles. This condition may be followed by death of current-year needles. The condition is observed on pines in California (fig. 1-9).

*Heat canker or bark scorch* — On rare occasions, the southwest sides of the main stems of young western white pine, Douglas-fir, spruces, and true firs will develop cankers during the first few years after the stand is thinned. In Douglas-fir, there is a yellowish to reddish discoloration followed by a slight sinking of bark tissue. Later, the bark cracks and scales off. Healing is generally very slow.

An apparently benign effect of high air temperature is sugar exudation by needles of Douglas-fir reported in eastern Washington. Sugar exudation and subsequent growth of sooty mold fungi on needle surfaces are commonly observed on conifers infested by aphids.

## Soil Moisture Deficiency

*Drought* — Soil-drought conditions usually develop first on gravels and sands that can hold very little water or on sites where shallow soils overlay rock or gravel. For this reason, drought-damaged trees usually occur in groups. Conifers that are undergoing only moderate moisture stress will shed older needles prematurely — often accompanied by needle tip and small twig dieback. Under more severe stress the needles of the leader and upper branch whorls turn light tan, advancing from tip to base of each needle with a narrow band of yellow tissue between green and tan portions. Drought stress symptoms progress from the top down and the outside in. The symptoms remaining on surviving trees in subsequent years include dead tops, fewer needle whorls and shortened needles in the whorls formed following the drought years. The growth of trees that survive drought is retarded. With some conifers, reduced diameter and height growth appear 1 year after the drought. Generally, seedlings and saplings are more severely affected and often killed because they have less extensive root systems than larger trees.

During severe drought conditions in California in 1929 and 1960, Douglas-fir and incense-cedar were killed or injured on poorer sites but ponderosa pine, sugar pine, and white fir on similar sites were less seriously affected. Small incense-cedar and Douglas-fir were the first to show drought symptoms. Western white pine were more seriously affected by drought than nearby Douglas-fir and lodgepole pine. Italian stone pine, aleppo pine, Italian cypress, and Arizona cypress were highly drought tolerant; Jeffrey and Coulter pines were slightly drought tolerant and Monterey pine was not drought tolerant in comparative tests. Knobcone pine, Torrey pine, single-leaf pinyon pine, and digger pine successfully occupy dry sites.

*Pole blight* — This disease is confined to pole-sized western white pine north of the Clearwater drainage in the Idaho panhandle and extending northward into parts of Montana, Washington, and British Columbia. Affected trees occur randomly first, later coalescing into limited patches. The first evidence of injury is a radial growth followed by reduced leader and branch growth. Older needles drop and remaining needles are shortened and yellow. The disease spreads downward and inward until the whole crown is affected. Resinous stem lesions, appearing as flattened areas on the stem, are a common symptom.

After extended dry and warm weather, western white pine does not regenerate rootlets fast enough to replace those lost due to moisture stress. The decline of the crown is a secondary reaction that reflects the effects of a degenerated root system. Dry sites, i.e., those with low soil moisture storage capacities and recharge potentials encourage pole blight development.

## Soil Moisture Excess

Damage by excess soil moisture is confined to specific sites. Problems occur along the shoreline of new reservoirs or beaver ponds and along new river channels formed by flooding (fig. 1-10). The water table may be raised where highway embankments impede normal drainage.

Overwatering of conifers in ornamental plantings is also a common problem. Damage is caused by the depletion of the oxygen supply to the roots and the problem is more severe on poorly drained and poorly aerated clay soils than on sandy soils (fig. 1-11). The death of native conifers in newly established lawns is a common problem.

The injury may be discovered at any stage ranging from greenish yellow or brown foliage throughout the crown to dead snags. Excess soil moisture may also encourage the "water mold" fungi, which causes serious root rots — particularly in ornamental plantings on former agricultural soils.

There may be some demonstrated differences in species response to high water table. For example, lodgepole pine may persist longer under these conditions than ponderosa pine.

F-700213

**Figure 1-10. These Jeffrey pines were killed by excess soil moisture when the water table was changed by a new beaver pond.**

F-700214

**Figure 1-11. A chronic problem of poor drainage over a period of year has caused yellowing and stunting of this juniper. Root rot fungi often are involved in such cases, thereby increasing damage and death.**

# Mineral Excess

## Excess Salt

*Roadside environment* — Mineral excess in needle tissue results from salt absorption through the roots or by direct foliar contact. The uptake of chloride salts by the roots of roadside trees is a common problem wherever sodium chloride and calcium chloride are applied to icy highways in the winter (fig. 1-12). In the Lake Tahoe Basin of California and Nevada, the average distances from the edges of highways to trees showing different salt damage ratings were: no damage 41 feet, light damage 21 feet, moderate damage 20 feet, and severe damage 15 feet. The final result of accumulation of salt in the tips of conifer needles is needle tip dieback. The cause can be confirmed by analysis of leaf tissue and soil for chloride content. The dead tissue is reddish brown and may occupy as little as 2 or 3 cm of the needle tip or as much as two-thirds of the needle. The increased salt content of the soil also decreases water uptake by trees, thus inducing an artificial drought. Highway maintenance programs sometimes use borate salts for weed control along roadsides (see Injury from Herbicides). Many roadside trees are killed by chloride and borate salts.

*Irrigation water* — Careful observations have been made of ponderosa pines receiving salty irrigation water in ornamental plantings. The symptoms were chronic foliar chlorosis and needle tip dieback initiated by a 3- to 5-mm band of resin-infiltrated tissue that caused

F-700215

**Figure 1-12. Absorption of chloride salts from de-icing compounds applied to highways can cause severe needle necrosis, as shown by this Jeffrey pine.**

the distal needle tissue to become brown. This process was repeated and the bands still remained visible as darker areas. Severely affected trees were randomly distributed, retained only the current-year needles and some trees died.

*Coastal environment* — Salt damage may be expected in locations along the coast where trees have been planted on land fill, e.g., a marina. Eventually, the roots grow down to the salty water table. The damage is characterized by reddish brown needle tip dieback, the living needle tissue is yellow, and needle length is reduced.

Salt spray can severely damage conifers and other trees at some distance from the beach or ocean front. Following a storm with high winds along the California coast, only the windward side of trees had brown needles and damage was observed up to 1/4 mile or more from the beach. Occasional storm-related salt injury causes no lasting damage. A more common foliar damage to coast redwood has been attributed to salt spray. The flag form of cypresses and other conifers may

F-700216

**Figure 1-13. The prostrate forms of Torrey pines growing on the bluffs immediately above the ocean may have resulted from both wind pressure and gradual absorption of windborne salts by foliage.**

not be as much a result of wind pressure as of constant salt absorption causing death of needles, buds, and twigs (fig. 1-13).

*Excess fertilizer* — Nitrogen compounds can cause a "burning" of needle tips. This disorder is usually limited to Christmas tree plantations and nurseries, or other locations where trees receive intensive care. It may also be confused with injury by selective herbicides applied in excess to the soil. Recovery from excess nitrogen injury may be expected to be more rapid than recovery from herbicide injury.

*Sewage effluent* — Trees growing near places of habitation may receive sewage water from drainage fields or treatment plants. After an initial growth stimulation, trees show symptoms resembling those caused by soil sterilants (boron) appear in the second year; some trees can be expected to die thereafter. Jeffrey pine, sugar pine, and white fir trees have been killed in the vicinity of leach lines.

## Soil Parent Material

*Serpentine soils* — Soils derived from igneous rocks of the same name occupy thousands of acres in Lake, Napa, Marin, and Sonoma counties, and in some Mother Lode counties of California, as well as in the Siskiyou mountains of Oregon. In Lake County, a sparse kind of chaparral, including digger pine, is present on the soils derived from serpentine. An abrupt line dividing vegetation types often marks the transition from serpentine soils to soils derived from other parent materials.

The dwarfing of trees on serpentine soils is attributed to high levels of magnesium that prevent absorption of calcium, further inducing a nutrient imbalance with respect to nitrogen, phosphorus, and some trace elements.

## Mineral Deficiency

Deficiency of the major nutrients, nitrogen, phosphorus, and potassium might be expected if trees are planted on land formerly used to grow crops. Nitrogen deficiency shows as chlorosis of the older needles, and stunted growth. Phosphorus deficiency results in a purple discoloration and withering of older foliage. Potassium deficiency causes chlorosis and needle tip dieback of older needles.

## Herbicide Injury

Chemical herbicide applications are usually associated with particular land-use situations, including the control of brush around dwellings, on fuelbreaks, and along roadsides, railroad tracks, and powerline rights-of-way. Damage to desirable species at the edge of the control area is usually caused by direct but accidental application or by drift of the spray droplets on foliage and root absorption when herbicides are applied to the surface near adjacent trees.

The symptoms of herbicide injury to conifers are numerous but not as well known as those on herbaceous plants. Some categories of symptoms to expect include: Twisting of needles and shoots and necrosis (hormone-type herbicides such as 2,4-D, 2,4,5-T, picrolam) (fig. 1-14); severe stunting (thiocarbamates); chlorosis and necrosis by root-absorbed herbicides (aminotriazole, triazines, substituted ureas, monuron, arsenics, borates, and chlorates); yellow-white bleaching (aminotriazole); and desiccation (weed oil) (fig. 1-15).

Sometimes herbicides that are absorbed by roots on one side of the tree will damage only that foliage supplied by those roots. Root-absorbed herbicides usually cause death or lasting damage in the most severe cases. Conifers usually recover from hormone-type herbicides with little lasting damage.

Herbicides like simizine used to control weeds selectively in Christmas tree plantations may cause injury to Monterey pines if soils are sandy.

## Injury From Air Pollutants

*Particulates* — Solid particles such as flyash, road dust, or dust from cement plants are often harmful to conifers in the immediate vicinity of the source. Injury results because light is prevented from reaching the needle surface, thereby reducing the photosynthetic activity of the tree. In some cases, the cement dust or flyash may have toxic compo-

F-700217

**Figure 1-14. Damage by 2,4-D spray drift occurring after needle elongation caused yellowing and drooping of the old needles of Jeffrey pine.**

nents that injure the needle tissue directly. Both effects result in premature defoliation of the tree. Damage can be expected only in the immediate vicinity of the source because all but the smallest particles settle out rapidly.

*Gaseous pollutants* — Gaseous air pollutants are dispersed over much wider areas than particulate pollutants. Sources may be classified as: (1) point sources — the stack of a power generating plant or factory, (2) an area source — a metropolitan complex, and (3) a line source — a heavily traveled highway.

Topography and local meteorological conditions are important factors that determine the degree to which pollutants concentrate in the atmosphere. These two factors define air basins, which are regions where communities share a simlar air mass and meteorologial conditions.

The meteorological conditions most responsible for concentration of air pollutants include the radiation temperature inversion, which is typical of inland valleys, and the marine temperature inversion, in

F-700218

Figure 1-15. Injury to incense-cedar as a result of direct spray application of weed oil.

coastal valleys. The distinctive feature of the temperature inversion is a warmer layer of air sandwiched in between a cool air layer near the ground where pollutants concentrate and the cool, relatively clean air above. The prevailing windspeed and direction determine the horizontal transport of the pollutants while the structure of the vertical temperature profile determines the vertical dispersion of pollutants. Low windspeed enhances concentration of pollutants. Both the inland flow of marine air and the daytime upcanyon or upslope flow on sunheated mountain slopes transport pollutants concentrated beneath the inversion layer to forested areas.

*Ozone* — The most important cause of air pollutant damage to conifers in California is ozone ($O_3$). Ozone damage is most severe in the southern California mountains; on the westside of the southern Sierra Nevada, injury has been slight and concentrated mainly east of Fresno. Ponderosa pines moderately and severely injured by ozone are more frequently attacked and killed by bark beetles.

Ozone is the major plant-damaging constituent of photochemical oxidant air pollution (smog). The source of this pollution is mainly automobiles and to a lesser extent industrial sources. Ozone is not emitted directly from automobiles or chimneys, but rather is formed by a complex chemical reaction in the atmosphere. Two primary pollutants, nitrogen dioxide and hydrocarbons (gasoline vapor) react with sunlight to produce ozone.

The distribution of ozone-damaged trees is typically near the border of an air basin (e.g., between coastal and desert areas) and in the predominant summer downwind direction from heavily populated areas. Damage is present as far as 80 miles east of the Los Angeles metropolitan area. The distribution of affected trees at a particular site is quite random. This indicates a high degree of variability in sensitivity within the species.

Ponderosa and Jeffrey pines are the first species to show injury and the amount of injury under field conditions to these pines can be identified with five descriptive categories.

1. *None* — four or more annual needle whorls retained, with no evidence of yellow or chlorotic mottle on any needles.

2. *Possible injury* — four or more annual needle whorls retained, but oldest whorl(s) displays distinct chlorotic needle mottle (fig. 1-2, upper), and sometimes may be easily pulled from the stem.

3. *Slight injury* — three or four annual needle whorls retained, with distinct chlorotic mottle on older needle whorls accompanied by premature needle abscission of oldest needles. The length of recent annual shoot growth may be reduced. Lowest branches show the most defoliation.

4. *Moderate injury* — two to three annual whorls retained, with intensification of other symptoms described under "slight injury."

5. *Severe injury* — one or two annual needle whorls retained in late summer, both with shortened yellow mottled needles with or without tip necrosis of the current and 1-year-old needles (fig. 1-16). Older needles fall easily from the stem. Chronic suppression of shoot growth is evident. Apical dominance is often diminished resulting in a flat-

F-700219

**Figure 1-16. Ponderosa pine needles injured by ozone show how the chlorotic mottle advances from tip to base and is always more intense on older needle whorls.**

topped crown. Lower and mid-crown branches are dead (fig. 1-17). Ozone injury to white fir develops according to the same sequence of events.

In fumigation trials, the order of decreasing ozone sensitivity of a number of western conifers where higher score ranges indicate more severe damage were 15 down to 10 — western white pine, Jeffrey x Coulter hybrid, red fir, Monterey x knobcone hybrid and ponderosa pine; 9.99 down to 5 — Coulter pine, Douglas-fir, Jeffrey pine, ponderosa pine (Rocky Mountain), white fir, big-cone Douglas-fir, and knobcone pine; 4.99 down to 1.5 — incense-cedar, sugar pine, and giant sequoia.

Monterey pine in Christmas tree plantations in southern California may have up to 10 percent of the trees severely injured by ozone; surrounding trees usually show some detectable injury (fig. 1-18).

*Sulfur dioxide* — Historically, sulfur dioxide has been a serious local problem in the Western States notably at Redding, Calif.; Anaconda, Mont.; and in the upper Columbia River Valley of Washington. Sulfur dioxide is a serious problem in areas where sulfur containing coal and oil is burned or where smelters process sulfide ores (copper, zinc, lead, iron).

F-700220

**Figure 1-17. During winter, only shortened current-year needles remain on this ponderosa pine severely damaged by ozone, and infested with bark beetles.**

On conifer needles, sulfur dioxide causes a reddish brown discoloration that often does not cover the entire needle but occurs in bands beginning at the needle tip. Middle-aged and older needle whorls are injured first and branches die progressively from the bottom of the tree to the top. Damage can occur anytime — even during mild winter weather. Less severe doses cause a chlorosis and premature abscission of older needles. Winter injury and drought symptoms usually cause a

F-700221

**Figure 1-18. In densely planted Monterey pine Christmas tree plantations, ozone damage is found in all degrees.**

brown discoloration of the entire needle but not as reddish as sulfur dioxide injury; symptoms appear in spring or late summer, respectively. Drought affects current-year's needles and the upper crown first; winter injury involves older needles as well, and is present throughout the crown.

The order of decreasing sulfur dioxide susceptibility of selected western conifers is: Grand fir, subalpine fir, western red cedar, western hemlock, Douglas-fir, western white pine, ponderosa pine, lodgepole pine, western larch, Engelmann spruce, western juniper, and Pacific yew.

*Hydrogen fluoride* — Fluoride damage to western conifer species was a difficult problem in the vicinity of Spokane, Wash., during the 1950's and more recently at Columbia Falls, Mont. Hydrogen fluoride is emitted from aluminum ore reduction plants, phosphate fertilizer plants, brick kilns, and glassworks.

The current-year's needles of conifers are the most sensitive to fluoride. Needle tip dieback begins while new needles are elongating in the spring, but the same needles become relatively resistant to further damage later in the season. Needle tips first become chlorotic and then turn brown. The needle tip dieback on older needles does not represent new injury but mainly injury which was received during elongation; these needles are usually shed. Foliar analysis for fluoride content is an excellent diagnostic method for confirming the cause if done by a laboratory with adequate experience. Serious errors result from poorly cleaned laboratory glassware. Ponderosa pine was virtually eliminated from some sites as the dominant species near Spokane, Wash. Other sensitive species include: Western larch, lodgepole pine, and Douglas-fir. Grand fir, blue spruce, and white spruce are less susceptible while arborvitae and juniper are tolerant.

*Minor air pollutants* — The air pollutants of minor importance are ammonia, chlorine, and hydrogen chloride. The first two pollutants are only present during brief episodes when containers in storage or transport accidentally burst or develop a serious leak. Hydrogen chloride results from incineration of polyvinyl chlorides. Ammonia and hydrogen chloride cause needle tip necrosis of all ages of needles. Chlorine causes both tip necrosis and various amounts of chlorotic mottle not unlike severe ozone injury.

## Effects of Fire

Conifers are most susceptible to fire damage early in the growing season when stem and shoot growth is active. The factors that determine tree survival after fire are the amount of bud and twig kill, foliage kill, and bark and cambium kill. Extensive heat kill of the foliage may occur without much damage to buds and twigs (fig. 1-19). A tree that overwinters with no live needles may survive unless high temperatures have killed the cambium tissue of the main stem. Several years after the fire, bark scaling is common on surviving thin bark species. Thicker bark has greater insulating capacity to protect the cambium from injury. Bark thickness varies from species to species and even within a species. The decreasing bark thickness and order of decreasing fire resistance of some selected western conifers is Sierra redwood, Douglas-fir, sugar pine, red fir, white fir, white pine, western red cedar, and lodgepole pine. Young trees of nearly all species are highly susceptible to ground fires (fig. 1-19).

F-700222

**Figure 1-19. Young trees are usually killed or extensively damaged by ground fires. This young plantation of sugar and Coulter pines shows heat kill of foliage that was not consumed by fire; older trees with thicker bark and no foliage close to the ground may survive fire.**

F-700223

**Figure 1-20. The large fire scar on this ponderosa pine is easily recognized by the charred heartwood remaining. Bole damage may vary from severely hollowed basal sections to flattened or depressed areas in the bark on one side of the stem, usually on the uphill side or leeward side of the tree with respect to the run of the fire.**

Cambium injury is ordinarily heaviest on the lee side of the tree with respect to the direction of run of the fire and on the uphill side of trees located on slopes. Killed patches of cambium are widest just above the ground and taper upward; however, charred heartwood is usually still present as confirming evidence of the cause of the canker-like area (fig. 1-20).

## Lightning Injury

The most common evidence of lightning injury to taller trees is the tearing off of bark and a thin layer of wood in a narrow strip, extending spirally around the trunk from the top of the bole to the butt (fig. 1-21). The tree top may be killed immediately; bark beetles often invade the

F-700224

**Figure 1-21. Symptom of lightning injury is typically a narrow strip of bark removed in a spiral course down the bole. This ponderosa pine had a powerline attached to the bole, which served as a ground. The strip usually continues to the soil.**

tree. This jagged furrow is easily distinguished from the ribs or cracks resulting from freezing or drought. Some trees, particularly white fir, are completely shattered. Either the top is broken or a large section of the lower bole "explodes" (fig. 1-22). Occasionally small circular groups of conifers may be killed by a diffuse electrical discharge without showing any outward signs of mechanical injury except for a foliage scorch.

## Injury by Mechanical Factors, Snow, and Ice

Heavy snow accumulations often bend or break the stems of younger conifers. Severely bent stems straighten after a few years, but snow bending can significantly reduce height growth the year after injury.

F-700225

Figure 1-22. Lightning often causes severe damage and kills trees. This white fir essentially "exploded" on being struck.

F-700226

**Figure 1-23. The flat-topped crowns of older pines are usually a sign of extreme age, but repeated removal of the top by heavy snow and ice loads causes the same appearance as shown in this small ponderosa pine.**

Extremely heavy accumulations of ice are common on ponderosa pine and other dominant conifers along exposed ridgetops in the southern California mountains. This results in broken tops as well as broken smaller branches throughout the crown. Many of the larger trees have broad, flat-topped crowns while the boles of pole-sized trees have many curves and distortions caused when lateral branches become terminal leaders (fig. 1-23). In areas where rotary snow plows are used, for example, along the Trans-Sierra highways in California, needle, twig, and branch damage and removal is common. The repeated impact of the snow plume can result in a tree with only half a crown along the lower and mid-sections of the stem on the side facing the road (fig. 1-24).

After a new fall of wet, heavy snow up to 3 or 4 feet deep, the snow settles immediately. The settling process tears small buried branches away from the bole which later may hang by a strip of bark.

F-525002

**Figure 1-24. Red fir severely debranched on one side due to the impact of the snow plume thrown by a rotary plow. This condition is common on several species along major all-weather highways in the Sierra Nevada.**

At higher elevations where deep snow is persistent, the freezing and thawing in the top layer produces large ice crystals under some conditions. High winds drive these crystals against the bark and the wood may be exposed in a 2- to 3-foot-long section on one side of the stem. This injury appears at heights up to 20 feet above the ground depending on snow depth.

## Hail

Hail causes defoliation, bud injury, and bruising or lesions on the upper side of stems and young cones. The trees are most severely damaged when new growth is in progress. The worst bruising occurs on upper branches and those on the windward side of trees. Immediately after the storm, many green needles and small shoots have fallen to the ground. Several years after a hail storm, the most obvious evidence is dead tops and one-sided crowns. Damage is sometimes confined to long, narrow strips through the forest. The species most severely damaged by hail is Douglas-fir; while white fir, incense-cedar, sugar pine, and ponderosa pine receive less injury.

## Wind

Topography, timber cutting practices, and land developments are important factors that determine the extent of windthrow or blowdown. Damage is usually heavy on ridgetops and upper slopes, but downslope winds can cause extensive damage. Winds at 40 to 50 miles per hour streamline or flow with the contour of the slope on the lee side, especially where the mountain barrier is at right angles to the wind. In the most severe situation, a clear-cut area on the windward side of the slope offers no barrier to the wind blowing into a timbered area on the lee side of the slope. As a result, winds blow with greater force along the contour of the lee slope than elsewhere and windthrow is more frequent.

Other associated factors that favor windthrow in decreasing order of importance are: Root and butt rot, particularly where roots on the leeward side fail under compression, shallow soils, and wet, poorly drained soils. The tree may also break at any point along the main stem, for example, at rust cankers, a beaver girdle, or where the bole is hollowed by fire. Swellings may develop at places where the stem was cracked but failed to break.

Some dominant trees that undergo constant wind rock tend to develop much sturdier root systems than those in the interior of a stand. It is common for individual trees left standing in a heavily cutover area to be windthrown within the first 2 years after the cut. Blowdowns create longer term problems like fire danger and bark beetle infestations. Extensive blowdowns have been reported frequently in the Pacific Northwest and in the Sierra Nevada.

## Human Activities

The use of heavy earth moving equipment can cause damage by severely debarking the stems or by severing large portions of the root system during excavation. These stressed trees are more susceptible to windthrow, stem decay, and bark beetle attack. The burial of the root systems by earth fill, asphalt pavement, or the deposition of silt on root systems downhill from construction sites will diminish the normal oxygen supply to the roots and may kill the trees in a single season (fig. 1-25).

The growth rates of larger conifers observed in public campgrounds throughout California have not revealed any changes over a 30-year period that could be directly related to recreational use. Young conifers, however, were susceptible to damage by recreation impact. No seedlings of the smallest size category were observed at any of several recreation sites and larger seedlings, saplings, and poles had generally decreased in number.

F-700227

**Figure 1-25. Incense-cedars killed by the anaerobic conditions induced when the dirt, rocks, and chunks of asphalt were dumped over the roots.**

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# 2. NEEDLE DISEASES

by

RICHARD S. SMITH, JR.*

Most conifers depend upon a 2- to 11-year complement of needles for maximum growth and development. When a large portion of these needles are killed, they are not replaced — and the growth of the tree is reduced. Complete defoliation is usually fatal.

Many agents are responsible for needle death. Older needles die naturally and are cast after a certain number of years on the tree.Some insects such as mites, scale, and aphids may kill needles. Abiotic factors, such as air pollution, herbicide sprays, salt injury, over-fertilization, high temperature, drought, and winter injury (red belt), kill needles or parts of them. Rust fungi may also cause needle diseases (Chapter 4). Root diseases (Chapter 6) may cause needles to yellow and die prematurely.

This chapter concerns needle diseases caused by fungi other than the rust fungi. Most of these diseases are identified by the fruiting bodies of the casual fungi which are found on the dead needles or dead portions of partially killed needles. These fungi often have life cycles which are timed with the growth and development of the host and may require 1, 2, or more years to complete.

Sporulation, spread, and infection of these fungi are frequently restricted to a specific season, such as spring, summer, or fall, and successful infection depends on whether conditions are favorable at the time. For example, in some needlecasts infection is frequently restricted to the newly developing needles, and sporulation is timed to coincide in spring with needle development. These rather rigid requirements for infection in some species result in only an occasional year of heavy infection on 1 year's set of needles. Consequently, the host is usually not completely defoliated and is not killed, but its growth rate may be reduced.

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# Descriptive Key

$A^1$ Needles and twigs enveloped in a brown felt-like mat of fungus — on lower branches or small or bent trees below snow line. . .Brown Felt Blight *(Herpotrichia nigra, Neopeckia coulteri).*

$A^2$ Needles not in brown felt-like mat — with various types of fruiting bodies on needle surface........................................................................B

- $B^1$ Needle diseases of Spruce...........................................C
- $B^2$ Needle diseases of Fir..................................................D
- $B^3$ Needle diseases of Douglas-fir ....................................H
- $B^4$ Needle diseases of Cupressaceae..................................I
- $B^5$ Needle diseases of Pine ...............................................J

## Spruce

$C^1$ On Brewer spruce — needles with black elliptical fruiting bodies in rows on either side of middle rib ........................................*Lophodermium crassum*

$C^2$ On Sitka spruce — needles with black elliptical fruiting bodies in rows on either side of middle rib ..............................................*Lophodermium picea*

## True fir

$D^1$ On bristlecone fir........................................E

$D^2$ On other firs................................................F

- $E^1$ Fruiting bodies brownish-black, large, extending down the middle of the needle for almost its whole length ...............................*Lirula nervisequia*
- $E^2$ Fruiting bodies greyish-black, elliptical, appearing in two rows, on each side of mid rib ......*Lophodermium decorum*

$F^1$ Fruiting bodies on needles of all ages, appearing as oval disc-like structures breaking through the lower epidermis in two rows, one on either side of the mid rib..........Snow mold, *Phacidium abietis*

$F^2$ Fruiting bodies brownish-black, large, elongate extending down center of lower surface of 2-year-old or older needles ................G

- $G^1$ Pycnidial fruiting structures appear as a single brownish line down the center groove of upper surface of needle ..............................................*Lirula abietis concoloris*
- $G^2$ Pycnidia needle colored to light brown appearing as two wrinkles or rows, one on each wing, along the upper needle surface .....................................*Virgella robusta*

## Douglas-fir

H[1] Fruiting bodies brown cushion-like elongate structures developing on lower needle surface on either side of mid rib
............Douglas-fir needle cast *Rhabdocline* spp.

H[2] Fruiting bodies small, black, spherical; appearing as soot-like streaks on undersurface of needle along each side of mid rib
.....Swiss Needle Cast *Phaeocryptopus gaumanni*

## Cupressaceae

I[1] Fruiting bodies appear as small shiny black elliptical fruiting bodies on leaves of juniper and incense-cedar .......*Lophodermium juniperi*

I[2] Fruiting bodies, olive brown to black, circular to elliptical breaking through upper leaf surface. Fruiting bodies later dropping out to leave a deep pit .............Cedar Leaf Blight *Didymascella thujina*
..........................................................or *Didymascella tetraspora*

## Pines

J[1] Infection perennial in twigs, resulting in necrotic flecks in inner bark; in a red flagging of almost all 1-year-old needles of infected twigs in the spring; and a brooming and upturning of infected twigs ..................................*Elytroderma deformans*

J[2] Infection not perennial in twigs; separate infection of each needle required; no brooming...............................................K

K[1] Infected needles with bright red bands or spots with black fruiting bodies on 1- , 2- , or 3-year-old needles
.................................................................*Scirrhia pini*

K[2] Infected needles not as above....................................L

L[1] Fruiting bodies on infected needles exposed by the splitting of the epidermis along stomatal lines and tearing at the ends of the fruiting body to form two door-like epidermal flaps which remain hinged at the side; exposed spore layer brown .....................
............................................*Naemacyclus niveus*

L[2] Fruiting bodies opening by a narrow slit, elliptical to elongate, black to brown ...............................M

M[1] Host in the White pine group ..................................................N

M[2] Host in the hard pine group ......................................................R

N[1] Fruiting body light brown to concolorous with the needle surface...............................*Lophodermella arcuata*

N[2] Fruiting body black ..................................................O

O[1] Fruiting body shiny black with irregular black crust-like growth of fungus tissue.............................*Bifusella linearis*

$O^2$ Fruiting body without associated crust-like growth ........... P

$P^1$ Fruiting bodies shiny black, elliptical, associated pycnidia brown, on needles of singleleaf pinyon pine ............ *Bifusella pini*

$P^2$ Fruiting bodies large black, associated pycnidia black on whitebark and limber pines .......... *Bifusella saccata*

$P^3$ On other white pines ............ Q

$Q^1$ Fruiting bodies shiny black, elliptical, occurring subcuticularly in groups on outer surface of needles; group of fruiting bodies separated from adjacent groups by distinct black lines bisecting the needle ............ *Lophodermium nitens*

$Q^2$ Fruiting bodies dull to shiny black, elliptical, occurring in rows on all surfaces of 3-year or older needles. Infected needles often remain on tree and turn grey ......... *Lophodermium pinastri* complex

$R^1$ Fruiting body light brown to concolorous with needle surface ............ S

$R^2$ Fruiting body black ............ T

$S^1$ Fruiting bodies oval and concolorous, on ponderosa and lodgepole pine ............ *Lophodermella cerina*

$S^2$ Fruiting bodies elongate, concolorous to brown on ponderosa and knobcone pine ............ *Lophodermella morbida*

$T^1$ Fruiting bodies often found in dead areas of live green needles ............ U

$T^2$ Fruiting bodies found on completely dead or faded needles ............ V

$U^1$ Fruiting bodies in dead areas of live green needles of *Pinus radiata* or *P. attenuata*. . .

either *Davisomycella lacrimiformis*

or *Davisomycella limitata*

$U^2$ On lodgepole pine, fruiting bodies in dead areas and separated from green areas by an orange-brown band which remains even after the whole needle dies ............ *Davisomycella montana*

$V^1$ Fruiting bodies, elongate, black ............ W

$V^2$ Fruiting bodies elliptical, dull to shiny black, occurring in rows on all surfaces of 3-year-old needles. Infected needles often remain on the tree and turn grey ............ *Lophodermium pinastri*

$W^1$ Fruiting bodies elongate, black, wide — one-third to one-half the width of the needle, variable in length, occurring on lighter colored zones on dead 3-year-old needles ............ *Davisomycella medusa*

$W^2$ Fruiting bodies elongate, thin, occurring on dead 1-year-old needles, not found in lighter colored zone ............ *Elytroderma deformans*

# Brown Felt Blight

*Herpotrichia nigra*

*Neopeckia coulteri*

## Hosts

The brown felt blight is a foliage disease of conifers caused by two similar fungi, *Herpotrichia nigra* and *Neopeckia coulteri*. In North America, *N. coulteri* attacks the foliage of pines only, while *H. nigra* attacks conifers other than pines. Macroscopically, these two fungi are indistinguishable; their effects on the hosts are identical, and their life cycles are quite similar. So, traditionally, these two fungi have been treated together. These fungi are commonly but erroneously referred to as "snow mold."

## Distribution and Damage

Brown felt blight is distributed worldwide, and generally found throughout the coniferous forests of North America. The two fungi are usually found only at the higher elevations of mountainous regions, where enough snow falls to meet the unique requirements of these fungi.

The disease develops only under cover of snow; therefore, its attacks are limited to smaller trees and the lower branches of larger trees that are buried under snow in the winter. These fungi envelop twigs and needles in a dark brown, felt-like growth. Needles within the felt are infected and killed. This disease may on occasion kill seedlings and saplings that are covered by snow, but it has little effect on trees once they reach pole size. The damage done in the forest is minimal, but it has at times been a serious problem in snow-covered forest nurseries.

## Disease Cycle

Infection of the host branch occurs under the snow during winter. The exact mode of infection is unknown, but it has been suggested that it originates from infested litter on the forest floor. Under cover of snow, the fungus envelops the branch in a gray mycelium. After snowmelt and exposure, the fungus felt stops growing and turns a dark brown. The following summer, the mycelium remains inactive. The second winter, fruiting bodies (perithecia) develop on the felt under the snow. The fruiting bodies remain immature while the infected twig is on the tree, but ripen in late summer on the fallen twigs. Their role in the infection cycle is uncertain.

## Field Identification

This disease is easily identified in the field by the dense, dark brown mat of mycelium that envelops the needles and twigs (fig. 2-1). Small, black, spherical fruiting bodies can be seen on the second-year mycelial mats.

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**Figure 2-1. The brown fungus mat of the Brown Felt Blight covering the ends of branches of a red fir (top) and a sugar pine (bottom.)**

# Spruce Needle Casts

## *Lophodermium crassum*

## *Lophodermium piceae*

Two minor needle casts of spruce are found in the Western United States. *Lophodermium crassum* has been reported on Brewer spruce, in Siskiyou County, California. *Lophodermium piceae* has been found on sitka and Engelmann spruces.

In *L. piceae,* the black, elliptical, fruiting bodies occur in longitudinal rows on either side of the middle ridge of the outer faces of the needles. The areas occupied by one or a group of fruiting bodies are separated from one another by heavy black lines extending through the needle and along which the needle readily breaks. *L. crassum* is very similar. These two species can be separated only by a cross sectional view of the fruiting bodies. *L. piceae* is intraepidermal; *L. crassum* is subepidermal.

# Bristlecone Fir Needle Cast

## *Lirula nervisequia* ssp. *conspicua*

A disease similar to the other true fir needle casts and caused by *Lirula nervisequia* is found on bristlecone fir in Monterey County, Calif. The fruiting bodies are brownish-black, large, elongate structures extending down the middle of the undersurface of the needle for most of its length. Appearing only rarely, this fungus does little damage.

# *Lophodermium Decorum*

In the Western United States, *Lophodermium decorum* is found on shaded and weakened needles of grand fir. This rare fungus is easily differentiated from the other true fir needle casts by its two rows of short, elliptical, brown to grayish-black, fruiting bodies on the lower needle surface, one row on each side of the midrib. A similar but as yet unnamed species of *Lophodermium* has been reported on bristlecone fir.

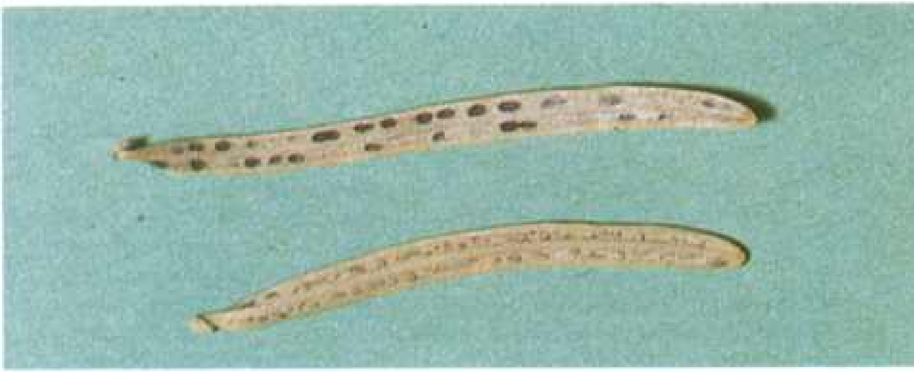

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**Figure 2-2. Snow blight of white fir caused by *Phacidium abietis*. The dark brown oval fruiting bodies are arranged in two rows along the lower needle surface.**

# Snow Blight

*Phacidium abietis*

Snow blight caused by the fungus *Phacidium abietis* has been found on the needles of white fir in the southern Cascade Mountains and the northern Sierra Nevada in California. At times, it has reached epidemic proportions in northern Idaho and eastern Oregon, killing reproduction of lowland white fir, alpine fir, and Douglas-fir. The fungus attacks all ages of needles during winter while under cover of snow. After the snow has melted, the infected needles remain on the tree and turn brown. Only those needles covered by snow during winter are attacked. In summer and fall, dark brown round to oval disc-like fruiting bodies break through the lower epidermis of the needle. The fruiting bodies are arranged in two rows — one on either side of the midrib (fig. 2-2). They mature and release spores from August to October. The following year the needles remain attached to the host and turn gray. The fruiting bodies fall away, leaving a cavity in the lower needle surface much like that which occurs in the cedar leaf blight.

# True Fir Needle Casts

*Lirula abietis-concoloris*

*Virgella robusta*

## Hosts

In the Western United States, *Lirula abietis-concoloris* and *Virgella robusta* have been found on white, grand, Noble, Pacific silver, and California red firs.

## Distribution and Damage

Both fungi are found throughout western North America generally wherever their hosts occur. As with many other needle casts, they appear sporadically and in many areas infrequently.

As a rule, these diseases are of little economic importance in the forest. Since they occur sporadically and attack only one year's complement of needles, they seldom kill a significant proportion of the host's foliage. Only if several successive years of infection were to occur would they defoliate trees and greatly affect host growth and vigor. Their most serious effect is to damage Christmas trees. The unsightly browning and premature dropping of the infected needles make the tree unsalable.

## Disease Cycle

Little information is available on the life history of these fungi. Field observations suggest a 2-year or longer life cycle, with infection occurring on young, developing needles, and fruiting structures maturing on these needles during the summer 2 or more years later.

## Field Identification

Both fungi may be identified by the presence of their elongate, dark brown to black fruiting bodies (hysterothecia) (figs. 2-3, 2-4) on 2-year-old or older straw colored needles. These fruiting bodies extend down the center of the lower needle surface for almost its full length. Infection is usually confined to 1 year's set of needles.

These fungi may be distinguished from each other by the arrangement of pycnidial fruiting bodies on the upper surface of the needles. In *V. robusta,* the pycnidia form two distinct concolorous rows or wrinkles — one on each wing of the infected needle (fig. 2-3). In *L. abietis-concoloris,* the pycnidia form a single brown line or occasionally a double row of dots in the groove down the center of the needle (fig. 2-4).

# Douglas-Fir Needle Cast

*Rhabdocline pseudotsugae*

*Rhabdocline weirii*

## Hosts

The two hosts of Douglas-fir needle cast are Douglas-fir and big-cone Douglas-fir.

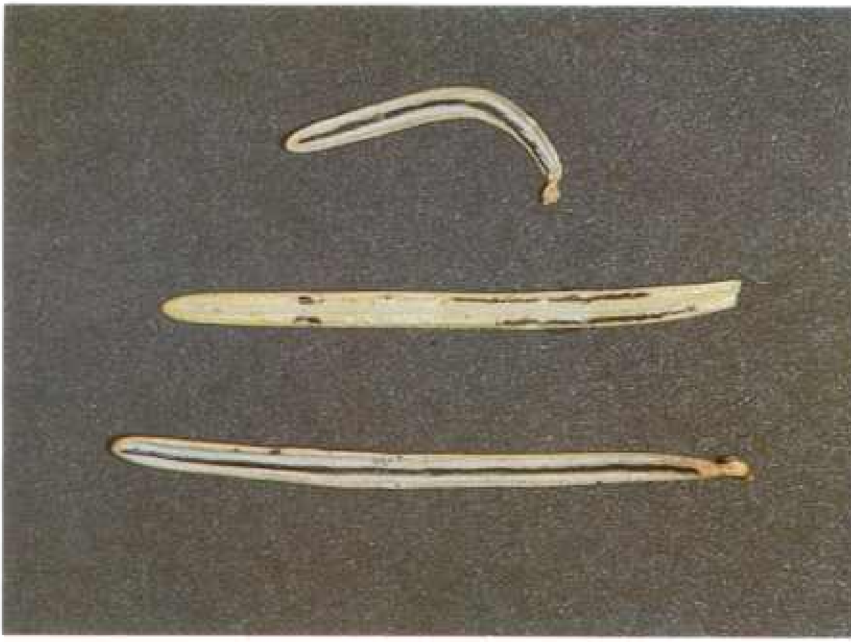

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Figure 2-3. *Virgella robusta* on the needles of white fir. The needle on the left shows the heavy dark hysterothecium on the lower surface of the needle, and the needle in the center shows the two rows of concolorous to brown pycnidia on the upper needle surfacece.

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Figure 2-4. The fruiting bodies of *Lirula abietis-concoloris* on white fir. The needle on the right shows the heavy dark hysterothecium on the lower needle surface. The needle on the left shows the single row of brown pycnidia down the center of the upper needle surface.

## Distribution and Damage

The Douglas-fir needle cast, the single most important needle disease of Douglas-fir, is caused by any of two subspecies of *Rhabdocline pseudotsugae* or three subspecies of *R. weirii*. Inasmuch as the main differences between these species and subspecies of fungi are microscopic, this handbook treats the disease, and its causal fungi, as one.

The disease, originally native to the Douglas-fir regions of western North America, is now also found in eastern North America and Europe. In California, it has been found in most native Douglas-fir stands, where it appears sporadically.

This disease appears on needles 1 year old or older. *R. pseudotsugae* is found only on 1-year-old needles, while *R. weirii* is found on older needles as well. And *R. weirii* subspecies *obovata* occurs only on needles 2-years-old or older. A single attack usually results in only partial defoliation of the host. Trees subjected to several consecutive years of attack may be completely defoliated and killed or severely restricted in growth. In California, where these conditions rarely occur, the disease is more unsightly than damaging. The greatest damage results from an attack on potential Christmas trees since the partial defoliation makes them unsalable for a few years. This disease is most severe on younger trees up to pole size. Mature trees when attacked usually are only slightly affected.

## Disease Cycle

Fruiting bodies, on the undersurface of needles infected the previous year, mature in May or June and ascospores are released at this time. These spores, carried by air currents, land on and infect this year's young developing needles. The fungus continues to develop in the newly infected needle that summer and fall. The first symptoms appear early that first winter as slightly yellowish spots at the site of infection. During the winter these spots become larger and more distinct. By spring the spots have changed to a deep red-brown color, and many of the spots have merged. In late spring, elliptical fruiting bodies (apothecia) appear on the undersurface of the needle on either side of the midrib. These mature and sporulate in May or June and the infected needles are cast during the following summer. It is suggested that those subspecies appearing on needles 2 years old or older attack current year's needles, but have a 2- to 3-year developmental cycle in which necrosis occurs and fruiting bodies appear a year or two later.

## Field Identification

The best time for identifying this disease is in late spring, when the needles are still retained and the red-brown needle spots and developing fruiting bodies are visible. During the summer, generally all of the needles are cast, and the only field symptom is the absence of needles of 1 year's growth of the host.

The disease is characterized by the red-brown needle spots and the long brown cushion-like fruiting bodies (apothecia) which develop on either side of the midrib on the underside of the infected needles (fig. 2-5). At maturity, the epidermis covering the fruiting bodies splits irregularly, exposing an orange to orange-brown spore-bearing surface.

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**Figure 2-5. Douglas-fir needle cast caused by *Rhabdocline* ssp. The light colored fruiting bodies of *R. pseudotsugae* are located in the red-brown spots on the underside of an infected needle, as shown on the needle on the left.**

## Swiss Needle Cast

*Phaeocryptopus gaumanni*

The Swiss needle cast caused by the fungus *Phaeocryptopus gaumanni* damages Douglas-fir in Asia, Europe, and parts of North America. Along the Pacific Coast, where both the host and fungus are native, the disease causes little or no damage. The fungus attacks the host's needles, causing them to yellow, brown, and finally drop. In Europe, the current year's needles are infected and they die and are cast over a 1- to 3-year period. In the Pacific Coast area, the current and last year's needles show no signs of infection. Only needles 3 years or older show such signs. The small fruiting bodies push their way through the stomata in fall and winter and mature in the spring. Spores are released in May and June. The numerous small black spherical fruiting bodies appear as soot-like streaks on the undersurface of the needle along each side of the midrib.

### *Lophodermium Juniperi*

In the Western United States, *Lophodermium juniperi* occurs on junipers and incense-cedar. There is little indication that it is parasitic. The fungus forms small, shiny, black elliptical fruiting bodies on the leaves of the host. It is quite common on many ornamental junipers in city plantings.

## Cedar Leaf Blight

*Didymascella thujina*

Cedar leaf blight is a needle disease of the genus Thuja caused by *Didymascella thujina.* Native to North America and introduced into Europe, this disease is severest on seedlings and the lower branches of older trees. The foliage is attacked and in severe cases appears as if scorched by fire. In spring, circular to elliptical olive-brown to black fruiting bodies are formed in the upper surfaces of infected leaves. These are exposed by the rupture of the covering host epidermis. In late autumn, many young infected twigs drop off. On the remaining leaves, the presence of the disease is easily recognized by the deep pits which remain in the leaves after the fruiting bodies drop out. The disease is of little or no economic importance in the Western United States.

# Elytroderma Disease

*Elytroderma deformans*

## Hosts

Elytroderma disease of pines caused by the fungus *Elytroderma deformans* (Weir) Darker is considered to be the most important needle cast of ponderosa and Jeffrey pines in western North America. Its perennial nature and capacity to infect the host twigs, which is unique among the needle casts, enables it to maintain its populations even under adverse environmental conditions.

Although mainly a disease of ponderosa and Jeffrey pines, Elytroderma disease has been found on knobcone, lodgepole, and pinyon pines.

## Distribution and Damage

Elytroderma disease is limited to North America — mainly west of the Rockies. It is scattered throughout most of the pine forests of California and has reached epidemic proportions in certain specific environments, such as around lakes and along stream bottoms. Its concentration around lakes such as Tahoe, Almanor and Manzanita Lakes results in considerable impact on recreation and esthetic forest uses.

This fungus causes the premature death of 1-year-old needles, and a brooming and deformation of infected twigs and branches. The effect of the disease depends on the proportion of the host crown which is diseased. There is little effect upon the host until more than two-fifths of the twigs are blighted. The disease is most severe on seedlings, saplings, and poles with poor crowns. Although direct killing of mature trees by this disease is infrequent, moderate to severe infection predisposes the host to other diseases and to bark beetle attack.

## Disease Cycle

Spores of the causal fungus are released in late summer and early fall from fruiting bodies borne on infected needles. Air currents carry the spores to the current years's needles of a susceptible host. Under suitable conditions, the spores germinate and infect the needles. The fungus spreads throughout the needles and into the twigs without initially killing the needles. The following spring the infected needles die and turn a red brown and fruiting bodies which mature in late summer begin to form. The infection within the twigs spreads into the growing tips and buds, where it causes a brooming and deformation of future growth. New needles formed each year from infected buds are infected as they form. These needles stay green their first year, die in spring of their second year, and produce fruiting bodies in late sum-

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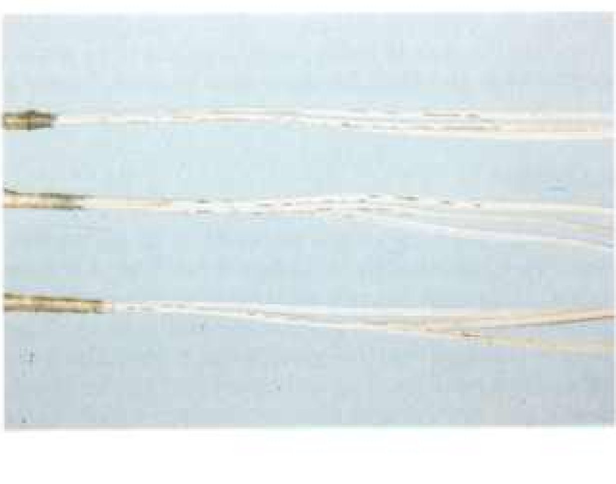
Figure 2-6. (Top left): A seedling infected by *Elytroderma deformans* shows the reddening of last year's needles and a brooming of the infected terminal. The current year's developing needles are green.

(Top right): Brown necrotic flecks in the inner bark of an older twig of ponderosa pine infected with *E. deformans*.



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(Bottom): The fruiting bodies of *E. deformans* appearing on brown needles in June are elongate, narrow, dull black, and scattered on all needle surfaces.

mer. Thus, *E. deformans* produces a new crop of spores each year for many years from the same infection.

## Field Identification

Elytroderma disease is relatively easy to identify in the field. The most conspicuous symptoms are reddening of the infected foliage in spring, the development of witches' brooms (fig. 2-6 — top left), and necrotic flecks in the inner bark of older infected twigs (fig. 2-6 — top right). The infected needles lose their bright red-brown color gradually through the summer. The brooms tend to be more compact and globose than those caused by dwarf mistletoe, and the ends of the twigs turn up. The brown necrotic flecks that appear in the inner bark of twigs infected for more than 3 years is quite characteristic. Their presence is one of the best evidences for confirming this disease. The fruiting structures of the fungus that appear on infected needles in June are elongate, narrow, dull black, and scattered on all surfaces of the needle (fig. 2-6 — bottom).

# Red Band Needle Blight

*Scirrhia pini*
*(Dothistroma pini)*

## Hosts

*Scirrhia pini* (imperfect stage — *Dothistroma pini*) attacks some 30 species, varieties, or hybrids of pines. In the West, it has been found on bishop, ponderosa, western white, lodgepole, knobcone, and Monterey pines and the Monterey x knobcone hybrid.

## Distribution and Damage

Red band needle blight is distributed worldwide. In western North America, it has been reported from north coastal California north into British Columbia and east to Idaho. In northern California, it is confined mostly to a few localized infection centers along the Pacific Coast.

This disease is considered to be the most destructive needle disease of pines on a world basis. Its recent discovery along the Pacific Coast, therefore, aroused considerable concern.

The fungus attacks the needles of susceptible pines, causing them to die and drop off. All ages of needles are susceptible. Under favorable environmental conditions, this disease can completely defoliate the host and eventually kill the infected trees. Monterey pine, although severely affected when young, becomes resistant to this disease after it becomes 20 to 30 years old.

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**Figure 2-7. The red band needle blight caused by *Scirrhia pini* showing the red banding around the infected needles.**

## Disease Cycle

Fruiting bodies (pycnidia) are produced in abundance on infected needles. In the presence of free water, these pycnidia liberate spores which are splashed or blown to uninfected needles. Under the right environmental conditions, the spores infect the new needles. The fungus grows within the needle tissue, killing the distal portion of the needle. Again, under favorable conditions, new pycnidia and spores are produced. Dead needles remain attached to the host and produce spores for about a year.

## Field Identification

The first noticeable symptoms are yellow to tan spots appearing at the site of infection. These spots turn a brownish-red and enlarge to produce the characteristic red band around the needle (fig. 2-7). This red banding of the infected needle is highly useful for diagnosing the disease. Small black fruiting bodies develop in the center of the red bands. The portion of the needle distal to the infection dies, while the uninfected base of the needle may remain green for some time.

# Sugar Pine Needle Cast

*Lophodermella arcuata*

## Hosts

The sugar pine needle cast caused by the fungus *Lophodermella arcuata* has been reported on sugar and western white pines from Idaho and Oregon. In California, it has been found only on sugar pine.

## Distribution and Damage

This disease is found generally throughout the West where sugar and western white pines grow. It appears more prevalent in Oregon and the northern part of California than in southern California, where it is found only in canyon bottoms.

This disease attacks only the current year's needles, and a single attack results in only partial defoliation of the host. Repeated consecutive infections, as have occurred in certain local areas, have led to reduced tree growth and vigor, and occasional mortality.

## Disease Cycle

This fungus infects newly developing foliage. Infected foliage remains green an entire year until the following spring (April to May), when the needles die and turn brown. This browning occurs before bud break, giving heavily infected trees a scorched appearance. At this time, there is no sign of the fruiting bodies. Fruiting bodies appear in mid-June and mature in July and August. The needles are cast in mid to late summer after spores are discharged.

## Field Identification

This disease can be identified in the field by the gray-brown to brown (almost the same color as the needle), elongate to elliptical fruiting structures, which develop on all surfaces of last year's dead needles.

# *Bifusella Linearis*

The fungus, *Bifusella linearis,* causes a needle cast of 2- to 3-year-old needles of western white, limber, and whitebark pines in the Western

United States. This disease ranges south from British Columbia to the higher mountains of California and east into Idaho. Because of its limited distribution, small host range, and restriction to older needles, the fungus is not considered to be a serious pest. The fungus forms shiny black, elongate, fruiting bodies of variable lengths on the surface of 2- to 3-year-old needles. Frequently associated with the fruiting bodies are black crust-like growths of fungus tissue (sometimes including pycnidia) that are irregular in size and outline (fig. 2-8). These crust-like formations are the most distinctive characteristic of this disease in the field.

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**Figure 2-8. The fruiting bodies of *Bifusella linearis* on the needles of limber pine. Note the black crustlike formation with its irregular margin.**

# Singleleaf Pine Needle Cast

## *Bifusella pini*

*Bifusella pini* occurs only on singleleaf pinyon pine in western Nevada and southern California. It forms long, shiny, black, elliptical, fruiting bodies (hysterothecia) on all surfaces of needles 4 years and older (fig. 2-9). Pycnidia, which are also formed, vary from brown dots to long irregular brown blotches on needles 3 years of age or older.

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**Figure 2-9. The long shiny black fruiting bodies of *Bifusella pini* on the two needles of singleleaf pinyon pine on the right and the brown pycnidia on the needle of the left.**

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**Figure 2-10. The fruiting bodies of *Bifusella saccata* on whitebark pine.**

# *Bifusella Saccata*

The fungus *Bifusella saccata* has been found on whitebark pine in California and limber and pinyon pines in Colorado. It has been reported only from elevations above 9,000 feet in the southern Sierra Nevada. Because of its limited distribution and small host range, this disease is not considered to be economically important. This fungus forms large, long, shiny, black fruiting bodies on the dead tips of green needles (fig. 2-10).

# *Lophodermium Nitens*

*Lophodermium nitens* is found in both eastern and western North America. In California, it is common on the needles of sugar pine, fairly common on western white pine, and rare on whitebark pine. The fruiting bodies are shining, black, elliptical, blister-like structures on the outer surface of the needles. They mature on dead fallen needles and occasionally on the tips of partially green attached needles. These fruiting bodies occur singly or in clusters. Each cluster is separated from adjacent clusters above and below by a very distinct black line bisecting the needle and along which the needle readily breaks (fig. 2-11).

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**Figure 2-11.** *Lophodermium nitens* **on the needles of sugar pine. Note the shiny black blister-like elliptical fruiting bodies and the fine black lines which cross the needles.**

# *Lophodermium Pinastri* Complex

In the Western United States, several similar but different species of needle cast fungi have in the past been lumped together and all called *Lophodermium pinastri*. This treatment of several species as one has caused much confusion in understanding the taxonomy and biology of *L. pinastri*. This complex contains a number of hard to separate and yet unnamed species. It is now under study and revision. Pending any changes, this handbook treats these species as a group of similar fungi that resemble *L. pinastri*.

The needle diseases caused by species of *Lophodermium* are found throughout the world and on many species of pine. In the Western United States, they have been found on digger, Jeffrey, Coulter, knob-cone, lodgepole, Monterey, ponderosa, sugar, western white, and whitebark pines. The diseases they cause are common, but do little or no damage to their hosts. In general, the fruiting bodies of most of these fungi appear on all surfaces of 3-year-old or older needles as dull to shining black, elliptical structures which tend to occur in lines or rows (fig. 2-12). Mature fruiting bodies open by a conspicuous longitudinal slit. The infected needles often remain on the tree for several years after dying and turn gray.

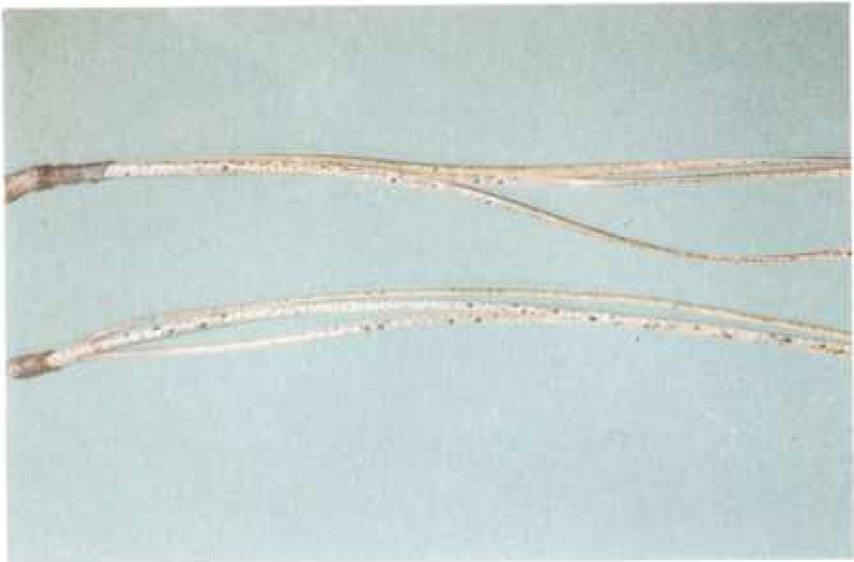

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**Figure 2-12. Needles of ponderosa pine infected by one of the fungi in the *Lophodermium pinastri* complex. The fruiting bodies are small, black, irregular in size, and scattered over the needle surface.**

# *Lophodermella Cerina*

The fungus *Lophodermella cerina* causes a needle blight of lodgepole and ponderosa pines in California from Modoc County south to Fresno County. The disease has been severe and damaging in certain areas for several years. The fruiting bodies of this fungus are short, oval, light brown to buff structures which are easily overlooked on necrotic pine needles. Af first, they are slightly darker and then the same color as the needle spot on which they occur. They develop in groups in buff to tawny waxy spots on live green or dead reddish-brown needles. The short concolorous fruiting body is the most distinctive characteristic of this fungus.

# *Lophodermella Morbida*

## Hosts

*Lophodermella morbida* is found on ponderosa pine in Oregon and Washington and knobcone pine in northern California.

## Distribution and Damage

This disease is found only in the mild, moist climate west of the Cascade crest in Oregon and Washington and the western slopes of the

F-700243

**Figure 2-13.** *Lophodermella morbida* **on ponderosa pine. The light to dark brown fruiting bodies occur in rows along the infected needles.**

Coast Range of northern California. It attacks the current year's needles, which become necrotic in late summer or early fall and then drop off the second summer. A single year's attack results in only partial defoliation, but repeated attacks, as have occurred in ponderosa pine in Oregon, result in complete defoliation and death of the tree. This pathogen has been described as a highly aggressive needle cast fungus.

## Disease Cycle

Needles of the current year are infected in June and become necrotic as early as the end of July. Pycnidia begin to appear in October, and light brown hysterothecia are faintly evident by mid-November. Ascospores are mature and ready for discharge by mid-June of the following year. Infected needles are cast shortly thereafter.

## Field Identification

This disease is characterized by light brown (concolorous) immature hysterothecia which darken as they mature. These elongate fruiting bodies (1 to 6 mm long) occur in an interrupted linear or occasionally double-rowed series that may extend the full length of the needle (fig. 2-13). The pycnidia are light brown, round to elongate structures, 0.25 mm in diameter and up to 3.5 mm long.

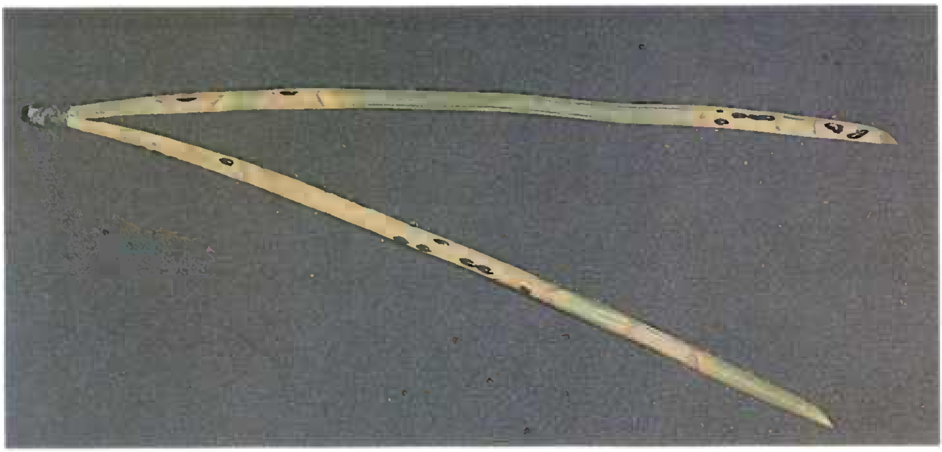

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**Figure 2-14.** *Davisomycella montana* **on lodgepole pine. The shiny black fruiting bodies are grouped in light straw-colored areas bordered by an orange-brown band.**

## *Davisomycella Limitata*
## *Davisomycella Lacrimiformis*

The two fungi *Davisomycella limitata* and *D. lacrimiformis* cause identical diseases of Monterey pine. The latter also attacks knobcone pine. The fruiting bodies are black, elliptical to oblong, often confluent and scattered on dead areas on still green living needles.

*D. limitata* has been found in central coastal California. *D. lacrimiformis* has been reported from the coastal mountains of California and Oregon. Both diseases appear to be of little economic importance.

## Lodgepole Pine Needle Cast

### *Davisomycella montana*

The lodgepole pine needle cast caused by the fungus *Davisomycella montana* has been reported in Idaho, Oregon, and California. Although widespread throughout California, the disease does not appear to cause much damage to its host except in a few localized areas. This disease is characterized by the appearance of fruiting bodies on dead brown areas on 2-year-old needles. The dead areas are frequently found on green needles and are separated from the green tissues by an orange-brown zone or band. This orange band remains visible even after the needle dies and turns brown. The fruiting bodies appear as shiny, black, raised, elliptical blisters scattered on all surfaces of the dead areas (fig. 2-14). These fruiting bodies mature during the period from July to September.

# Medusa Needle Blight

*Davisomycella medusa*

## Hosts

The medusa needle blight is found on lodgepole, Jeffrey, and ponderosa pines.

## Distribution and Damage

This needle disease is widely distributed throughout the ponderosa-Jeffrey pine forests east of the Cascades in Washington, Oregon, and northern and central California. It becomes a serious pest in local areas on individual trees, often causing a marked decrease in growth. It characteristically occurs in relatively pure open stands and tends to be most pronounced on medium to poor sites. It also tends to become more intense after a drought.

## Life Cycle

Fruiting bodies (hysterothecia) mature on infected needles in June, and spore discharge occurs in summer and fall. These spores are wind blown to nearby pines, where they infect the current year's needles. The disease remains latent for 2 to 4 years within the infected needles before a greenish-white fading of the infected foliage occurs. The fruiting bodies of the fungus then appear on the affected needles as elongate, blackish raised blisters.

## Field Identification

The best time for identifying this disease is in late spring to early summer. The elongate, black, raised, fruiting bodies are one-third to one-half the width of the needle and variable in length (fig. 2-15). They appear on greenish-white to straw-colored zones, which are lighter in color than the rest of the needle. These zones, occupying one-fifth to one-third the length of the needle, may occur on any portion of the needle, but are found more commonly near the base.

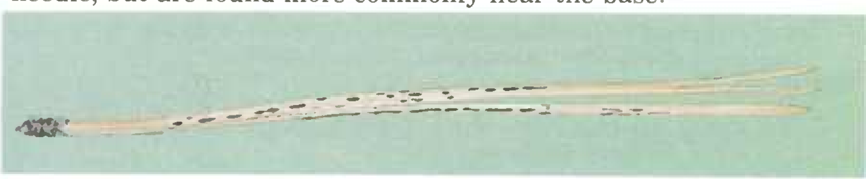

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**Figure 2-15.** *Davisomycella medusa* **on the needles of ponderosa pine. Elongate, raised, black fruiting bodies appear in the light-colored zones of the infected needles and are more numerous towards the base of the needle.**

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# 3. CANKERS, DIEBACKS, AND GALLS

by

ROBERT F. SCHARPF*

This chapter describes tree diseases known as cankers, diebacks, and galls. The term *canker* as discussed here refers to any localized necrotic area or spot on branches or trunks of trees caused by certain species of fungi. *Dieback* refers to rapid girdling or tip killing of twigs and branches that are caused mainly by canker fungi. *Galls,* commonly called burls, are pronounced swellings on trees caused by fungi, bacteria, mistletoes, insects, or other agents.

In many instances, initial infection by a fungus results in a localized canker that subsequently girdles a branch, causing dieback. Often dead branches are the only symptoms of the disease — particularly in small branches that are girdled and killed quickly with no apparent canker development. In other instances, both dieback and cankers occur on the same tree.

Cankers vary considerably in appearance and occurrence. They may be sunken or slightly swollen, circular or elongate in shape. Some show little or no healing, whereas others are progressively callused over so that concentric rings are formed. Cankers are either *annual* or *perennial*.

Annual cankers occur sporadically — for one year or one season only. They are caused directly by unusually severe weather conditions (see Chapter 2 for a description of cankers caused by adverse climate) or by a particular sequence of climatic conditions that favor the attack of trees by certain weakly parasitic fungi. Thus, annual cankers usually occur only during a year following periods of unusual weather conditions. Dead tissues eventually slough off annual cankers and the affected area becomes covered with callus in much the same way a wound is healed. Prolonged growth of annual cankers often results in dieback.

Perennial cankers are caused by biotic agents that remain active in trees more than 1 year. Sometimes fungi causing perennial cankers

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kill branches and trees, but more often they weaken and deform the hosts. Usually the circumferential growth of the tree exceeds the growth in canker size, thus preventing the tree from being girdled and killed. Perennial cankers often result in sunken, resinous, unhealed wounds on branches or trunks. See chapters 5 and 6 for descriptions of cankers caused by rust fungi and mistletoes. Perennial cankers caused by other organisms are described here.

In general, cankers do not constitute a serious disease problem in the coniferous forests of the West. With few exceptions they seldom reach epidemic proportions. Cankers are considered most serious in plantations and on ornamental or high-value trees. Occasionally, larger trees with trunk cankers constitute a hazard in some high-use areas because these trees are weakened or decayed at the canker site and may break during high winds.

# Descriptive Key

1. On Monterey Cypress .......................... *Seridium cardinale*
2. On Coastal Redwood ..................................... *Coryneum* sp.
3. On Giant Sequoia or Incense-Cedar ... *Botryosphaeria ribis*
4. On Douglas-fir
   - A¹ Fruiting bodies disc or cup-shaped when fresh, shriveled when dry .................................................. B
   - A² Fruiting bodies small globose, black, mostly embedded in the bark of larger dead branches ....................................................... *Diaporthe lokoyae*
     - B¹ Center of cup yellow to orange; outer margin hairy ......................................... *Dasyscyphus* sp.
     - B² Fruiting bodies small (1 to 1.5 mm diameter), black; formed on twigs or branches dead for about 1 year ............................... *Dermea pseudotsugae*
5. On True Firs
   - A¹ No branch dieback, spindle-shaped branch swellings often bearing leafless greenish shoots ......................................... Dwarf mistletoes-(Chap. 5.)
     - A² Branch dieback resulting in reddish brown flags ......................................... *Cytospora abietis*
     - A³ Branch and twig dieback but no conspicuous red-brown flags ................................................. B
       - B¹ Dieback of current year's growth only ....................................... *Sydowia polyspora*
       - B² Dieback on all ages of wood ..................... C
         - C¹ Fruiting bodies yellow to orange colored; cup-shaped when fresh or moist, brown to black outer surface, hairy margin (2 to 8 mm diameter) ................................ *Dasyscyphus* sp.
         - C² Fruiting bodies black; cup shaped

when fresh or moist........................D

D[1] Fruiting bodies (1 to 2mm diameter).....*Cenangium ferruginosum*

D[2] Fruiting bodies very small (0.5 to 1mm in diameter) .................*Grovesiella abieticola*

6. On Pines

A[1] Wood of cankered areas showing blackish stain ..........................................................................B

A[2] Wood of cankered areas not showing blackish stain ..........................................................................D

B[1] Sunken trunk cankers common and conspicuous ...........................................*Atropellis piniphila*

B[2] Sunken trunk cankers not conspicuous, infection mainly on branches and needles......................C

C[1] Noticeable disc-shaped black fruiting bodies 2 to 4mm in diameter on dead or dying branches..............*Atropellis pinicola*

C[2] Fruiting bodies not disc-shaped and conspicuous......................................................

(1) *Diplodia pinea*[1]

(2) *Dothichiza pythiophila*[1]

D[1] Branch swelling often present .........................E

D[2] Branch swelling not present ............................F

E[1] Small leafless orange-green shoots arising from swelling ...........................Dwarf mistletoe (chap. 5)

E[2] Yellow-orange spore bearing pustules arising from swelling.................Rust (chap. 4)

F[1] Fruiting bodies cup-shaped when moist, yellow or orange, outer margin hairy, 2 to 8 mm diameter ...................*Dasyscyphus* sp.

F[2] Fruiting bodies small, globose when fresh or moist, black 1 to 2 mm in diameter ..........................*Cenangium ferruginosum*

[1]These two fungi are difficult to differentiate under field conditions and must be examined in the laboratory for positive identification.

# Atropellis Canker

*Atropellis pinicola*

*Atropellis piniphila*

## Atropellis pinicola
## Hosts

Sugar pine is the most common host, but the fungus also occurs on western white, ponderosa, and lodgepole pine.

## Distribution and Damage

Although commonly found in the West, this organism primarily infects only branches of young, suppressed, or weakened trees or shaded, suppressed, lower branches of larger healthy trees. Except for young sugar pines in Oregon and California, trees seldom are killed or severely damaged. Thus, this fungus poses little threat to vigorous trees in well-managed stands.

## Field Identification

Typical symptoms and signs of infection by *Atropellis pinicola* include branch flagging, the presence of black fruiting bodies 2 to 4 mm in diameter on living or dead branches (fig. 3-1) and a blackish stain of the wood under the dead bark (fig. 3-2). The dry fruiting bodies are shriveled, irregular shaped structures. Fresh or moist fruiting bodies are cup-shaped.

## Atropellis piniphila

## Hosts

Lodgepole pine.

## Distribution and Damage

*A. piniphila* is a fungus that causes a perennial canker of lodgepole pines in the Pacific Coast States and Western Canada. Its southernmost distribution along the coast is the northern Sierra Nevada.

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Figure 3-1. Dried, shriveled, fruiting bodies of *Atropellis pinicola* arising from the bark of a twig of sugar pine.

F-700247

Figure 3-2. Black stain of the infected wood of a branch of sugar pine infected with *Atropellis pinicola*.

The organism appears to be restricted in occurrence by rather specific ecologic factors. Infection is often limited to trees growing on cool, moist sites, such as those in wet meadows and around lake shores.

## Field Identification

The most obvious symptom of infection is the presence of large, sunken, perennial, resin-soaked cankers on the trunks and branches of infected trees (fig. 3-3). Noticeable black, disc-shaped fruiting bodies 2 to 5 mm in size are usually present on the sunken bark surface. A bluish-black stain of the wood at the canker site is also an apparent symptom for identifying this disease.

Although bole cankers cause severe trunk deformation with an increase in infection age, only occasionally do they girdle and kill trees.

F-525003

**Figure 3-3. Sunken cankers formed on lodgepole pine as a result of infection by** *Atropellis piniphila.*

# Botryosphaeria Canker of Giant Sequoia

*Botryosphaeria ribis*

## Hosts

Giant sequoia, incense-cedar.

## Distribution and Damage

This fungus is common on giant sequoia and occasionally on incense-cedar planted outside of the natural range of these species. This organism is particularly damaging when giant sequoia is grown in the warmer lower elevational regions in the West. Trees in ornamental plantings frequently are attacked after the trees are several years old. The fungus progressively kills branches and may severely damage or kill trees.

## Field Identification

Initial symptoms of infection are scattered dieback of twigs and branches. With time, the fungus builds up and spreads throughout the crown. Occasionally tops are killed. Recently killed branches appear as reddish brown flags (fig. 3-4). Branches dead for longer periods are grey-brown and bare of much of their foliage. Infected branches often exude drops of pitch.

F-700248

**Figure 3-4. Severe branch flagging of giant sequoia caused by** *Botryosphaeria ribis.*

# Cenangium Canker

*Cenangium ferruginosum*

## Hosts

Common on Jeffrey pines, but also occurs on other pines and true firs.

## Distribution and Damage

This organism occurs throughout the West and is most common on trees up to pole size. Considered a weak parasite, this organism seldom kills trees. Suppressed or weakened lower branches are most commonly infected, but trees growing under poor conditions or weakened from other causes may be more severely attacked.

## Field Identification

Symptoms and signs of *Cenangium* include dead or dying lower branches usually 2 cm or less in diameter, and the presence of small, black fruiting bodies 1 to 2 mm in diameter on the dead branches. The fruiting bodies are cup-shaped when fresh or moist and shriveled when dry (fig. 3-5). Unlike *Atropellis pinicola,* no black stain of the infected wood is associated with this fungus.

F-700249

**Figure 3-5. Clustered black fruiting bodies of *Cenangium ferruginosum* arising from within the bark of a branch of Jeffrey pine.**

# Redwood Canker

*Coryneum* sp.

## Hosts

Coast redwood

## Distribution and Damage

This fungus has been found in native stands of redwood north of San Francisco. For the most part, it occurs only spottily, and appears to be most common on trees on poor sites for redwood. For example, trees growing on warm, dry southern slopes in Mendocino County, Calif. have occasionally suffered severe branch killing and some top kill. Smaller ones are most commonly infected, and usually the lower branches are attacked first. But this fungus has been observed killing branches in the tops of old-growth redwood.

## Field Identification

Symptoms of this disease are nearly identical to those of Monterey cypress caused by the cypress canker. In fact, there is some evidence that the redwood canker fungus and the cypress canker fungus may be the same species. Further studies are needed, however, to determine the actual host-disease relationships between these two canker fungi.

# Cytospora Canker of True Firs

*Cytospora abietis*

## Hosts

True firs, rarely Douglas-fir.

## Distribution and Damage

*Cytospora abietis* is a damaging, canker-inducing fungus that commonly occurs on true firs throughout their natural range in California and frequently on firs and Douglas-fir elsewhere in the West. A weak parasite, it attacks only trees that have been debilitated by other disease-causing agents, drought, fire, insects, and human activities.

One of the important factors that predisposes firs to attack by *C. abietis* is dwarf mistletoe (*Arceuthobium*). Practically all fir stands in California infested with dwarf mistletoe are attacked by this fungus. For reasons not fully known, *C. abietis* more commonly infects branches invaded by dwarf mistletoe. In some stands, nearly a fourth of all branches bearing mistletoe are infected. Thus, in mistletoe-infected fir stands, considerable branch killing occurs each year as a result of this canker organism.

Because this fungus is widely found in California's true fir stands and it occasionally reaches damaging proportions in certain years, *C. abietis* constitutes a threat to the management of these tree species.

## Field Identification

Numerous brick-red flagged branches, conspicuous in spring and summer, are the best symptom of the disease (fig. 3-6). Later in the year the foliage dries and becomes more brown to tan in appearance.

Trees of all ages are attacked. Young trees or tops of young trees are often killed by the fungus, whereas only branches are killed on larger trees. Other symptoms and signs of infection are sunken, dead patches of bark tissue, resin exudation at the canker site, small pimple-like fungus fruiting bodies imbedded in the dead bark and the presence of thread-like spore masses exuded from the fruiting bodies (fig. 3-7).

F-700250

**Figure 3-6. Branch flagging of red fir caused by** *Cytospora abietis.*

F-700251

Figure 3-7. Orange, thread-like spore masses exuded from the fruiting bodies of *Cytospora abietis* partially imbedded within the bark of red fir.

# Dasyscyphus Canker of Conifers

*Dasyscyphus* sp.

## Hosts

Douglas-fir, pines, true firs.

## Distribution and Damage

Apparently, more than one fungus species is involved, and these attack several conifer species in the West. The disease is spotty in occurrence and seldom causes serious damage. It appears to be most serious on Douglas-fir and on high-elevation pine species. Otherwise, *Dasyscyphus* species are weak parasites and infect only weakened or suppressed lower branches and twigs. Occasionally, trunk cankers may develop on small trees.

## Field Identification

The fruiting bodies of the fungus are quite distinctive. When fresh or moist, they are cup-shaped, vary in color from a light cream to orange, have a fuzzy outer margin, and are about 2 to 8 mm in diameter (fig. 3-8). When dry, they appear as shriveled light-colored bodies on the dead bark of the infected branch or canker. The wood of the infected branch at the canker site does not stain black as it does with some of the other canker fungi.

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**Figure 3-8. Orange, cup-shaped fruiting bodies formed on branches of white fir infected by *Dasyscyphus* sp.**

# Dermea Canker of Douglas-Fir

*Dermea pseudotsugae*

## Hosts

Douglas-fir.

## Distribution and Damage

This disease occurs on Douglas-fir from northwestern California to British Columbia. Because of the severe damage caused by this organism it poses some management problems. Plantations of young trees are most severely attacked, but the fungus also develops on young trees in natural stands. In some plantations surveyed, 10 to 50 percent of the trees were killed by this organism in less than 10 years. Both limb dieback and trunk cankers occur on infected trees. Trunk cankers often girdle the tree, resulting in top kill and eventually death of the tree.

## Field Identification

Dieback of limbs, tops, and entire trees is the most obvious symptom of the disease. Trunk cankers originate from infected limbs and when fresh have a characteristic reddish margin that disappears when the tree dies (fig. 3-9). Sexual fruiting bodies (*apothecia*) do not appear on freshly killed tissue, but arise on dead bark about a year later. They appear as tiny, black discs about 1.0 to 1.5 mm in diameter. The bark beetle *Scolytus unispinosus* is often associated with cankers.

# Phomopsis Canker of Douglas-Fir

*Diaporthe (Phomopsis) lokoyae*

## Hosts

Douglas-fir.

## Distribution and Damage

*Phomopsis* canker of Douglas-fir is most common in the north Coast Range of California, but is found elsewhere on natural and planted stands in the State and along the Pacific Coast. It occurs sporadically and becomes a problem only in years when certain climatic conditions weaken the host and favor buildup of the fungus. Usually only single trees or small groups of trees are affected. The disease is primarily one

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**Figure 3-9. Canker caused by *Dermea pseudotsugae* on trunk of sapling-sized Douglas-fir.**

of young trees. Trees up to 3 inches in diameter are often killed by the fungus while larger ones usually survive. On the larger trees, top and branch killing often occurs. Cankers may also develop on the trunk. After the initial attack, these often heal in much the same way an axe wound heals.

The fungus, for the most part, is not a serious problem in natural forest stands. In nurseries, forest plantations, and in areas planted to Christmas trees in northern California, however, serious damage and economic losses have occasionally resulted.

## Field Identification

The presence of branch or trunk cankers is one of the best field symptoms of the disease. Cankers almost always result from the fungus first infecting young twigs and branches and then growing into the adjoining stem. Cankers are usually sunken and several times longer than they are wide (fig. 3-10). On branches and tree tops girdled by the

F-700254

**Figure 3-10. Elongate canker on branch of Douglas-fir resulting from infection by** ***Diaporthe lokoyae.***

fungus there is usually a distinct margin between the infected and the healthy portion of the stems. Small, black fruiting bodies (less than 0.5 mm diameter) imbedded in the dead bark may be seen in spring and early summer on the cankered tissues. Cankers caused by this fungus are similar to those caused by *Dermea pseudotsugae,* but no conspicuous reddish canker margin is present.

# Diplodia Canker

*Diplodia pinea*

## Hosts

Pines, rarely Douglas-fir.

## Distribution and Damage

This fungus may occur on pines throughout the West. In California, it is found on low elevation and coastal pine species. The fungus is considered a weak parasite and usually infects only trees that are planted out of their natural environment or are weakened by drought or other agents. For example, branches weakened by dwarf mistletoe infection are reported to be commonly attacked and killed by this organism. The fungus spreads from infected branches into the trunks of trees, causing top kill or tree mortality. For the most part, however, vigorous trees suffer only dieback of weakened branches as a result of infection by *D. pinea*.

## Disease Cycle

This fungus is one of the few canker and dieback-inducing organisms that also infects needles. Infection takes place through the stomata of young needles. The fungus then grows through the needles into young twigs, causing a dieback. Infection by spores may also occur through wounds or bark cracks on branches. Much of the dieback and cankering of older branches and trunks probably takes place by this mode of infection.

## Field Identification

Dying needles and twigs as well as top dieback and tree mortality are indicative of infection by *D. pinea*. The presence of the fruiting bodies on all infected portions also suggests infection by this fungus. The fruiting bodies are small (less than 0.5 mm in diameter), black, globose, and imbedded within the needles or bark of infected stems. Usually only the beak of the fruiting body protrudes through the surface of the infected tissues, and these resemble numerous small, black pinpoint spots. A noticeable black stain of the wood is also associated with infection by *D. pinea*.

# Dothichiza Canker of Pines

*Dothichiza pythiophila*

## Hosts

Pines.

## Distribution and Damage

This fungus is known in California as a weak parasite of pines. It grows mostly on smaller trees up to about 15 to 20 feet in height. The disease causes no threat to forest stands, but may damage trees in plantations or trees grown for ornamental purposes.

## Field Identification

This fungus causes both a needle and twig disease. Branches may be defoliated. Trees may suffer from top dieback and occasionally are killed back two or three whorls. Infected wood is stained a bluish-black. Symptoms and signs in the field closely resemble those caused by *Diplodia pinea*. Laboratory examination is often necessary to distinguish between these two fungi.

# Grovesiella Canker

*Grovesiella (Scleroderris) abieticola*

## Hosts

White fir, grand fir, Pacific silver fir, alpine fir, and red fir.

## Distribution and Damage

This fungus grows on *Abies* along the Pacific Coast from northern California through British Columbia. Highly sporadic in occurrence, it is usually not a serious disease-causing agent. Annual cankers and twig dieback develop as a result of infection and these conditions usually do not continue for more than one l year. Occasionally some tops are killed. Small trees are most often attacked, but lower branches of poles sometimes are infected.

## Field Identification

The fruiting bodies of this fungus are similar to but somewhat smaller (0.5 to 1 mm in diameter) than the black, cup-shaped fruiting bodies of *Cenangium* that is also found on firs. The fruiting bodies of *G. abieticola,* although small, are usually very abundant on the dead bark (fig. 3-11). This organism is seldom found on 1-year-old wood, but attacks older stems. Canker development is often pronounced, but no staining of wood accompanies infection.

F-700255

**Figure 3-11. Scattered, small, black fruiting bodies on the surface of a branch of white fir infected by** ***Grovesiella abieticola.***

# Cypress Canker

*Seridium (Coryneum) cardinale*

## Hosts

Principal host is Monterey cypress; occasional hosts are some other species of cypress, but rarely juniper.

## Distribution and Damage

The cypress canker is absent from the native stands in California and is rare on trees planted immediately along the Pacific Coast. But the disease is widespread and serious on Monterey cypress planted in the warmer, drier inland areas. Over the period of about a decade in the early 1900's, the fungus spread throughout the range of planted Monterey cypress in the West.

Damage caused by this organism was so severe that planting of cypress outside of its natural range is discouraged. Why the fungus suddenly appeared and became epidemic on planted Monterey cypress is not known, but it is now widespread and well established.

## Infection Cycle

Long-distance spread of cypress cankers is by windborne spores, whereas local buildup and spread within tree crowns is by spores washed out of the fruiting bodies by rains. Most infection occurs at the bases of small branches or in branch forks. Both wounded and unwounded tissues are sites for infection.

Cankers grow more rapidly along a branch than around it, and they usually have a length-width ratio of about 3:1. Infected trees or branches 2 to 3 years old may be killed within a year, whereas, on larger trees, infected branches or trunks may remain alive for 5 to 10 years.

## Field Identification

Fading and death of twigs, branches, and tops of trees are the most conspicuous symptoms of infection. Trees of all ages and sizes are equally susceptible to infection. The presence of cankers (fig. 3-12) is a sure indication of infection. Resin flow usually accompanies canker development and as the killed bark tissues dry out, a sunken area develops. Bark cracking commonly accompanies canker development. Dark, irregularly-shaped, blister-like fruiting bodies 0.3 to 1.5 mm in size are produced and break through the bark of the dead tissues. Cypress bark beetles are often associated with, and hasten the death of, infected trees.

F-700256

**Figure 3-12. Branch canker on Monterey cypress caused by *Seridium cardinale*. Note abundant resin flow and small, black fruiting bodies on bark surface.**

# Sydowia Tip Dieback of Fir

*Sydowia polyspora*

## Hosts

White fir.

## Distribution and Damage

This organism has been reported only in northwestern California. It has been found primarily in white fir stands managed for Christmas trees. From the timber management standpoint, damage is negligible, but losses do occur in firs grown for Christmas trees. In general, infection of firs is sporadic, and only tip dieback of twigs occurs.

## Field Identification

The symptoms and signs of this disease closely resemble those of *Scleroderris abieticola*. But this organism infects only 1-year-old wood, causing tip dieback (fig. 3-13). Occasionally, a canker margin may be found about a third of the way down 2-year-old wood on a branch. Black, fruiting bodies less than 0.2 mm in diameter appear from under the bark of twigs that have been dead for a year or more.

F-700257

**Figure 3-13. Tip dieback of white fir caused by *Sydowia polyspora*. Note swollen branch at canker margin.**

# Galls

Many galls found on conifers in California are of unknown origin, but some are caused by bacteria, insects, rust fungi and mistletoes. Although numerous on some hosts in certain areas, galls are relatively unimportant forest diseases. They are usually found on scattered trees rather than on most trees in a stand. They cause relatively little damage to the trees on which they develop — except for galls that occasionally occur on the main stem.

## Bacterial Gall of Douglas-fir

Bacterial gall of Douglas-fir caused by the bacterium *Pseudomonas pseudotsugae* is a disease commonly observed on young Douglas-fir in northern California and Oregon. Galls are roughly globose and may become several inches in diameter (fig. 3-14). Tops of young trees may be killed, but galls on branches or boles of larger trees affect growth only slightly. The gall-forming bacterium is transmitted by two sucking insects — the orchard cicada and Cooley's chermes — that feed on Douglas-fir.

F-525004

**Figure 3-14. Bacterial gall of Douglas-fir caused by the bacterium *Pseudomonas pseudotsugae*.**

## Galls of Unknown Origin

Redwood gall, a gall of unknown origin, develops on coast redwood. Often huge galls grow on the trunks of old-growth redwood. Because of their beautifully figured grain, they are highly prized for use in furniture or for novelty items. Galls also occur on branches. Occasional trees support many of them with little apparent effect on growth or vigor of the tree.

Other galls of unknown origin also are found on other conifers, particularly the pines, in the West. Their effect on the growth of trees is minimal. They are of no real importance in the management of forest lands.

Galls caused by rust fungi and mistletoes are covered in Chapters 5 and 6.

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# 4. RUSTS

by

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Rust diseases are caused by obligately parasitic fungi — they develop only on living hosts. Most rusts described in this chapter are considered "native rusts." Although these native rusts are not known to have destroyed whole forests of their hosts as has *Cronartium ribicola,* an introduced rust, they kill individual trees, reduce wood quality, and retard tree growth. About 56 species of native rust fungi are known to attack conifers in the Western United States and about 40 others complete their life cycles on conifers, but are found only on non-coniferous alternate hosts.

To complete their life cycles, nearly all the major rust fungi on conifers must alternate between the conifer host and an unrelated type of host plant. Those that require two different hosts are called "heteroecious rusts." Most produce four to five different kinds of spore stages, as indicated either by name or by the numerals 0 through IV. Two major rust diseases — western gall rust and possibly a limb rust — do not require these two unrelated types of host plants, but spread directly. Rusts requiring no alternate host are called "autoecious rusts."

Figure 4-1 illustrates the heteroecious type cycle, using *C. ribicola* as an example.

Pycnia (0) are the first spore bodies produced on the aecial host. Pycniospores that serve in sexual fertilization are exuded from the pycnia and are not known to be infective agents. Sexual fertilization is required before maturation of the aecial stage (I) which produces aeciospores that can infect their alternate host as much as 600 to 800 miles distant from their point source. On their alternate hosts, rusts of most genera produce the repeating or uredinial stage (II) from which urediniospores are produced. These again are dispersed short distances by wind and infect other individuals of the same host species or reinfect the plant on which they were borne. Later, these infections produce the telial stage (III), which is composed of teliospores that remain in place and germinate under the right climatic conditions in a

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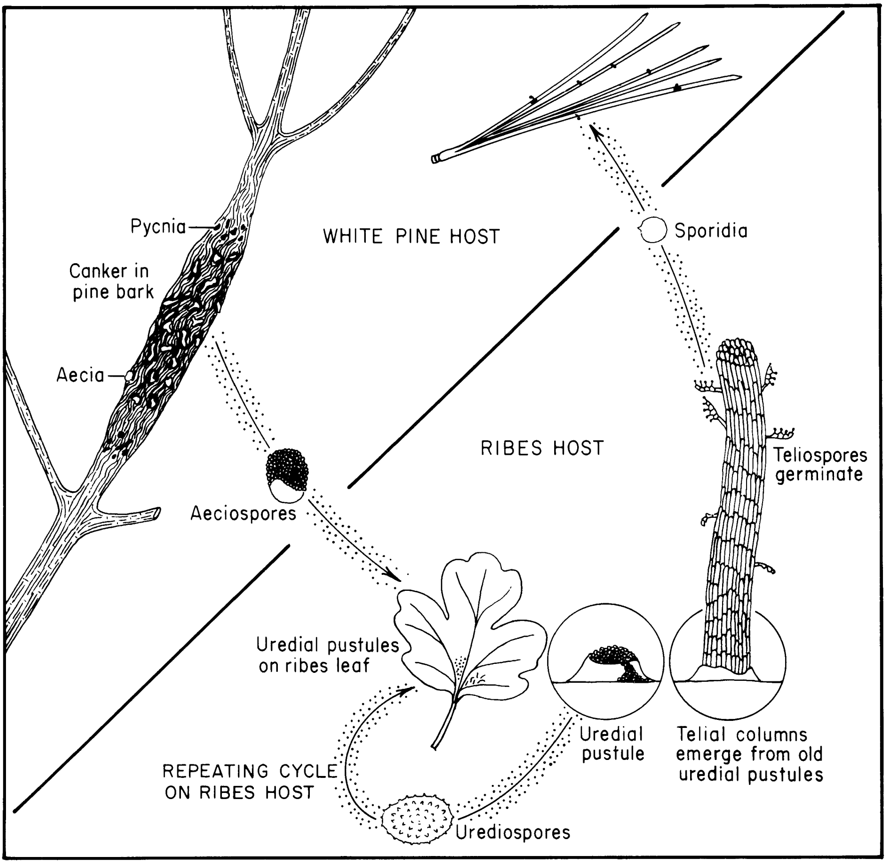


**Figure 4-1. Life cycle of** *C. ribicola.*

few days to produce basidiospores (also called sporidia) (IV). Windborne for short distances, basidiospores infect only the aecial host.

Local climate and land use that favor growth of alternate hosts often intensify rust diseases. For example, ribes species must be closely associated with pinyon pine in a favorable regime of moisture and temperature before infection of pines by pinyon rust *(Cronartium occidentale)* can occur. Similarly, concentrations of *Comandra* species are needed to trigger outbreaks of comandra rust *(C. comandrae).* Western gall rust *(P. harknessii),* an autoecious rust, will be most troublesome in localities where high humidity and moderately cool temperatures prevail or where there are even-age young stands or plantations. This gall rust can be especially destructive in nurseries and ornamental plantings. An intricately balanced interaction of host, parasite, and environmental factors determines rust outbreaks. Most outbreaks often involve a burst of infection during a single season or even a single moist period and then years may pass with no new infections occurring. Major outbreaks may come decades apart. Even with the fungus *P. harknessii* that spreads from pine to pine, infection may be sporadic in spite of its simplified life cycle.

Among the numerous rust fungi that attack conifers, most are minor needle rusts that cause partial defoliation only during years favorable for infection. Some rusts may be more damaging to their alternate hosts. Several native rusts cause deformities, dieback, and limited mortality to conifers of little commercial value but of high or potentially high recreational and esthetic value.

The most damaging rusts in the Western United States are: white pine blister rust on white pines, comandra rust, western gall rust, stalactiform canker rust, and filamentosum limb rust on hard pines; broom rust on true firs and spruce; and broom rust of incense-cedar. Others are a problem only in selected areas, such as Christmas tree farms and recreational sites.

## Descriptive Key

A¹ On hard pines ........................................................................B

- B¹ Causes globose woody stem galls or cankers with central-marginal gall swellings ..................................................C
  - C¹ Galls of hard secondary tissue having annual rings ..............................................................*P. harknessii* *(Endocronartium harknessii)*
- B² Causes limb rust or cankers without woody galls ..........D¹
  - D¹ Causes elongate cankers on tree bole and branches ........................................................................E
    - E¹ Cankers two to usually many times longer than broad, aecial filaments pendant ..............................................*P. stalactiforme* *(C. coleosporioides)*
    - E² Cankers usually not more than two times longer than broad. Aeciospores pear-shaped (under hand lens)....................................*C. comandrae*
- B³ Causing limb rust only ..................................................F
  - F¹ Aecia, mostly taller than broad; often more than 2.5 mm tall; bark normal ......................*P. filamentosum* *(C. coleosporioides)*
  - F² Aecia, mostly broader than tall; seldom more than 2.5 mm tall; bark rough..........................*P. stalactiforme* *(C. coleosporioides)*

A² On soft pines ........................................................................G

- G¹ On pinyon pines, aecia to more than 1 cm broad under bark ....................................................................*C. occidentale*
- G² On other white pines, aecia less than 8mm broad, spindle-shaped branch cankers or diamond-shaped trunk cankers ..............................................................*C. ribicola*

A³ On incense-cedar and true firs ...............................................H

- H¹ In brooms on incense-cedar....*Gymnosporangium libocedri*
- H² In brooms on true firs...*Melampsorella caryophyllacearum*

# White Pine Blister Rust

*Cronartium ribicola*

White pine blister rust, caused by the rust fungus *Cronartium ribicola,* is a textbook example of the heteroecious rust fungi found throughout the world. Its life cycle, symptoms, and climatic requirements are typical of most native western rust fungi described in this chapter. It differs only in its rate of spread and the amount of damage that it causes.

## Hosts

*C. ribicola* can infect nearly all white pines, and is restricted to this group. Its native North American hosts are: eastern white pine, western white pine, sugar pine, limber pine, white bark pine, bristle cone pine, foxtail pine, and Mexican white pine. In addition, it infects all species of its alternate hosts — ribes.

## Distribution and Damage

The disease was introduced from Europe into North America on seedlings of a native North American white pine. It was not native to Europe, however, but is believed to have been introduced from Asia. Its introduction to North America from Europe, between 1898 and 1908, on seedlings of eastern white pine resulted in one of our most serious disease outbreaks on conifers. White pine blister rust is now widely found in the Northeastern United States, the Lake State regions, and the West. After its introduction into British Columbia in 1910, it has spread throughout most white pine regions of Washington, Idaho, Montana, Wyoming, Oregon, and California.

In North America, white pine blister rust has caused more damage and costs more to control than any other conifer disease. Since the 1920's, millions of dollars have been spent on the eradication of the alternate host, ribes, and thousands of white pine stands have been severely damaged. In the Western United States and Canada, some stands have been completely destroyed. When the main stem of a tree is invaded, death is only a question of time. Frequently, in western white pine and sugar pine, death results without trunk infection — the branches are killed by numerous infections before the disease reaches the main stem.

## Disease Cycle

The sporidia produced from the teliospores on leaves of ribes species are windblown short distances, and infect pine needles during late summer and early autumn. Infection can take place on needles of the current year, but is more frequent on 2- to 3-year-old needles. One to 2 and frequently 3 years after infection, the fungus has penetrated the needle into the stem and becomes obvious as a yellow or orange discoloration of the bark accompanied by spindle-shaped swellings. Later, pycnia appear as small blisters on the bark. These blisters then discharge droplets of honey-colored liquid containing pycniospores that are thought to play a sexual role and are required for the production of the aecial stage. Aecia produced from aeciospores are the prominent blisters (fig. 4-2) that burst in spring to disclose masses of orange spores.

F-700258

**Figure 4-2. Aecial stage of *Cronartium ribicola* on sugar pine.**

Aeciospores can travel long distances — as much as 600 to 800 miles — to infect young ribes leaves. Within a few weeks of infection, small yellow uredial pustules appear on the lower leaf surfaces. The resultant urediniospores infect other ribes, but cannot infect pines. This stage of the fungus is the "repeating" stage. The spores are airborne for only short distances, and infect not only other species of ribes, but also its own host plant. A large buildup of inoculum occurs within a local area. Late in summer or early fall, the telial stage is produced. These are brown hair-like structures which sometimes occur in such numbers as to give a faintly felt-like appearance to the under side of the leaves (fig. 4-3). These structures then germinate in place under proper climatic conditions, giving rise to the sporidial stage. The cycle is then completed.

F-700259

**Figure 4-3. Ribes leaf showing uredinial pustules and telial horns of** *C. ribicola.*

## Field Identification

On pine the first noticeable symptoms are tiny yellow spots on the needle. The spots later turn golden yellow, producing a yellow mottle. As the fungus invades the twig it too turns yellow. Invasion of branches then subsequently occurs from the infected twigs. Infection sites then enlarge to produce the spindle-like swellings. Cankers on branches and trunks then continue to enlarge from year to year. The invaded bark first becomes yellow or bronzed. The pycnial stage, containing an exudate of pycniospores, then appears. Later aecia are produced in place of the pycnia, and new pycnia appear in the outer zone. In spring, the aecia appear as raised blisters. They push through the bark to the surface and discharge yellow, dusty masses of aeciospores. After the aecia have shed their aeciospores, the bark tissue dies. As a canker progresses, there will be found a yellow zone, a zone showing pycnia, a zone bearing aecia, and an inner area of dead bark where aecia have formed in the previous season. A common symptom in pines (fig. 4-4) first noticeable to the casual observer is branch killing or flagging after the fungus has completely girdled the branch and killed the cambium.

F-700260

Figure 4-4. Multiple branch flagging on sugar pine caused by *C. ribicola*.

On ribes, the uredia appear as slightly raised yellow spots on the lower side of the leaves, petioles, and young stems. Telia, which follow uredia, are darker, and the teliospores are borne in columns up to 2mm in length. Heavy infection on some ribes hosts such as *R. roezli* may cause premature defoliation. In the Western United States, *C. ribicola* is frequently confused with *C. occidentale* (see pinyon blister rust). On ribes, the two fungi cannot be separated macroscopically. This similarity has caused a great deal of confusion in attempts to determine the distribution of *C. ribicola* on ribes species in a given year.

# Native Limb and Canker Rusts

*Cronartium coleosporioides*

Taxonomic knowledge of this group of fungi, sometimes referred to as part of the *Cronartium coleosporioides* complex, is incomplete. This handbook follows nomenclature based on the imperfect (aecial) stage of the fungi. This stage is better understood than the perfect stage. Therefore, little attempt will be made to describe the taxonomic differences because they are based principally on microscopic variations in the spore stages. Effects on pine hosts are classified for field identification as to whether infection results in cankers, galls, or limb rust. This classification, however, does not separate the causal fungi; for example, gall fungi all cause cankers, too. Though always originating on the current season's growth, they may, depending on host species attacked, become systemic and cause cankers or galls on the main stem of the tree.

Two distinct species — stalactiform rust *(P. stalactiforme)* and filamentosum rust *(P. filamentosum)* – cause 'limb rust' on pine.

# Stalactiform Rust

*Peridermium stalactiforme*

## Hosts

The principal pine hosts of *P. stalactiforme* are lodgepole, Jeffrey, and ponderosa pines. In the Laguna Mountains in San Diego County it has been found on Coulter pine. Its alternate hosts are in the figwort family, particularly castilleja species.

## Distribution and Damage

The disease occurs from the Southwestern United States and California, northward into Canada, and eastward into Michigan, and the Maritime Provinces of Canada. It is most common along the Pacific Coast.

*P. stalactiforme* causes cankers on most pine species, but is known to cause limb rust only on Jeffrey pine from Plumas County southward to San Diego County in California, and in Washoe, Ormsby, and Douglas Counties in Nevada. Whether it also causes limb rust in ponderosa pine is uncertain. *P. stalactiforme* in the Sierra Nevada usually occurs on immature pines in concentrated infection centers and often in obvious relationship to the presence of its alternate host. Most infections are found low in the tree crowns.

In the West, the main damage is from trunk cankers and resulting cull on lodgepole pine. Stalactiform rust can kill trees by girdling, but this is uncommon except in seedlings or where two or more cankers coalesce. Infected branches are occasionally killed, but no appreciable growth loss is known.

## Disease Cycle

In late summer and fall, the airborne sporidia infect susceptible pines. Although rarely seen, pycnia may appear the following spring or one or more years later, depending on the age of the pine and its environment. Aecia then appear during the same season, but frequently do not mature until early spring of the following year. The aeciospores are not known to infect pine, but readily infect the telial host (Castilleja) and can be windborne for greater distances. Uredia are produced on the telial hosts a few weeks after infection. Urediospores are windborne short distances, and serve to intensify the disease on other telial hosts or its own nearby host plant. They cannot infect pine, however. Telia then appear on the host later in the summer and early fall. The teliospores germinate in place and produce sporidia. The sporidia then are windborne short distances to nearby susceptible pines.

## Field Identification

Branch swelling, and on most hosts, cankers, that finally become more than 10 times as long as wide are common. On Jeffrey pine, fungus growth becomes systemic and limb rust results. It can be distinguished from the limb rust caused by *P. filamentosum,* by bark roughening, or by ill-defined cankers on branches that are invaded in contrast to the lack of roughening when *P. filamentosum* invades. Monoliform swellings are occasionally found on branches with systemic infections. In stem and branch tissues, the fungus spreads much slower laterally than longitudinally. Typically on the trunks of older lodgepole pines, the fungus causes elongated or sunken trunk cankers up to 30 feet or more long (fig. 4-5). Each year, cankers grow about 7 inches vertically, but only about one-fourth to one-half inch horizontally. Because rodents usually chew the canker margins, aecia are not easily seen on older trunk cankers. Pine infection in general is more frequent and more localized when this rust appears than with com-

F-700261

**Figure 4-5. Elongate canker caused by** *Peridermium stalactiforme.*

andra rust or filamentosum limb rust. Symptoms and signs on the alternate host are typical of those described for white pine blister rust.

In Jeffrey pines, stalactiform rust mainly attacks the lower crowns (fig. 4-6). The fungus spreads slowly and in some trees appears not to keep up with stem growth. Thus mature infected pines are found, but usually the fungus has been in them for several decades. Stalactiform rust, however, has been found occasionally in mid-crowns or upper crowns of mature trees in southern California.

Both *P. stalactiforme* and *P. filamentosum* may occur as a limb rust in the same stands of Jeffrey pine in some areas. Stalactiform rust may be distinguished from that caused by *P. filamentosum* by (1) fungus morphology, notably the lower more confluent aecia and the thick smooth areas on aeciospore walls of *P. stalactiforme,* (2) lack of peridial fragments retained on infected twigs from previous year's growth of aecia, and (3) the constant presence of rough bark on cankers as well as symptoms of systemic limb rust.

F-525005

**Figure 4-6.** *Peridermium stalactiforme* **nearly always infects the lower crown of pine and spreads upward.**

# Filamentosum Rust

*Peridermium filamentosum*

## Hosts

*Peridermium filamentosum* has the following pine hosts: Apache, Jeffrey, ponderosa, and Montezuma. One form is heteroecious on Castilleja species of the figwort family. Two other forms, also called *P. filamentosum,* appear to spread directly from pine to pine without requiring the alternate host.

## Distribution and Damage

The disease is found in California, the Southwestern United States, and from western South Dakota and northeastern Utah southward to Colorado, New Mexico, and Arizona. It has been found in the Sierra Nevada from Plumas County, California, to northern Baja California, Mexico.

No intense outbreaks of this rust have been found in species other than ponderosa and Jeffrey pines. Since little is known of its epidemiology, its potential importance cannot be fully gauged.

## Disease Cycle

The life cycle of *P. filamentosum* is almost identical to that of *P. stalactiforme. P. filamentosum,* however, consists of at least three races in the Western United States. One race alternates with Castilleja, thereby resembling *P. stalactiforme* in life cycle. Alternate hosts are unknown for the other two races. The second race attacks ponderosa pine in Utah and adjacent States. The third is found on Jeffrey pine. In California, aecia of *P. filamentosum* begin to emerge in the Sierra Nevada during early spring at low elevations, but are produced mainly in late June and July. Commonly, aecia may be found still intact in August and retain their spores until September.

## Field Identification

*P. filamentosum* commonly attacks mid-crowns or upper crowns of mature trees (fig. 4-7). In the Sierra Nevada, it is usually found in scattered, mature, and over-mature pines, although occasional concentrations occur without apparent reference to topography.

F-525006
**Figure 4-7.** *Peridermium filamentosum* **nearly always infects the mid or upper crown of trees and spreads in both directions.**

# Western Gall Rust

*Peridermium harknessii*

## Hosts

Throughout its range, *P. harknessii (Endocronartium harknessii)* has been found on 22 species, which represent 8 of the 9 subsections of hard pines.

## Distribution and Damage

Western gall rust ranges from Mexico and Nebraska to Alaska and eastward in Canada (with decreasing abundance) to the mid-Atlantic areas. In California, it is widespread throughout the State, occurring on nearly all of the species of hard pines. It is especially prominent on Monterey pine in both its natural range and throughout the State wherever it has been planted, and on lodgepole pine throughout the Sierra Nevada and southern Cascades.

This rust damages pines by (1) killing seedlings; (2) producing branch galls so numerous that larger trees may be killed outright or their growth is diminished by loss of branches; and (3) producing trunk cankers so deforming that they reduce the strength of the tree and increase the likelihood of wind breakage. Western gall rust is the native stem rust found most often in the California Disease Survey. All signs suggest that it will become an even more serious problem in the West when plantations become more abundant. It is now a serious problem in Christmas tree plantations and nurseries in the West.

## Disease Cycle

In spring, aecia emerge from the living bark of the globose galls (fig. 4-8) and the marginal swellings of the trunk (hip) cankers. Aeciospores can directly infect other pines rather than go through an alternate host. These spores are wind disseminated and may spread the disease for hundreds of miles.

F-525007

**Figure 4-8. Globose galls are common on Monterey pine infected by** ***Peridermium harknessii.***

## Field Identification

The disease is characterized by the formation of globose to pear-shaped galls as large as 12 inches in diameter on branches and stems of pine of all ages. Trunk or "hip" cankers are common. Each new pine infection is followed by formation of well delimited globose galls. Thereafter, the galls continue to enlarge and produce new spores each spring until they have girdled and killed the branch or stem. However, the fungus may survive in cankers for up to 200 years before girdling is complete (fig. 4-9).

F-525008

**Figure 4-9. Old but still active "hip canker" on lodgepole pine caused by** *Peridermium harknessii.*

# Yellow Witches Broom of Fir

*Melampsorella caryophyllacearum*

## Hosts

The fungus causing yellow witches broom has as its aecial host the true firs. In the Western United States, these tree species are principally white fir, red fir, grand fir, and sub-alpine fir. Trees of all ages are susceptible to the parasite. The alternate hosts are species of chickweed.

## Distribution and Damage

*M. caryophyllacearum* is found on fir species in North America from Labrador, Newfoundland, west to Alaska, south through Canada to the Northern United States and in the Western United States, and from California to Mexico. The disease is abundant in southern Idaho, western Wyoming, and northern Utah on sub-alpine fir, and in the south and central Sierra Nevada of California on red fir. Elsewhere in the West, brooms are only occasionally found. Most of the infected trees have branch brooms and less frequently, trunk burls or spike tops. Multiple brooms can reduce tree growth, provide infection courts for heart rots, and even kill trees — particularly seedlings and saplings.

## Disease Cycle

*M. caryophyllacearum* has a typical heteroecious life cycle, alternating between true firs and members of the chickweed family. The fungus is, however, systemic and perennial not only in firs (the aecial host) but also on the telial host plants that are perennial species.

## Field Identification

The most noticeable characteristic of this disease is the witches-broom it produces. The brooms are most conspicuous from midsummer to late fall, when their yellowish-orange color reaches a peak of intensity and stands out in striking contrast to the normal dark green foliage (fig. 4-10). Aecia production on the diseased needles

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**Figure 4-10. Witches-broom of white fir caused by *Melampsorella caryophyllacearum* showing compact growth and light-colored, infected branches.**

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**Figure 4-11. Light-colored pustules of the yellow broom rust on infected needles of white fir.**

contributes to this color. Witches-brooms are upright, typically compact, and have a dense growth of many small and shortened branches that rarely exceed 3 feet in diameter. The diseased needles are greatly shortened and thickened (fig. 4-11). In winter, the brooms appear to be dead as the affected needles shrivel and become dark. In autumn, the needles drop, leaving the brooms bare until new growth starts. The new needles are yellowish-green until mid-summer. On the alternate host — chickweed — the fungus forms the uredinial and telial stages. The abundance of fir broom rust appears to be related to change in abundance of alternate chickweed host. Seasonal, climatic differences are also responsible for outbreaks.

## Comandra Blister Rust

*Cronartium comandrae*

### Hosts

The rust is a typical heteroecious fungus whose alternate hosts in the Western States are two species of bastard toad flax or comandra. Aecial hosts are hard pines — principally ponderosa, Jeffrey, lodgepole, knobcone, and Scots pines. Field evidence, however, shows that lodgepole and ponderosa pines are especially susceptible while Jeffrey and knobcone pines are rarely attacked.

## Distribution and Damage

The fungus is perennial in trunk cankers or branch swellings. Studies on the chronology of disease outbreaks in California indicate that infection was abundant for several years, but has become extremely scarce owing principally to extreme fluctuations in the abundance of its alternate host.

The fungus is widely distributed, ranging from Quebec to the Northwest Territory to British Columbia, and southward to New Mexico and California. But it has not been found outside of North America. In the Western United States, the fungus is found in all States from the Rocky Mountains to the Pacific Ocean. The disease is now common on lodgepole pine in the Rocky Mountains. In California, it occurs mainly on ponderosa pine in the Shasta and Klamath River drainages.

Comandra blister rust has been most damaging to lodgepole pine in western Wyoming and adjacent States, where mortality continues to be heavy as a result of an epidemic that started in the late 1940's. Although significant recent outbreaks have not taken place in California for many years, the rust is still common in the Shasta River drainage, where the advanced growth of ponderosa pine from seedlings to small poles was badly infected in the early 1900's, and many young trees were killed.

## Disease Cycle

Seasonal activity of the fungus usually starts in late spring with the production of whitish-colored spore sacs (aecia) on the pine cankers. The sacs soon break, releasing many orange-colored spores (aeciospores) that are wind-disseminated to the alternate host, comandra. About 10 days later, the uredial stage forms on the comandra leaves and produces urediospores. These spores can infect other comandra plants. This is the repeating stage of the rust, and serves to intensify the disease on comandra during the growing season. In early summer, the uredial stage is followed by the telial stage. Telia may grow up to nearly one-tenth inch in size. It consists of a mass of teliospores held together in a gelatinous matrix.

Moisture and mild temperatures are required for germination of all spore types produced by the fungus and for the subsequent infection of either host. Since wet seasons favor spread and intensification of comandra rust, dry seasons discourage it. Not every year in which the rust is prevalent on the comandra host is the weather favorable for infection of pines. The lack of recent infections on pines in California is due, in part, to unfavorable environmental conditions, but when outbreaks occur they can be damaging.

## Field Identification

The rust on hard pines is quite similar to blister rust on white pines in its growth and the damage it causes. On pine, comandra rust causes slight swellings followed by cracking of the infected bark. Small branches or seedling stems are usually girdled quickly as the fungus spreads in the bark and outer wood. Death follows within a few years. The rust eventually encircles trunks or branches, and soon the bark and parts distal to the girdle die. When the fungus reaches large branches or trunks, elongate cankers are formed and copious resin flow from these cankers is common. Rodents usually hasten girdling action by removing bark from cankers (fig. 4-12). On trunks of older

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**Figure 4-12. Typical large trunk canker caused by *Cronartium comandrae* on ponderosa pine.**

trees with comandra rust, little or no swelling is apparent. Frequently, the symptom is a constriction with the infected bark becoming roughened. Aecia are seldom produced on the trunk cankers in large trees — probably because of the thick bark. Symptoms on the comandra host are primarily restricted to leaves and occasionally to stems. These appear in the spring as yellowish spots (uredia) about the size of a pinhead. Then, in early summer, brownish hair-like structures or telia develop. Curling and necrosis of heavily infected comandra leaves is common in most areas (fig. 4-13).

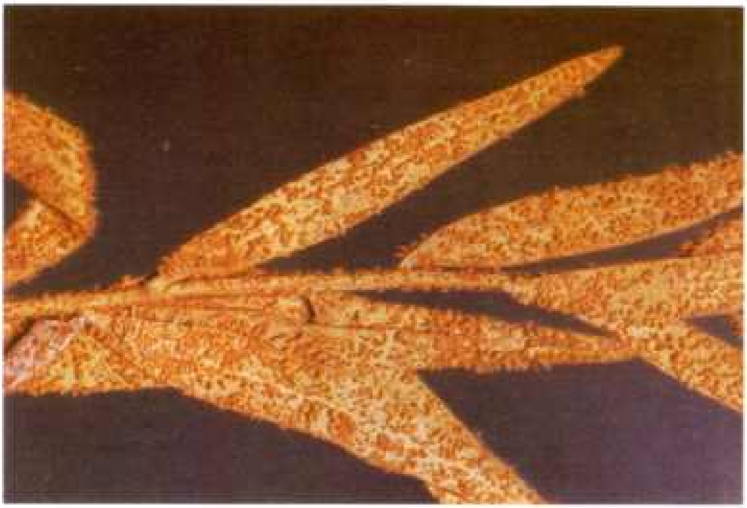

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**Figure 4-13. Uredinial and telial stages of *Cronartium comandrae* on bastard toad flax (*Comandra* sp.).**

# Incense-Cedar Rust

*Gymnosporangium libocedri*

## Hosts

One of the most abundant rust fungi on conifers in the Western United States, *G. libocedri,* alternates between incense-cedar and rosaceous shrubs, predominantly serviceberry. It causes only minor damage except on the leaves and fruits of serviceberry and hawthorn. This rust is occasionally found on apple, pear, quince, and mountain ash.

## Distribution and Damage

The disease caused by *G. libocedri* is found throughout the range of incense-cedar in the Western United States. It infects incense-cedar of all ages. It causes witches-brooms and only infrequently kills smaller branches. When the mycelium penetrates an older twig, it results in the typical witches-brooms, which are numerous and conspicuous. Badly infected trees may be seriously injured, but we know of no record of tree mortality. The infection in the main stem of incense-cedar may result in burls that cause defect in lumber. In northern California, it has caused some damage to commercial pear orchards. It has also been reported on pears in Oregon.

## Disease Cycle and Field Identification

*G. libocedri* is a typical heteroecious rust fungus alternating between incense-cedar and several members of the rose family. In contrast to the other major heteroecious rusts described in this chapter, *G. libocedri* has its pycnial and aecial stages on rosaceous hosts; it lacks a uredinial stage, and the telial stage is on the conifer host. In early spring, infected small branches of incense-cedar trees appear slightly discolored. On the underside, rarely on the upperside, of the green, flat, scale-like leaves, a number of small brown to brick-colored tufts or telial cushions appear (fig. 4-14). When they mature, the cushions become gelatinous during wet periods in spring and finally form con-

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**Figure 4-14. Telial cushions of *Gymnosporangium libocedri* on scale-like leaves of incense-cedar.**

spicuous light orange-colored masses that later dry to a thin film (fig. 4-15). The sporidial stage is blown to the rosaceous host, where small, orange-colored, cup-shaped fruiting bodies appear on the leaves and petioles, and sometimes on the fruit. These bodies produce the aeciospore, which can again infect the tree.

Witches-brooms caused by *G. libocedri* are frequently mistaken for plants of the incense-cedar mistletoe. This mistletoe, however, always hangs down in thick clusters while the bushy witches brooms caused by the rusts are more or less erect.

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**Figure 4-15. Gelantinous telial stage of** ***Gymnosporangium libocedri*** **on incense-cedar.**

# Pinyon Rust

*Cronartium occidentale*

## Hosts

The aecial stage of this rust is found on pinyon and singleleaf pinyon pines. The telial stage occurs on ribes species.

## Distribution and Damage

The disease is found throughout the Western United States on pines and ribes. In California, infection on pinyon pine occurs only in a narrow belt, about 50 miles long by 10 miles wide, stretching north from the east central border of California and Nevada at the base of the eastern slope of the Sierra Nevada. From this source of aeciospores, however, annual infection on ribes can be found throughout northern, central, and north coastal California and southern Oregon. On pine, multiple branch and trunk cankers are common and occasionally kill trees. On ribes, damage is restricted to partial defoliation; the plant seldom dies as a result.

## Disease Cycle

*C. occidentale* is a heteroecious rust fungus with a disease and life cycle identical to that of *C. ribicola.*

## Field Identification

Because the uredinial and telial stages on ribes are macroscopically indistinguishable from *C. ribicola,* pest control workers in search of *C. occidentale* may have problems in identification.

The aecial stage on the pine host is less distinct than that of *C. ribicola* and native limb and stem rusts. It seldom causes swellings on either branches or stems; the orange-colored aeciospores are borne in large irregular cracks in the bark. The aecia themselves are seldom prominent, often not visible, in contrast with other stem rusts (see *C. ribicola, P. filamentosum).* Rodents often chew on cankers. This characteristic, however, cannot be used as a definite indicator of rust infection.

# Sweetfern Rust

*Cronartium comptoniae*

## Hosts

The aecial stage is found on lodgepole, ponderosa, Monterey, Jeffrey, and bishop pines in the West and on several other pines in other parts of the United States. Its telial hosts are principally sweetfern and sweetgale.

## Distribution and Damage

The disease is common on 2- and 3-needle pines throughout the Eastern United States and Canada, and in the West from Alaska to California. Branch and especially trunk cankers deform the tree and frequently kill it. Young trees are more often attacked than older ones. Damage can be extensive in nurseries.

## Disease Cycle

*C. comptoniae* is a heteroecious rust fungus and, except for differences in aecial and telial hosts, has a life cycle nearly identical to that of *C. ribicola.*

## Field Identification

The rust on pines usually first becomes evident as elongated swelling on branches of older trees or on the stem of seedlings. These swellings become evident within 1 to 2 years after infection. They are most conspicuous in spring when the orange-yellow aeciospores are formed. Older cankers may vary from deep, vertical fissures to a very slight depression in the bark.

The uredial stage appears as orange-colored pustules on the underside of the leaves of sweetfern and sweetgale. In autumn, telia are formed around and within the uredia.

# Tarweed Rust

*Coleosporium madiae*

## Hosts

This typical heteroecious rust fungus has its aecial stage primarily on Monterey pine, Coulter pine, and Jeffrey pine. The telial hosts are principally the tarweeds.

## Distribution and Damage

The rust is found occasionally on its tarweeds hosts from British Columbia south to central California. It has not been found on its aecial hosts north of southern Oregon.

The fungus is restricted to needles of its conifer hosts and, except in occasional wet years when it may build up and cause heavy defoliation, damage is minimal. On its telial hosts, damage is also minimal.

## Field Identification

Aecia occur on all surfaces of the needle. They are white, globoid, and broadly ellipsoid, and usually appear in early spring. On tarweed leaves, uredinia appear as small, round, golden yellow pustules. Telia are waxy, compact and orange-yellow when fresh.

# Aster Rust

*Coleosporium asterum*

The uredinial stage of this rust on species of aster and goldenrod is one of the most common rusts in the United States. *C. solidaginis* is a synonym. C. asterum usually overwinters on the rosettes of these species. On its aecial host in the West, it is mostly found on needles of lodgepole pine, but occurs only sporadically. Damage to the pine host is usually negligible. Symptoms on pine are discolored spots on needles, with firm, protruding, light-orange aecial sacs. On aster and goldenrod, the uredinia are round, orange-yellow pustules on the leaves, while the telia are scattered and reddish-orange with cylindrical teliospores rounded at both ends.

## Rusts on Fir and Douglas-fir

Several needle rusts infect true firs in western North America. Except for *Melampsorella caryophyllacearum,* however, most of them are usually of minor importance and scattered in incidence except in Christmas tree plantations. The two most common are *Pucciniastrum goeppertianum* and *Pucciniastrum epilobii.* On Douglas-fir and bigcone Douglas-fir, only two rusts have been reported of any significance in the Western United States: *Melampsora medusae* and *Melampsora occidentalis.* Both alternate between needles of Douglas-fir and leaves of poplars and aspens.

### Fir Blueberry Rust

*(Pucciniastrum goeppertianum)*

The hosts are true firs and blueberry. On true fir, *P. goeppertianum* forms white tubules on the lower side of needles. These tubules contain orange powdery aeciospores. Frequently, witches-brooms with annual needles form on true firs. Uredinia are absent on blueberry species. Telia produce witches-brooms on stems, forming a continuous layer around the stem with polished reddish-brown surface. Teliospores are found within the epidermis in single, closely pressed layers.

### Fir Willow Weed Rust

*(Pucciniastrum epilobii)*

This disease is scattered but not uncommon on true fir species throughout the Western United States. The fungus is also known as *Pucciniastrum pustulatum.* The aecia are cylindric, yellow to colorless pustules on the leaves of fir. On the herbaceous willow herbs, uredinia appear as powdery orange-yellow pustules followed by telia, which are reddish-brown to blackish-brown crusts that overwinter in the leaves.

### Douglas-fir Rust

*(Melampsora medusae)*

Distributed throughout the Western United States from Colorado and Wyoming to British Columbia and Oregon, and into California, this Douglas-fir rust has also been found in bigcone Douglas-fir in southern California. The fungus is also known as *M. albertensis.* On Douglas-fir, the aecia form as tubules 1mm long in two rows — one on either side of the midrib of the needle. These tubules contain powdery yellow spores which, in turn, infect leaves of cottonwood and poplar species. The uredinial stage of the rust on cottonwood and poplar species appears as powdery yellow pustules on the lower leaf surface. Later, these become waxy, orange-brown mats that form under the epidermis, forming the telial stage.

## Rusts on Junipers

A large number of rusts, primarily in the genus *Gymnosporangium,* are found scattered throughout the Western United States and, although of little importance in forest stands from a damage standpoint, they can cause considerable damage to ornamental plantings.

### Pear-Juniper Rust

*(Gymnosporangium fuscum)*

This disease was found for the first time in California in 1960 on several ornamental juniper plantings and on pear trees in one area. Although damage can be severe on juniper hosts, the greatest economic damage occurs on the pear host. The growth and fruit set of heavily infected trees are reduced and, infected leaves tend to fall early in the season. The fungus also attacks pear fruits.

On juniper, the telial stage appears on branches and twigs, causing very slight to fusiform swellings several inches long. The perennial infection in juniper often kills the infected branch or twig in 3 to 4 years. The telia occur in horns, which are small, firm, dark-brown bodies a few mm across. Under moist conditions, they may swell and become gelatinous, cylindrical, or conical and compressed and reddish-brown. Telia horns are composed of teliospores and their stocks.

On pear, the aecial stage first appears as circular or irregularly shaped yellow-orange spots up to 2 cm in diameter on the lower surface of the leaves. The stage appears as orange-brown cushions of diseased tissue, with the aecium an off-white, acorn-shaped tubule 2 to 5 mm high.

### Amelanchier Rust

*(Gymnosporangium harknessianum)*

This rust is found chiefly on western juniper in California and central Oregon. Its alternate host is primarily western serviceberry. On the juniper host, uredinia have not been found. Telia form a reddish-brown gelatinous masses on juniper leaves. Aecia are found chiefly on western serviceberry fruits, usually over the entire surface. They are cinnamon-brown, cylindrical tubules, 4 to 7 mm tall.

## Inconspicuous Juniper Rust

*(Gymnosporangium inconspicuum)*

Probably the most abundant *Gymnosporangium* on juniper and on Saskatoon serviceberry in the Western United States, this rust is found primarily on Utah juniper and western juniper.

On the juniper host, uredinia have not been found. Telia appear as golden yellow to brown felt-like structures arising between the scale-like leaves on green twigs or frequently through the bark of woody twigs. In some parts of Utah and Nevada, the telial stage is common on older branches and larger stems. The host tissue swells slightly, but its bark appears to be abnormally rough. Although telia frequently fall off green twigs after maturation and leave no obvious signs, on woody bark they are often retained in the cracks so that the disease can be diagnosed at any time of the year. The fungus can also cause woody swellings, but these are rarely found. The aecial stage on the serviceberry host is chiefly on the fruits being scattered or crowded over the entire surface. Aecia appear as pale yellow, oblong cylindrical tubules. In some areas, fruits may be so heavily infested that it is almost impossible to find mature ones. Infected fruits are often colored bright yellow or orange by the rust, so that the whole bush may appear at first glance to bear yellow or orange fruit.

## Serviceberry Rust

*(Gymnosporangium kernianum)*

This rust is common on several species of juniper throughout the Western United States. Its principal conifer hosts are Utah, California, and western junipers. Its principal alternate host is serviceberry species, but the rust is also found on pear, hawthorn, and quince. On the conifer host, uredinia are not found. Telia are found developing between the scale-like juniper leaves as globose witches-brooms caused by fungus infection. Telia are hemispheric and dark reddish-brown.

On the alternate host, aecia are found principally on leaves and occasionally on fruits and leaf petioles. The aecia are usually inconspicuous, cylindric, cinnamon-brown pustules. They are sometimes found in mixed infections among the larger, brighter, more abundant aecia of *G. inconspicuum* on the same fruits of serviceberry.

## Juniper Rust

### *(Gymnosporangium multiporum)*

This rust is a seldom collected species and is of unknown life cycle. It occurs on western juniper in California and on one-seed and Utah junipers in Colorado, New Mexico, and central California. An alternate host for the pycnial and aecial stages is not known. On the juniper host, uredinia have not been found. Telia develop between the scale-like leaves on green branches. They are chestnut brown with oblong teliospores.

## Nelson's Juniper Rust

### *(Gymnosporangium nelsonii)*

This rust is found frequently throughout the Western United States on creeping, one-seed, western, Rocky mountain, California, and Utah junipers. Uredinia are not found on the conifer host. Telia, however, cause conspicuous woody, globose galls of varying size on branches and small stems. The telia are chestnut brown, irregularly flattened, 3 to 5 mm high. The alternate hosts are principally species of serviceberry, on which the aecia are found on leaves, petioles, and fruits. They are cylindric, 2 to 4 mm high, with chestnut brown pustules.

## Hawthorn-Juniper Rust

### *(Gymnosporangium confusum)*

This disease is found only in one area of California, but is common in Eurasia on several telial and aecial hosts. In a restricted area of California, it has become well established on *Juniperus sabina,* its telial host, and on one-seed hawthorn, which is the aecial host. Telia develop first as gelatinous horns in spring. When dry, they become very dark, velvety, reddish-brown. They develop principally in fusiform cortical swellings on woody branches. Pycnia and later aecia develop on swellings of the leaves, petioles, succulent stems, pedicels, and calyxes. Aeciospores are reddish-brown and begin to develop usually in May.

# Rusts on Cypress

Two distinct species of rust fungi are found on cypress in the Western United States: *Uredio cupressicola* and *Gymnosporangium cupressi.* Both occur only rarely.

## Gymnosporangium cupressi

This fungus has been reported on Arizona and Modoc cypress in the telial stage, and on serviceberry species in the aecial stage. The telial stage causes elongate or globoid swellings in cypress often in rows on larger branches and form irregularly wedge-shaped, chestnut-brown telial pustules. Although most common on green twigs, all stages of gall and canker development to ages 100 years or more have been found. The old cankers resemble the hip cankers of *Peridermium harknessii* on pine, with flaring sides of mostly uninfected tissue.

## Uredio cupressicola

Only the uredinial stage of this fungus has been found, and only on Gowan cypress and Arizona cypress variety *montana*. It has been found only in California and Baja California. The uredinia first appear between the scale leaves of young twigs without producing any perceptible swelling. Later, large fusiform swellings are evident on twigs 4 years old or older. Cankers usually kill the twigs within a few years, but occasionally occur on branches up to 25 years old.

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# 5. MISTLETOES

by

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The parasitic flowering plants commonly known as mistletoes are found throughout North America. Two genera of mistletoes grow in the Western United States: *Phoradendron* ("true" mistletoes) and *Arceuthobium* (dwarf mistletoes). The "true" mistletoes grow on both conifers and broadleaf trees; the dwarf mistletoes grow only on conifers. Male and female flowers are produced on separate plants in both genera.

True mistletoes are large woody plants with mature shoots more than 6 inches long and one-eighth inch or more in diameter. Foliage is leafy or scaly. The fruit resembles white or pink globes. On the Pacific Coast the true mistletoes on conifers are easily identified. Only two species and two subspecies are known. They can be distinguished on the basis of foliage characteristics and the host species.

In contrast, dwarf mistletoes are small plants, with mature shoots less than 6 to 8 inches long and one-eighth inch in diameter. The shoots are non-woody, segmented and have scale-like leaves. Seeds produced in oval-shaped bicolored fruit are forcibly released when ripe.

Although both mistletoes are damaging parasites of trees, by far the greatest timber loss in coniferous forests of the West is attributed to the dwarf mistletoes. Billions of board feet of lumber are lost each year as a result of growth reduction and mortality from these parasites. They also cause serious damage to high-value, high-use forest recreational areas.

## 1. True Mistletoes

The true mistletoes are probably more often seen and recognized than the dwarf mistletoes. Even the leafless true mistletoes usually appear as conspicuous clumps or balls of foliage growing on conifers (fig. 5-1). True mistletoes are totally dependent on their hosts, but they

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**Figure 5-1. Incense-cedar often becomes severely infected throughout its crown by the mistletoe** ***Phoradendron juniperinum*** **ssp.** ***libocedri*****.**

carry on photosynthetic activity. Thus, much of their growth is attributed to their ability to make foodstuffs from water and certain mineral elements provided by the host. In the absence of the aerial portions of the plant, however, the roots remain alive and continue to grow within the host branch, eventually producing new shoots and foliage.

Mistletoe flowers are inconspicuous, but the fruits, commonly known as berries, are readily seen (fig. 5-2). They are about the size of a pea (1/8 to 1/4 inch in diameter), when ripe, and grow in clusters. Usually one seed develops in each berry. The sticky pulp of the berry surrounding the seed is a preferred food of certain birds. In fact, the seeds are distributed mainly by birds. Consequently, these mistletoes tend to be most abundant in the tops of trees (fig. 5-3). When eaten, the seeds pass intact through the digestive tract of the birds and are deposited along with their excrement on tree branches. Thread-like strands on the seedcoat enable the seeds to adhere to branches, where they germinate, penetrate, and infect the host.

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Figure 5-2. Pinkish fruit of the incense-cedar mistletoe.

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Figure 5-3. Large clusters of mistletoe, *Phoradendron bolleanum* ssp. *pauciflorum* occur mainly in the tops of mature white fir.

Both the root and shoot system are initially produced from the germinating seed. Thereafter, buds produced from the roots break through the bark to form additional aerial shoots. Woody perennial stems develop and often persist for many years unless they are broken off or killed. Often clumps of shoots and foliage 2 to 3 feet in diameter are seen in trees.

The true mistletoes on conifers on the Pacific Coast are easy to identify. Only two species and two subspecies are known. As shown below, the true mistletoes may be distinguished on the basis of foliage and host species.

Plants with leaves

1. on *Juniperus* or *Cupressus* – *Phoradendron bolleanum* ssp. *densum*
2. on *Abies concolor* – *Phoradendron bolleanum* ssp. *pauciflorum*

Plants leafless

1. on *Juniperus* – *P. juniperinum* ssp. *juniperinum*
2. on *Libocedrus* – *P. juniperinum* ssp. *libocedri*

# Cypress — Juniper Mistletoe, "Dense" Mistletoe

*Phoradendron bolleanum* ssp. *densum*

## Hosts

Cypress, juniper.

## Distribution and Damage

This mistletoe is widespread throughout certain areas of the West. Its occurrence on *Cypress* ranges along the coast from the mountains of northwestern California southward to Marin County. Inland, it ranges from Butte County, Calif., northward along the western slope of the Sierra Nevada and into the southern Cascades. This mistletoe is also found on cypress in central Arizona.

On *Juniper,* the mistletoe extends from Baja California and Arizona northward along the eastern slope of the Sierra Nevada and southern Cascades. Along the coast, it ranges from San Diego to Monterey County, Calif.

Many plants may occur on and damage individual trees. But losses to forests from this particular mistletoe appear minimal.

## Field Identification

Clusters of mistletoe foliage occur on branches throughout the host

F-525011

**Figure 5-4. Branch of** *Cupressus* **infected by the leafy mistletoe** *Phoradendron bolleanum* **ssp.** *densum.*

crown. The shoots bear oval-shaped leaves that are usually about 0.1 to 0.2 inch wide and 0.4 to 0.8 inch long (fig. 5-4).

# White Fir Mistletoe

*Phoradendron bolleanum* ssp. *pauciflorum*

## Hosts

White fir.

## Distribution and Damage

White fir growing in the Sierra Nevada from Placer County southward and in the mountains of southern California is the host of this parasite. It also occurs in the Santa Catalina Mountains of Arizona and the Sierra San Pedro Martir in Baja California, Mexico.

This mistletoe is for the most part only a serious parasite of larger and older trees. Many years are required for it to build up and become damaging to white fir. In some instances, it becomes so dense that tree tops and sometimes entire trees are weakened and die or are attacked and killed by bark beetles.

## Field Identification

This mistletoe is most often observed in the tops of the tallest trees in the stand. Large clumps of foliage may grow along the trunk of the tree for 20 to 30 feet down from the top (fig. 5-3). Often the tree foliage in this zone is nearly completely replaced by mistletoe foliage. Spike tops are also common in white fir stands infected with this parasite. The dead mistletoe shoots remain attached to the dead top and branches for some years after death.

The leaves are smooth, oval-shaped, about 0.2 to 0.4 inch wide and 0.5 to 1.2 inches long.

# Juniper Mistletoe

*Phoradendron juniperinum* ssp. *juniperinum*

## Hosts

Juniper.

## Distribution and Damage

Along the Pacific Coast, this mistletoe ranges from the eastern slope of the southern Cascades in central Oregon, through the upper elevations of the Sierra Nevada, and south into the San Bernardino Mountains of southern California. Elsewhere in the West, it extends from northern Utah into northern Mexico. Although this mistletoe builds up to high populations on some trees, the damage it causes to stands appears to be negligible.

## Field Identification

*P. juniperinum* appears as upright clumps of shoots in the crowns of trees. The single characteristic that distinguishes it from *P. bolleanum,* which also grows on juniper, is the absence of leaves. The leaves on this particular species are reduced to inconspicuous scales less than one-sixteenth inch long. Berries are light pink.

# Incense—Cedar Mistletoe

*Phoradendron juniperinum* ssp. *libocedri*

## Hosts

Incense-cedar.

## Distribution and Damage

This mistletoe is found in the southern Cascades, on the western slope of the Sierra Nevada, and in the mountains of southern California.

For the most part, this mistletoe causes negligible damage to its host. On older trees, however, it occasionally builds up to high populations. It may weaken a tree, but rarely kills it.

## Field Identification

Round, usually pendant, clumps of mistletoe shoots in the crowns of incense-cedar identify this organism (fig. 5-1). Like the other subspecies that occur on juniper, the leaves are inconspicuous scales about one-sixteenth inch long. This mistletoe occasionally infects tree trunks and causes some swelling, but this only occurs in cases in which the root system of the parasite has been in the trunk for many years. The berries are light pink (fig. 5-2).

# 2. Dwarf Mistletoes[1]

Unlike the true mistletoes, dwarf mistletoes depend almost entirely on food produced by the host; they photosynthesize little material for themselves. The aerial shoot system, therefore, functions mainly for reproduction.

Small, inconspicuous flowers are produced in the axils of the shoot segment (fig. 5-5). Flowers are both insect and wind pollinated. Short stalks bear fruits that are about 0.1 inch long when ripe (fig. 5-6).

Unlike the true mistletoes, dwarf mistletoes are not disseminated by birds, but depend on an explosive mechanism for spread. During maturation the fruits swell with water and build up considerable hydraulic pressure. At maturity the seeds, usually one per fruit, are explosively discharged by the water pressure in the fruit. Discharged seeds may travel horizontally for 30 to 40 feet. With the aid of the wind, seeds

[1]The genus of dwarf mistletoe has been revised, and many of the species names used reflect changes in the names of the previously known dwarf mistletoes in California (Hawksworth and Wiens 1972).

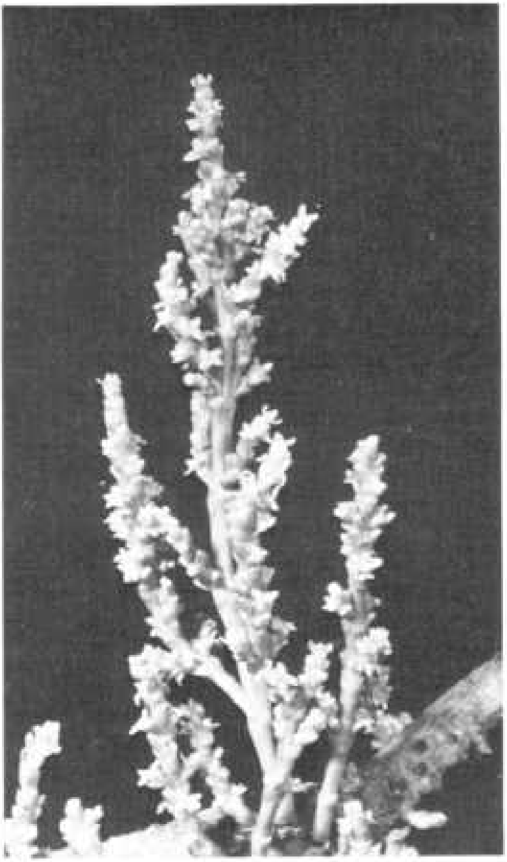

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Figure 5-5. Male plant of *Arceuthobium occidentale* bearing mature flowers.

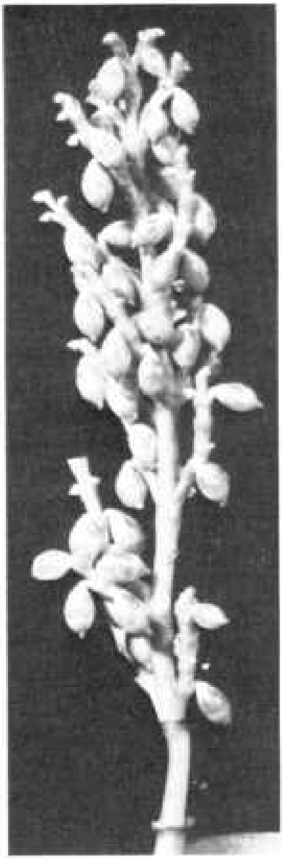

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Figure 5-6. Shoot from female plant of *Arceuthobium occidentale* bearing mature fruit.

discharged from the tops of trees may travel as far as 100 feet or more.

Like the true mistletoes, the seeds are sticky. They initially adhere to the foliage of surrounding branches and trees (fig. 5-7). During rains, the seeds swell with water, become slippery, and wash down on and adhere to host branches where germination and infection occur. The root system of dwarf mistletoe penetrates and grows within the tree branch in much the same way described for true mistletoes.

Trees respond in several ways to infection by dwarf mistletoe. Usually a localized swelling of the branch occurs (fig. 5-8). Occasionally, however, pronounced swelling of the main stem of a tree occurs as a result of the parasite infecting the trunk directly or by growing into the trunk from an infected branch. With time, these swellings may grow to a size of twice the normal diameter of the tree trunk. To compound the problem, decay fungi often enter bark cracks and openings at the site of swelling causing heart rot (fig. 5-9). Frequently these decaying trees break at the swelling, causing loss of timber and pre-

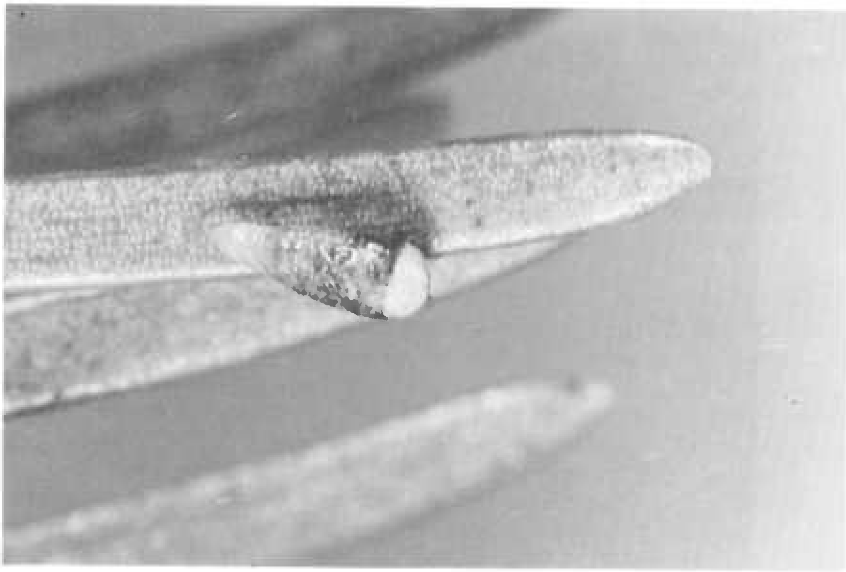

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Figure 5-7. Seed of dwarf mistletoe, *Arceuthobium abietinum* adhering to needle of white fir.

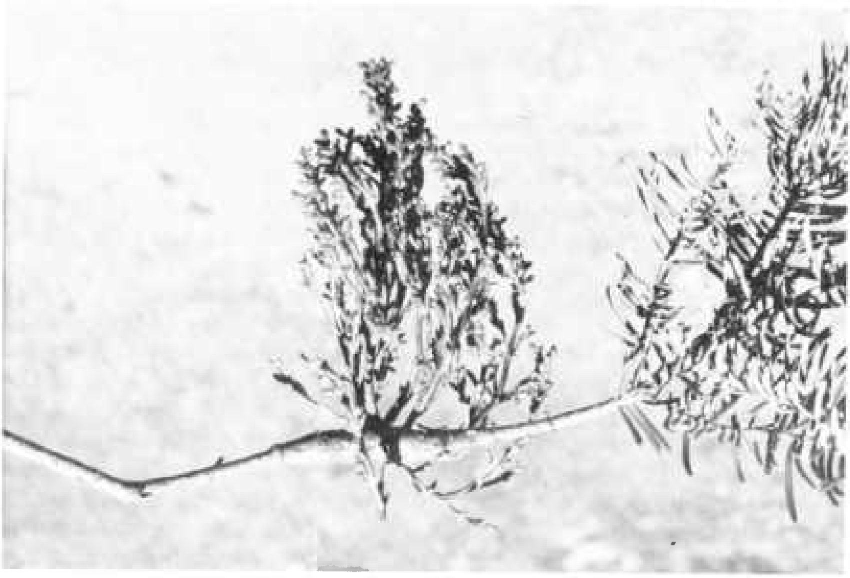

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Figure 5-8. Dwarf mistletoe plant, *Arceuthobium abietinum* arising from the infected, swollen part of a branch of white fir.

F-525016

**Figure 5-9. Open, decayed, bole swelling on white fir caused by dwarf mistletoe,** *Arceuthobium abietinum.*

senting a hazard in recreational and high-use areas.

With certain dwarf mistletoe species, branches react to infection by producing what is commonly known as a "broom." A broom is an abnormal proliferation of many small twigs on a branch which appear as a clustered mass of twigs and foliage. Brooms vary in appearance from ball-shaped to loosely fan-shaped structures. Some brooms remain small (fig. 5-10) whereas others may comprise the bulk of the foliage on a tree (fig. 5-11).

Many of the species of dwarf mistletoe are host specific and occur on only one species of tree. Others may occur on three or four different species of conifers, but only rarely do they cross infect from one genus of conifer to another. When they do, they usually spread from the primary host to secondary hosts in stands in which both hosts are growing close to one another. As a result of their host specificity, the dwarf mistletoes of the West can best be distinguished from one another on the basis of host species and host distribution.

F-525017

**Figure 5-10. Characteristically open, fan-shaped brooms on white fir caused by the dwarf mistletoe,** *Arceuthobium abietinum.*

F-525018

**Figure 5-11. Massive tight brooms develop on Douglas-fir as a result of infection by dwarf mistletoe,** *Arceuthobium douglasii.*

# Descriptive Key

On pines

| | | |
|---|---|---|
| $A^1$ | Pinyon pines | *A. divaricatum* |
| $A^2$ | 2-3-needle pines | *B.* |
| $B^1$ | Digger, Monterey, and bishop pines; occasionally on Coulter and knobcone pines in the coastal mountains of central California | *A. occidentale* |
| $B^2$ | On ponderosa and Jeffrey pines in California, Oregon, Idaho, and Washington; also on Coulter and knobcone pines in areas other than those mentioned above. | *A. campylopodum* |
| $B^3$ | On lodgepole pine | *A. americanum* |
| $A^3$ | 5-needle pines | *C.* |
| $C^1$ | On sugar pine; rarely western white pine. Plants with shoots 4- to 6- inches long | *A. californicum* |
| $C^2$ | On limber pines, rarely on whitebark and western white pines. Small plants (shoots usually less than 2 inches long). | *A. cyanocarpum* |

On fir, hemlock, Douglas-fir, western larch

| | | |
|---|---|---|
| $A^1$ | On fir | *B.* |
| $B^1$ | On white fir or grand fir | *A. abietinum* f. sp. *concoloris* |
| $B^2$ | Red fir or noble fir | *A. abietinum* f. sp. *magnificae* |
| $A^2$ | On western and mountain hemlock | *A. tsugense* |
| $A^3$ | On Douglas-fir | *A. douglasii* |
| $A^4$ | On western larch | *A. laricis* |

# True Fir Dwarf Mistletoe

*Arceuthobium abietinum*

**(f. sp.** *concoloris)* **— white fir, grand fir**

**(f. sp.** *magnificae)* **— red fir, noble fir**

## Hosts

This unique dwarf mistletoe is the only species known that has two specialized host forms. These forms, although identical in appearance, are host specific — one infecting only red fir and noble fir and the other infecting only white fir and grand fir.

The white fir-grand fir form has never been found on red fir or noble fir. It rarely infects sugar pine in the Sierra Nevada and Brewer spruce in southern Oregon.

## Distribution and Damage

The fir dwarf mistletoes are common and widespread on their hosts through their range in the central and southern Cascades, Sierra Nevada, and coastal mountains of northern California and southern Oregon. In California, about 30 percent of the white fir stands and about 50 percent of the red fir stands are infested with this parasite. As a result of its widespread distribution, dwarf mistletoe constitutes one of the most serious forest disease problems in the management of true firs.

## Field Identification

The presence of dwarf mistletoe plants and fusiform branch swellings is a sure sign of infection (fig. 5-8). One of the best indications of infection in fir stands is the presence of branch flagging. Branches infected by dwarf mistletoe are commonly attacked and killed by a canker fungus, *Cytospora abietis,* and flagging results. The brick red-flagged branches are most conspicuous in late spring and summer when the foliage on the killed branch begins to dry. Later in the fall, the dead foliage turns more gray-brown in color.

Large swellings as a result of invasion of the tree trunk by the parasite are common on large, old firs (fig. 5-9). These swellings are often very pronounced and may reach a diameter of twice the normal size of the trunk.

Some brooming occurs on older infected branches, but is not conspicuous (fig. 5-10). Brooms caused by fir broom rust (see Chap. 4) also occur on firs in the West and could be confused with those caused by dwarf mistletoe.

# Lodgepole Pine Dwarf Mistletoe

*Arceuthobium americanum*

## Hosts

Lodgepole pine *(Pinus contorta* ssp. *murrayana)* is the common host for this mistletoe, although it has been found rarely on ponderosa pine.

## Distribution and Damage

*A. americanum* has the widest range of any North American dwarf mistletoe, mainly because of the wide range of its principal host. It occurs throughout the Western United States and Canada. On the Pacific Coast it occurs on lodgepole pine in the Cascades and Sierra Nevada. It has not been found on shore pine (*P. contorta* ssp. *contorta*) or *P. contorta* ssp. *bolanderi* along the coast.

Forest disease surveys indicate that nearly 30 percent of the lodgepole pine stands in California are infested with this parasite. Where it occurs, it is damaging and causes considerable growth reduction and mortality to lodgepole pine.

## Field Identification

Pronounced brooming of trees is the most conspicuous symptom of infection. Brooms on older, heavily infected trees often make up nearly the entire live crown. The presence of dwarf mistletoe plants and some fusiform swelling of branches also indicate infection.

# Sugar Pine Dwarf Mistletoe

*Arceuthobium californicum*

## Hosts

The principal host of this mistletoe is sugar pine. It occurs rarely on western white pine.

## Distribution and Damage

This dwarf mistletoe occurs throughout the range of sugar pine in the west from the southern Cascades, through the Sierra Nevada to the Cuyamaca Mountains of southern California. It also occurs on sugar pine in coastal mountains of northern California from about Lake County to the Oregon border.

Although this mistletoe occurs essentially throughout the natural range of sugar pine, it is not as common as dwarf mistletoes on other species. Forest disease surveys have shown that about 20 percent of the forest stands containing sugar pine are infested with this parasite. The frequency of dwarf mistletoe is probably lower on sugar pine than on other host species because sugar pine rarely forms pure stands but occurs in mixture with other conifer species. Sugar pine seldom comprises more than 50 percent of a stand. This mixed stand situation undoubtedly limits the spread of the parasite under natural forest conditions.

Where sugar pine is infected, heavy damage can occur. Numerous infections may develop and large brooms on older trees are common. Severe growth reduction results from heavy infection. Weakened trees are also often attacked and killed by bark beetles.

## Field Identification

Large compact brooms in the crowns of older trees are the best symptoms of infection. Numerous individual fusiform branch swellings and the presence of aerial shoots of the parasite are also easily recognized symptoms and signs of infection.

# Western Dwarf Mistletoe

*Arceuthobium campylopodum*

## Hosts

Ponderosa pine, Jeffrey pine, knobcone pine, Coulter pine.

## Distribution and Damage

This parasite ranges throughout the forested regions of the West from Washington and Idaho, through Oregon and California, but it is not known in the coastal mountains south of Lake County, Calif.

The western dwarf mistletoe is one of the most damaging forest disease agents in the Western United States. Many commercial pine stands there have been killed or suffered reduced growth. Jeffrey pine is considered to be more susceptible to this parasite than ponderosa pine, but both species are heavily attacked. Coulter pines in southern California suffer heavy mortality and are among the most seriously damaged species.

## Field Identification

The presence of fusiform branch swellings and aerial shoots of the plant are conspicuous indications of infection. Brooms may form. On larger trees, they become well developed and are easily observed. Swelling as a result of trunk infection is not as pronounced as that in true firs. But, in some cases, old trunk infections result in open, pitch-infiltrated bole cankers.

# Limber Pine Dwarf Mistletoe

*Arceuohobium cyanocarpum*

## Hosts

Limber, whitebark, foxtail, and western white pines.

## Distribution and Damage

This mistletoe occurs on its hosts mainly in the Rocky Mountain region. In the far West, it occurs only in the southern Cascades, east side Sierra Nevada, San Bernardino, and San Jacinto Mountains of California.

Infected trees are often severely damaged and deformed and a high rate of mortality has been observed.

## Field Identification

Infected trees bear numerous infections and the parasite is easily recognized by the presence of numerous small, densely clustered shoots. Brooms are formed, but are typically small and compact. Stands infested by the parasite may show mortality to such an extent that "ghost forests" result.

# Pinyon Dwarf Mistletoe

*Arceuthobium divaricatum*

## Hosts

Singleleaf pinyon pine.

## Distribution and Damage

This parasite infects pinyon pines in the Rocky Mountains and on the east side of the Sierra Nevada and in mountains of southern California. Damage is usually not severe even when trees are heavily infected. Tree mortality is slight, although growth is reduced.

## Field Identification

Heavily infected trees often bear hundreds of individual branch infections. Broom formation, however, is not conspicuous.

# Douglas Fir Dwarf Mistletoe

*Arceuthobium douglasii*

## Hosts

The principal host is Douglas-fir, but it has been found occasionally on several species of true fir and spruce in association with infected Douglas-fir.

## Distribution and Damage

This parasite occurs on Douglas-fir in the Pacific Northwest east of the crest of the Cascades. Elsewhere, it occurs on Douglas-fir from southern British Columbia to central Mexico. Only in southwestern Oregon and California does it occur along the coast, and then only as far south as Shasta, Siskiyou, and Trinity Counties.

Douglas-fir is severely damaged by this parasite. Heavily infected trees are weakened, deformed, and often killed. Because Douglas-fir often grows in pure stands or is the predominant species, damage to commercial forests by this mistletoe is often widespread.

## Field Identification

Huge brooms are common on older infected trees (fig. 5-11) and are nearly certain indication of infection by dwarf mistletoe. Young infected trees may be stunted and deformed. The mistletoe plant itself is very small and inconspicuous. The aerial shoots often arise from along infected branches of a broom or from the spindle-shaped localized infections, but seldom grow to more than 1 inch in length (fig. 5-12).

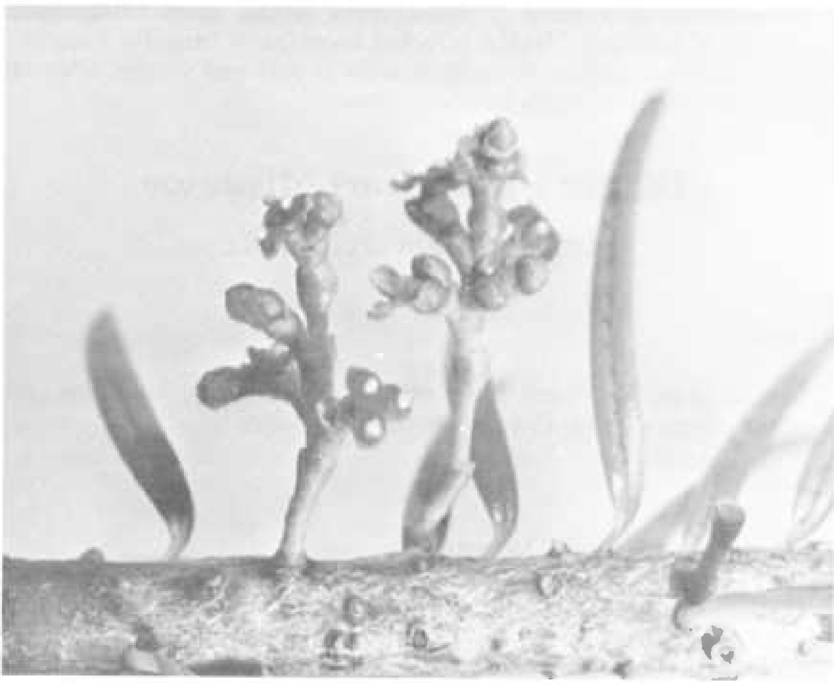

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**Figure 5-12. Small, inconspicuous plants are produced by dwarf mistletoe, *Arceuthobium douglasii* on Douglas-fir (male shoots with mature flowers).**

# Larch Dwarf Mistletoe

*Arceuthobium laricis*

## Hosts

Western larch (*Larix occidentalis*) is the principal host for this species. Several other conifer species are sometimes infected when they grow in association with infected larch.

## Distribution and Damage

In general, larch dwarf mistletoe occurs throughout the range of western larch. It is found east of the Cascades in Oregon and Washington, but does not occur in California. Western larch suffers severe damage from larch dwarf mistletoe. A high proportion of larch stands are badly infested and heavy mortality and growth loss is common.

## Field Identification

Pronounced brooming of older trees is the most conspicuous symptom of infection. Badly infected trees have literally dozens of brooms that are particularly noticeable in fall and winter after the deciduous foliage of larch has been shed.

# Digger Pine Dwarf Mistletoe

*Arceuthobium occidentale*

## Hosts

Digger pine, Monterey pine; occasionally bishop, knobcone, and Coulter pines; rare on *P. contorta* ssp. *bolanderi*.

## Distribution and Damage

Until recently this species of dwarf mistletoe was considered to be the western dwarf mistletoe, *A. campylopodum*. However, recent studies have shown that this dwarf mistletoe does not infect ponderosa and Jeffrey pines, but is restricted to the lower elevational digger and coastal pines of California. In general, this mistletoe occurs on its hosts throughout their natural range in the State.

Severe damage occurs to trees and stands heavily infected by this parasite. Trees are reduced in growth, deformed, and often killed. Digger and Monterey pines are particularly susceptible to infection. Hundreds of individual infections may occur on trees over a period of just several years and the upward spread of the parasite on this host species is known to be very rapid and equal to the height growth of vigorous trees.

## Field Identification

The presence of numerous dwarf mistletoe plants and fusiform swollen branches is probably the best symptom of infection. Because of the rapid rate of buildup and upward spread of this parasite, infections may be seen throughout the crowns of heavily infected trees.

Although some broom formation occurs, brooms never become as well developed as those caused by western dwarf mistletoe or sugar pine dwarf mistletoe.

# Hemlock Dwarf Mistletoe

*Arceuthobium tsugense*

## Hosts

The principal hosts are western hemlock and mountain hemlock although some other conifer species (usually pines and true firs) are occasionally attacked, particularly when they grow in association with hemlocks.

## Distribution and Damage

This mistletoe occurs on western hemlock along with the Pacific Coast from Alaska to northern California. Inland, it occurs on mountain hemlock in the southern Cascades and as far south as Alpine County in the central Sierra Nevada.

Forest trees and stands are severely damaged by this mistletoe, particularly the western hemlock along the Pacific Coast. Severe growth loss, deformation, and mortality result from heavy infection.

## Field Identification

Brooming of older trees is the most noticeable symptom of infection. Brooms are often large and abundant (fig. 5-13). Smaller trees are often severely stunted. Aerial shoots of the plant are not always formed particularly under the densely shaded conditions of the coastal forests. Only under open growing conditions or in the tops of trees does

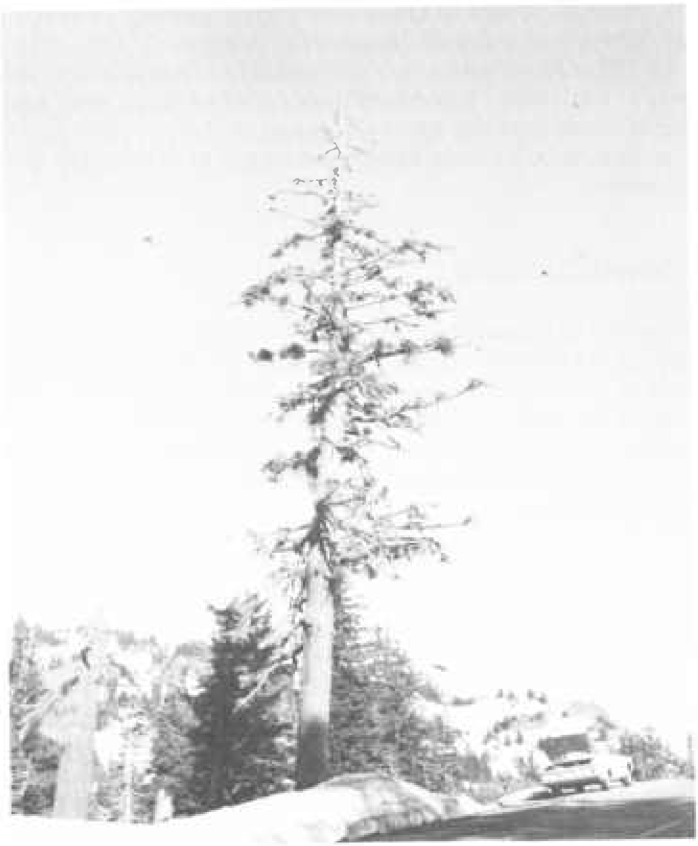

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**Figure 5-13. Large mountain hemlock killed by dwarf mistletoe, *Arceuthobium tsugense*. Note the numerous compact brooms formed on branches.**

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# 6. ROOT DISEASES

by

RICHARD S. SMITH, JR.*

Root diseases are becoming increasingly more important in the forests of the Western United States. Each year more areas of root disease infestation and greater numbers of infected trees are detected because of increased awareness, more intensive surveys, and better diagnostic techniques. And, in many areas, forest management practices have increased the incidence and severity of root diseases in the past and unless control measures are taken, they will continue to do so in the future.

The major root diseases in western forests are doubly destructive. They not only kill the trees now growing on the site, but can exist in dead roots and soils for many years, killing any future trees which become established within the infested site. Some root disease fungi remain alive and active in infested sites for more than 50 years. The losses resulting from these diseases then should include the trees destroyed initially plus the loss in productivity of the site for the number of years it is infested.

Four major tree root diseases are found in the Western United States: annosus root disease, Armillaria root disease, black stain root disease, and *Phellinus (Poria) weirii* root disease. The relative importance of each disease, however, varies from area to area. Several lesser diseases may be important in local areas or in certain periods of a stand's development.

The diagnosis of root diseases is difficult and can seldom be made only on above-ground symptoms. The above-ground symptoms of chlorosis, reduced tree growth, reduced needle length, fading crown, and finally death are the same for all root diseases. These symptoms also are similar to those caused by drought, high water table, air pollution, and bark beetle attack, except that the decline of the tree affected by root disease or air pollution is usually extended over a period of 3 to several years and these other causes kill the tree in 1 to 2 years.

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The pattern of the dead and dying trees often is helpful in diagnosing root disease as the cause of a problem. Characteristically, root diseases start in a tree or stump and spread slowly outward in all directions. This results in a slowly enlarging group of dead trees, with the oldest kills at the center and with a fringe of dying and recently killed trees around the outer edge. Thus, if one finds a pocket of dead trees that were all killed at once, he would suspect some other cause which would fit this pattern of kill, such as ground fire, high water table, or insect attack.

Accurate diagnosis depends upon examination of part or all of the root crown and major buttress roots. This portion of the tree provides the most helpful signs and symptoms of each root disease, such as sapwood stain and decay, mycelial fans, rhizomorphs, resinosis, and fruiting bodies. It is best to choose a recently killed tree for examination for these below-ground signs. Frequently, these signs are destroyed after a year or two by secondary invaders — both insects and fungi.

## Descriptive Key

A1 Black to chocolate-brown stain or streaks of stain in the sapwood of the roots, root crown, and/or lower bole ............................................................Black stain root disease

A2 No black stain, stain if present blue, blue-gray, or gray ........B

- B1 Large white mycelial fans between bark and wood of roots and root crown. Shoestring-like strands (rhizomorphs) sometimes present on roots and/or under the bark. Associated decay white to yellowish stringy rot sometimes with fine black zone lines...............Armillaria root disease
- B2 White mycelial fans and rhizomorphs absent...................C
  - C1 Bark of roots and root crown separate easily from wood. Small white flecks of mycelium on inner side of bark — numerous brown resin canals noted on wood surface. Small white amorphous fruiting bodies or buttonlike fruiting body initials may be present on roots or root crown below soil surface, or shelf-like cream to light orange colored fruiting bodies inside hollow stumps. Associated decay white to cream colored, soft and spongy.................Annosus root disease
  - C2 Roots and lower bole decayed, leaving a yellow to buff laminated rot with dark brown mycelial felts often between sheets of decayed wood and in shrinkage cracks. Fruiting bodies inconspicuous, crustlike, covered with many small pores, buff with white margin when young, turning dark brown with age .........................*Phellinus (Poria) weirii* root disease.

# Annosus Root Disease

*Fomes annosus*

## Hosts

*Fomes annosus* has an extensive host range, including most conifers, some hardwoods, and a few species of brush. To date, it has been found on nearly all native and many introduced conifers in the West.

## Distribution and Damage

Worldwide in distribution, *F. annosus* is also widely distributed throughout the conifer forests of the Western United States. It has been found from the dry pinyon-juniper woodland of the Southwest to the high rainfall cedar-hemlock forests of the Pacific Northwest. This fungus is indigenous and most abundant in the true fir forests of California and hemlock forests of Oregon and Washington. It is being found with greater frequency in the logged pine forests of California.

In Europe and the Southeastern United States, the incidence of this disease has increased directly with increased forest management until now it is one of the major disease problems. Experience indicates that, without control measures, this disease in the West will follow the same pattern.

Although most conifers are attacked by *F. annosus,* the way in which the host is affected and the type of resulting damage differ. In pine, the fungus spreads through the root system, first attacking the inner bark and sapwood, killing these tissues. Its penetration into the heartwood is delayed. Within 2 to 6 years after initial infection, the fungus reaches the root crown and girdles the tree. The tree dies, but the fungus remains active as a saprophytic wood-decaying organism within the roots and butt of the dead tree. Thus, in pine, *F. annosus* kills the host within a short period.

In true firs, Douglas-fir, and hemlock, the fungus seldom attacks the root tissues to the extent that the host is directly killed. In these hosts, the sapwood and inner bark usually are invaded in the small-to-medium-sized roots. And the fungus is confined to the heartwood and inner sapwood of the larger roots. Within the heartwood, the fungus spreads through the roots and root crown into the lower trunk of the host, where it causes a butt rot of the heartwood. Thus, infection in these species usually does not kill the host directly, although it may affect its growth or thriftiness. Losses in true firs from *F. annosus* are mainly the result of butt rot, increased susceptibility to insect attack, and increased windthrow.

## Disease Cycle

This fungus can survive for as long as 50 years as a saprophyte in the roots of infected stumps and trees. During favorable periods, the fungus in these stumps and roots forms fruiting bodies which in turn produce numerous spores. Air currents distribute the spores to new infection sites. These sites are usually freshly cut stump surfaces of all conifer species and basal wounds of hemlock and fir. Spores landing on a fresh stump surface germinate, infect the new stump, grow down into the roots, and eventually colonize the stump and its root system.

Once established in the stump, the fungus grows into the roots of neighboring trees wherever root contact between the infested stump and the surrounding trees exists. From these newly established infections at the site of root contact, the fungus spreads through the roots of the new host to the root crown. The rest of this tree's root system is colonized and the fungus spreads to its neighbors, again through root contact. By this method, enlarging infection centers are formed.

## Field Identification

In pines, the pattern of dying within the stand and individual trees is often helpful in diagnosing this root disease. The presence of annosus root disease is indicated by group killings of trees over a period of years with the oldest deaths at the center and the most recent dead and dying trees on the periphery. The presence of a stump at the center near the oldest kill suggests *F. annosus* root disease. If death of individual trees were preceded by a period of reduced growth or stunting as indicated by the terminal height growth and if the crowns of the dying trees are thin and chlorotic, a root disease is again suspected.

The presence of *F. annosus* fruiting bodies on the infected trees are the best field evidence of this root disease. These fruiting bodies vary in size and form from a small button up to a bracket-type conk several inches wide (fig. 6-1 left) to rather irregular amorphous fruiting bodies (fig. 6-1 right).The fruiting bodies found on the root crowns of infected pines range from ½ inch to 2 inches across, with a light brown to gray upper surface and a creamy white lower pore surface. It is usually necessary to remove the duff from around the base of the tree to expose the fruiting bodies, which are characteristically found below the litter layer. Conks found in the cavities of old hollow heartrotted stumps (especially fir) are larger — sometimes up to 10 inches wide — and tend to have a pale orange cast to the pore surface.

Symptoms of this disease may also be found by exposing the roots and root crown and examining the inner bark. Indications of *F. annosus* infection in pine are: (a) the bark separates easily from the wood; (b) the separated surfaces are a light brown to buff and the surface of the wood is streaked with darker brown lines (fig. 6-2); and (c) the surface of the inner bark has numerous small silver to white flecks. These symptoms may be difficult to see when the roots are wet in the spring. In addition, small white to buff mycelial pads or out-growths

F-700269

Figure 6-1. Fruiting bodies of *Fomes annosus.* (Left): A small bracket-like conk formed on the root crown just below the duff. Note the buff upper surface and white lower surface.

F-700270

(Right): a larger amorphous-type of conk typical of those found inside stumps. Note the pale orange color of the pore surface.

F-700271

Figure 6-2. A root infected by *Fomes annosus* showing the tan streaking of outer wood surface and the silver pockets of fungus growth on the inner surface of the bark. The white pocket rot characteristic of *F. annosus* rot is shown in the piece of wood.

are sometimes found between the outer bark scales or on the bark surface. Infected roots are often heavily infiltrated with resin, and balls of resin are often found in the soil next to infected roots.

In fir and hemlock, mortality from the disease is infrequent. Therefore, it is seldom necessary to diagnose a *F. annosus* problem unless it has been aggravated by windthrow, beetle attack, or other conditions. The best signs are the presence of fruiting bodies in the hollow roots and trunk and the type of wood decay in the roots and trunk. This decay is described in Chapter 7 on Rots.

# Armillaria Root Disease

## Armillaria mellea

*Armillaria mellea* is responsible for the root disease known as Armillaria root disease, shoestring root disease, or oak root disease of conifer and orchard trees. Widespread throughout the tropical and temperate regions of the world, it has long been recognized as the cause of a major root disease and as a widespread forest saprophyte. These two roles of *A. mellea* have done much to cloud the picture and our judgments of its importance.

### Hosts

*A. mellea* has an extremely wide host range, including trees, shrubs, and herbaceous plants. Most conifers in the West are probably at least moderately susceptible to this fungus. Some are highly susceptible.

### Distribution and Damage

*A. mellea* is found in most forest areas, both conifer and hardwood. It is a major pest on orchard crops in agricultural lands and on ornamental trees and shrubs in many cities, towns, and parks.

The fungus attacks the roots and root crown of trees of all ages, killing the cambium and inner bark and causing a decay of both sapwood and heartwood. It is highly aggressive and damaging in some young conifer plantations and ornamental plantings. In younger trees, the pathogen advances rapidly through the inner bark to the root collar, where it girdles and kills the tree. In older trees, this advance through the inner bark proceeds much slower and is often blocked by the host before the fungus reaches the root crown. In cases where cambial advance is checked, decay of inner wood may continue to advance. Thus in older, vigorous forest trees, *A. mellea* often does not kill its host, although, as a decay organism, it often structurally weakens the roots and predisposes the tree to windthrow. The virulence of this pathogen is greatly influenced by the environment, host vigor, and the pathogens inoculum potential (food base). Available information also indicates that there are races of this fungus that vary in their virulence to a given host.

## Disease Cycle

In general, this fungus lives as a decay organism in the roots, lower boles, and stumps of either dead or living trees. In some cases, however, it becomes actively parasitic on living trees. Its fruiting bodies (fig. 6-3), which are typical gill fungi (mushrooms), develop in the fall in clusters at or near the base of infected dead or dying trees and stumps. The mature fruiting bodies release many small spores that are windborne to other infection sites, such as stumps or woody debris on the forest floor. Infection of living trees by spores has not been demonstrated.

*A. mellea* is most commonly spread to living trees by rhizomorphs or root contact (fig. 6-4). Rhizomorphs are specialized fungus structures that grow out from an established food base to colonize new sites. When these rhizomorphs, growing through the upper soil and litter layers, contact the root or root crown of a new host, they penetrate through the bark and attempt to establish an infection. The disease also spreads when the roots of an uninfected tree come in contact with an old infected root or stump and grow into the new host root.

F-700272

**Figure 6-3. A cluster of fruiting bodies of *Armillaria mellea*. Note the light brown color, the annulus, and the gills attached to the stalk.**

## Field Identification

Occasionally, the fungus can be identified in the field by its fruiting bodies (fig. 6-3), which develop in groups around the bases of infected trees in fall. These fruiting bodies are light brown to honey colored mushrooms with a central stalk 3 to 10 inches long. A ring or annulus is usually found around the stalk. The cap, 2 to 5 inches across, is honey yellow and may be dotted with dark brown scales. The lower surface of gills are white to pale yellow and are attached to the stalk. They are of limited diagnostic value in many areas of the West because of their infrequent production and their short season of appearance.

The rhizomorphs (fig. 6-4) and mycelial fans (fig. 6-5), which the fungus produces on the host, are of greater aid in diagnosis. Rhizomorphs may be produced between the bark and the wood, on bark surfaces below the soil line, and in the litter and soil around the roots and root crown. They are dark brown to black flattened string-like structures with a white central core. They may resemble small rootlets, but closer examination will show that they adhere to and penetrate directly into infected root surfaces and that they branch differently than do true rootlets.

Mycelial fans (fig. 6-5) are creamy white flat thin leathery sheets of fungus growth which develop in the cambial area between the bark and the wood of an infected host. The advancing margin of these sheets is fan-shaped and often veined.

F-700273

**Figure 6-4. A closeup of the rhizomorphs of *Armillaria mellea* typically found on or under the bark of infected roots and root crowns.**

F700274

**Figure 6-5. Mycelial fans of *Armillaria mellea* on an incense-cedar. These creamy white leathery sheets of fungus grow beneath the bark of infected roots, root crowns, and lower stems.**

Other characteristics used in identifying this disease are resinosis and type of decay. Excess resin and resin flow is frequently encountered at the root crown in the bark and surrounding soil. The wood decay caused by *A. mellea* is a white to yellowish stringy rot that may be accompanied by fine black zone lines.

# Black Stain Root Disease

*Verticicladiella wagenerii*

## Hosts

This disease has been found on Jeffrey, ponderosa, knobcone, lodgepole, pinyon, singleleaf pinyon, sugar, western white, and eastern white pines, and on Douglas-fir. All other pines tested have been susceptible. Greenhouse studies and field observation show that white and red firs are resistant.

## Distribution and Damage

The black stain root disease caused by the fungus *Verticicladiella wagenerii* is a recently reported disease of conifers. Although this disease is not currently causing great losses in commercial forests, the damage it has done in the non commercial pinyon forests in Mesa Verde National Park and in southern California indicates that *V. wagenerii* is potentially a dangerous pest. The disease is similar to oak wilt and Dutch elm disease — two very damaging vascular wilt diseases of eastern hardwoods.

This disease is known to exist only in the Western United States. It is widely but sparsely distributed in two dozen or so general infection areas in eight western States. The largest of these areas is in southern California, where several thousand acres of singleleaf pinyon pine forests are infested.

*V. wagenerii* attacks trees of all ages. It infects the roots, where it spreads throughout the sapwood of the root system, root crown, and lower bole. This infection of the root system causes a visible decline in the tree crown. Terminal growth is reduced, needles become shorter and chlorotic, the number of needles produced and retained is reduced, and finally the host dies. Trees weakened by this disease are predisposed to bark beetle attack. This fungus does not decay the root wood.

## Disease Cycle

There are two distinct phases of the spread of this disease — local spread and long distance spread. Local spread — within an existing infection center — occurs through root contacts. Infection occurs at the site of root contact between an infected and healthy root. Once established in the root, the fungus colonizes the distal portion of the root and grows toward the root crown. From the root crown, it colonizes the remaining roots. Long distance spread involves the establishment of new infection centers away from existing ones. How this occurs is not known.

## Field Identification

This disease is relatively easy to identify in the field: It produces a distinctive sapwood stain in the roots, root crown, and sometimes the lower bole (fig. 6-6). The stained sapwood is black to dark chocolate brown, and often is infiltrated with resin. In cross section, the stain tends to occur in arcs that follow annual rings (fig. 6-7) rather than in the wedge-shaped patterns characteristic of other sapwood stains. Blue stain, which is sometimes confused with black stain, has a wedge-shaped pattern and a bluish gray cast.

F-700275

**Figure 6-6.** The black to dark brown stain of *Verticicladiella wagenerii* in the sapwood of the root crown of a western white pine.

F-700276

**Figure 6-7.** A cross-section of a pinyon pine root infected with *Verticicladiella wagenerii* showing how stain tends to occur in arcs which follow the growth rings.

# Phellinus Weirii Root Rot

*Phellinus (Poria) weirii*

## Hosts

*Phellinus (Poria) weirii* occurs most frequently on Douglas-fir and western red cedar, but also has been found on grand fir, alpine fir, silver fir, white fir, lodgepole pine, ponderosa pine, western white pine, western hemlock, mountain hemlock, western larch, Sitka spruce, Engelmann spruce, and incense-cedar.

## Distribution and Damage

The range of this root rot extends from Southwestern Canada to the Northwestern United States.

*P. weirii* causes both a necrosis of the inner bark of the roots and the root crown, and a wood decay of the roots and the lower bole. This results in growth loss and eventually death of the infected tree. Windthrow of infected living trees caused by excess root decay is also common.

This is the most damaging disease to Douglas-fir in the Pacific Northwest. It is responsible for an estimated annual loss of 115 million cubic feet of timber. Available evidence suggests that root disease centers probably contribute materially to maintaining populations of Douglas-fir bark beetles between outbreak years.

## Disease Cycle

*P. weirii* is a native inhabitant of many forest stands in the Pacific Northwest. Initial infection of the current stand of trees starts when their roots contact *P. weirii*-infested stumps and roots of the previous stand. The fungus spreads to the surfaces of new roots and penetrates directly through the bark to the living tissues. Once in the root, the fungus may develop in the heartwood or sapwood. Spread within a stand occurs through root contacts between infected and healthy trees. The fungus does not grow through the soil for any distance. The fungus forms fruiting bodies, which produce basidiospores, but their role is unknown. No asexual spores are formed.

## Field Identification

Above-ground symptoms of *Poria weirii* infection are chlorosis, a reduction in growth, a gradual thinning of the crown, and frequently a crop of distress cones. Live trees with advance root-decay are frequently windthrown.

Incipient decay in the roots and lower bole appears as a red-brown

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**Figure 6-8. The buff colored pore surface of the fruiting body of** *Phellinus (Poria) weirii.*

stain frequently in the outer heartwood. As decay proceeds, the wood softens, small pits appear, and the annual rings separate to form the typical yellow laminated rot. Brown mycelium often can be found between the sheets of decayed wood.

Fruiting bodies, which are infrequent, are found on upturned roots and on the underside of decayed logs (fig. 6-8). They appear as light buff-colored crusts with a white margin. The exposed surface of the fruiting body is covered with many small, uniform-sized regular pores. As they age, these fruiting bodies turn dark brown.

## Minor Root Diseases

*Polyporous schweinitzii,* the velvet top fungus, commonly causes a root and butt rot of conifers. It has, however, been found causing a root disease of young plantation conifers which on occasion resulted in rather high mortality. The decay of the roots of older trees by this fungus often predisposes the host to windthrow. See Chapter 7 on Decays for a description of the velvet top fungus and the decay it causes.

*Phytophthora cinnamomi* causes a root disease of many tree species, including conifers. *P. cinnamomi* is limited by environmental factors; it requires soils which are warm and moist — two conditions that do not occur simultaneously in most Western forest lands. Because of these limitations, *P. cinnamomi* is usually found in the irrigated warmer soils of the Sierra Nevada foothills and southern California. Forest nurseries, Christmas tree farms, parks, and other sites with summer irrigation are the areas in which *P. cinnamomi* is most often found.

Other species of *Phytophthora* also produce conifer root diseases. *P. lateralis* causes a very destructive root disease of Port Offord cedar in coastal Oregon. *Phytophthora* spp., in general, infect and kill the host's roots. They grow from the roots up through the root crown and into the lower stems, where they kill the inner bark and cause a browning of the new sapwood.

*Macrophomina phaseoli*, which is responsible for charcoal root disease of tree seedlings in forest nurseries, is occasionally found causing a root disease of older planted trees. It is limited to very warm sites and is most often detected during periods of moisture stress. The disease can be identified by the presence of numerous small, spherical, black, fungus bodies (microsclerotia) in the inner bark and on the xylem surface of infected roots.

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# 7. ROTS

by

ROBERT F. SCHARPF*

Heart rots are caused by fungi that attack and rot (decay) the nonliving heartwood in the central core of a tree. The living outer cylinder of wood commonly called sapwood is usually free of attack.

About a dozen different fungus species are considered major heart rot organisms of conifers along the Pacific Coast. A few of these fungi are host specific — they attack only a single tree species. Others rot heartwood of nearly every major conifer and even some hardwoods. Many heart rot organisms decay only heartwood of living trees, whereas others also decay heartwood and sapwood of dead trees, deteriorate wood in use, and decompose slash and organic matter in soil.

Heart rots are considered one of the most serious forest disease problems in the Western United States. Collectively, they are responsible for the loss of millions of board feet of lumber each year. Old-growth stands are particularly heavily attacked by heart rot fungi, but even second-growth stands suffer heavy losses in certain instances. Rots not only render timber unmerchantable, but reduce the quality of the wood that is used. Rot fungi also predispose trees to windthrow and breakage. This not only causes additional loss of timber, but also constitutes a hazard in recreational and high-use areas.

As a rule, heart rot fungi do not penetrate sound trees, but require an opening into the heartwood through which to invade. Any opening into the heartwood or exposure of dead sapwood next to heartwood is a potential site for heart rot fungi to become established. Wounds caused by fire or human activities are common points of entry by these fungi and may increase the incidence of heart rots in trees. The elimination of all wounds is, however, not possible. Certain animals, particularly rodents, birds, and insects, wound trees. Also, wounds associated with weather, such as lightning, wind, snow, ice, excessive heat and cold, provide entrance courts for heart rot fungi. But these types of wounds are considered less important than those caused by human activity and by fire.

Certain natural openings in trees also provide a means of entrance

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for heart rot organisms. Among these are branch stubs, open knots, and dead branches. A few heart rot fungi penetrate through living branches. Some heart rot fungi, particularly the "butt rot" organisms, may enter the tree through the roots or through basal fire scars. Fungi, such as *Fomes annosus* and *Polyporus schweinitzii,* are root parasites as well as heart rot fungi and kill roots before invading the heartwood. Butt rot organisms also enter the heartwood through roots killed or injured by other means.

Several systems have been devised to classify the heart rots conveniently. But, for the most part, only three of these are useful for field identification. One system is based on the type of rot produced; the second, on the characteristics of the fungus fruiting body; and the third, on the location of the rot within the tree.

The first system recognizes two general types of rots, the brown rots and the white rots. Brown rots develop as a result of the selective utilization of carbohydrates (primarily cellulose) by the fungus, leaving behind the brownish lignin component of wood. Brown rotted wood usually is dry and fragile and tends to crumble readily or break into various sized cubes. Most brown rots form a solid column of rot, but some appear in pockets, such as those caused by *Polyporus amarus* and *Poria sequoiae*. A few brown rot fungi produce a stringy, brown rot that in some cases is similar to that produced by certain white rot fungi.

The white rots are produced by fungi that attack both the carbohydrate and lignin components of wood. They may be further divided into (1) pocket rots, (2) white stringy rots, (3) yellow stringy rots, and (4) others, depending on their appearance and texture.

For some species, the type of rot is a distinctive characteristic, as for example, the pocket rot caused by *Polyporus amarus*. In other cases, however, the type of rot produced by a given species is not distinctive and only suggests the fungus responsible.

The second classification system used to identify heart rot fungi in the field is based on the fruiting body, more commonly known as a "conk" or "sporophore." These spore-producing bodies vary in form from fleshy, typically mushroom-shaped structures to woody "brackets" found on trees. Color, texture, and the nature of the spore producing surface are other examples of characteristics used to identify the fruiting bodies of these heart rot fungi. It is usually possible to identify the heart rot species by observing the characteristics of the fruiting body and the type and location of decay associated with it.

The third classification system is based on the location of the rot in trees. Some fungi cause primarily root and butt rots; others cause trunk rot; and others attack roots, butts, and trunks. This system is used merely as a convenient method of classifying the heart rot fungi based on their general location within the tree. It is used along with other systems to help determine which rot fungi are involved.

Problems arise in trying to identify a specific heart rot fungus. Often heart rots occur without the presence of fruiting bodies. And, often more than one type of rot is present in a tree. The "early" stage of decay, known as incipient rot, is not easily recognized and may be confused with "wetwood," stain, or other heartwood discoloration. Recent studies have shown that for many heart rot conditions in trees, a succession or community of wood-invading organisms is necessary. Bacteria as well as wood rotting fungi and other fungi that do not decay wood may be involved. Therefore, in trying to determine the type of decay and the organism(s) responsible for the rot, use the characteristics of both the rot and the fruiting body in helping to decide on the rot organisms involved. More than one rot organism may be associated with a particular heart rot condition. Use of all the features available in examining trees for heart rot will increase the observers' chances for correct identification.

## Some of the Important Rots of Conifers of the Pacific Coast

### Trunk Rots

1. Brown Trunk rot — *Fomes officinalis*
2. Brown crumbly rot — *F. pinicola*
3. Red ring rot — *F. pini*
4. Juniper pocket rot — *F. juniperinus*
5. Brown top rot — *F. roseus*
6. Brown stringy rot — *Echinodontium tinctorium*
7. Red rot — *Polyporus anceps*
8. Pocket dry rot — *P. amarus*
9. Pouch fungus — *P. volvatus*
10. Oyster mushroom — *Pleurotus ostreatus*

### Root and Butt Rots

1. Fomes root and butt rot — *Fomes annosus*
2. Brown cubical rot — *Polyporus basilarus*
3. Red-brown butt rot — *P. schweinitzii*
4. Brown cubical rot — *P. sulphureus*
5. Red root and butt rot — *P. tomenotsus*
6. Laminated root rot — *Phellinus (Poria) weirii*
7. Shoestring root rot — *Armillaria mellea*
8. Lacquer fungus — *Ganoderma oregonense*

### Butt and/or Trunk Rots

1. Brown cubical rot — *Poria sequoiae*
2. White ring rot — *P. albipellucida*
3. Mottled rot — *Pholiota adiposa*
4. Yellow pitted rot — *Hericium abietis*
5. Scaly cap fungus — *Lentinus lepideus*

# Descriptive Key

A[1] On incense-cedar, juniper or redwood ........................................B

B[1] On incense-cedar ........................................................C

C[1] A brown pocket dry rot (Pocket dry rot) *Polyporus amarus*

C[2] A white stringy root or butt rot (Fomes root and butt rot) *Fomes annosus*

B[2] On Juniper ............(Juniper pocket rot) *Fomes juniperinus*

B[3] On coast redwood ........................................................D

D[1] Advanced decay, a brown pocket rot ..............................(Brown cubical rot) *Poria sequoiae*

D[2] Advanced decay, a white ring rot .....(White ring rot) *Poria albipellucida*

A[2] On other conifer hosts ........................................................E

E[1] Advanced decay brown, cubically cracked (Brown rot)....F

F[1] Fruiting body large, white, mushroom shaped; upper surface scaly, lower surface with gills (Scaly cap fungus).............................................*Lentinus lepideus*

F[2] Fruiting body not as above; lower surface with pores, not gills ........................................................G

G[1] Fruiting bodies on the soil or on the base of the tree ........................................................H

H[1] Fruiting body brown to greenish and velvet-like in texture when fresh; often clustered. Typically a root and butt rot (Red-brown butt rot) *Polyporus schweinitzii*

H[2] Large, fleshy annual, bracket-type, fruiting bodies; bright sulphur yellow when fresh, chalky white when old (Brown cubical rot) *Polyporus sulphureus*

G[2] Fruiting bodies occurring anywhere on the tree ........................................................J

J[1] Perennial woody chalky white fruiting bodies, very bitter to taste (Brown trunk rot) *Fomes officinalis*

J[2] Large rubbery to woody bracket-type fruiting bodies; dark upper surface, reddish margin, buff to cream colored pore surface (Brown crumbly rot) *Fomes pinicola*

E[2] Advanced decay not distinctly brown and cubically cracked; usually white to light brown, in pockets, spongy or stringy (White rots)........................................................K

K[1] Advanced decay as small white pockets in the heartwood (occasionally sapwood of trees)...............L

L[1] Pockets white, fibrous....................................M

M[1] Fruiting bodies on tree trunk often clustered, light to dark brown, bracket-type, woody, with pores on lower surface (Red ring rot) .................................... *Fomes pini*

M[2] Fruiting bodies produced at the base of trees or on soil, brown to light tan; hairy zonate upper surface. Root and butt rot (Red root and butt rot) ............ *Polyporus tomentosus*

K[2] Advanced decay white to yellowish, stringy or spongy, pockets not conspicuous .......................................... N

N[1] Rot confined to roots and butt of tree. Fine, black zone lines present in rotted wood. White mycelial fans often present between bark and wood and black rhizomorphs often associated with the rot. Fruiting bodies mushroom-shaped with gills on the lower surface, honey-colored and occurring in clusters from the decayed wood or soil at the base of the tree (Shoestring root rot) *Amillaria mellea*

N[2] Rot usually always associated with roots and butt of the tree. No zone lines or rhizomorphs present. Fruiting bodies irregular in shape and varying in size from small button-shaped structures to large conspicuous brackets (Fomes root and butt rot) ..................................... *Fomes annosus*

L[2] Pockets of rot empty; fruiting bodies creamy-white, coral-like (Yellow pitted rot) *Hericium abietis*

K[3] Advanced decay yellow to yellowish-brown ............ O

O[1] Wood in advanced decay separating into distinct laminations along growth rings. Root and butt rot (laminated root and butt rot) *Phellinus weirii*

O[2] Distinct separation of wood along growth rings not obvious ........................................................ P

P[1] Yellow to yellow-brown stringy rot in heartwood, tree trunk usually hollow. Fruiting bodies large, black, bracket-type, woody with a toothed undersurface and a brick-red interior (Brown stringy rot) ......................... *Echinodontium tinctorium*

P[2] Decayed heartwood having a dark colored, streaked or mottled appearance. No rhizomorphs. Yellowish brown mycelial strands present in the advanced decay. Fruiting bodies mushroom-shaped, yellow, with gills on lower surface and often arising in clusters from the decayed wood or base of the tree (Mottled rot) ...... *Pholiota adiposa*

# Brown Rots

# Quinine Fungus — Brown Trunk Rot

*Fomes officinalis*

## Hosts

Douglas-fir, pines, western larch, spruce, hemlock, rarely true firs.

## Distribution and Damage

This fungus is known in both Europe and North America. In the Western United States, it has traditionally been considered to be an important trunk rot of old-growth conifers. It is found most commonly on Douglas-fir and larch, but attacks pines and some other species as well. The incidence of this organism in second-growth forests, however, is not well known. It is believed that wounds, broken tops, and branch stubs are common entrance points for the fungus. It may also occasionally enter fire scars.

## Field Identification

*Rot* — The rot caused by this fungus is almost indistinguishable from the cubical brown rot caused by *Polyporus sulphureus*. Unlike the sulphur fungus, however, the rot only occasionally occurs in the butt and is mainly found in the trunk and upper bole of the tree. Another characteristic that distinguishes it from *P. sulphureus* is the bitter taste of fresh mycelial felts present in the decayed wood. Thus, it has been named "Quinine fungus."

*Fruiting body* — The fruiting bodies do not commonly occur on trees attacked by the fungus. When present, they are pendant, woody, perennial, and often hoof-shaped structures that may range in size from several inches to more than 2 feet long (fig. 7-1). The fruiting bodies are white and leathery when young, but chalky and crumbly when old. Like the mycelial felts, they also have a bitter taste.

F-700278

**Figure 7-1. Woody, perennial fruiting body of *Fomes officinalis* growing from the base of a Douglas-fir stump.**

# Red Belt Fungus — Brown Crumbly Rot

*Fomes pinicola*

## Hosts

Pines, firs, Douglas-fir, western hemlock, western larch, spruce, western red cedar.

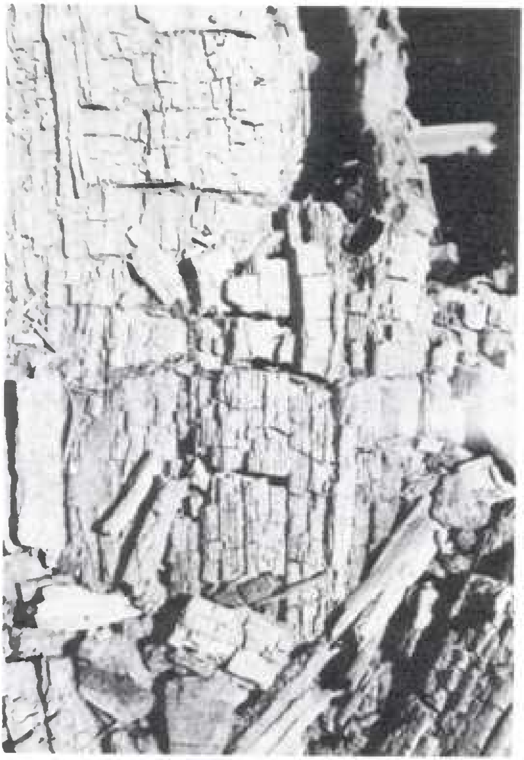
## Distribution and Damage

This fungus is one of the most common wood rot organisms in western coniferous forests. Although it is mainly a decomposer of dead and down timber, it has also been known to cause heart rot in living trees. The mode of entrance for this fungus is mainly through wounds and broken or dead tops. Decay in living true firs from the red belt fungus has also been found associated with the large open bole swellings caused by dwarf mistletoe.

## Field Identification

*Rot* — The rot caused by this fungus is somewhat lighter than that caused by some of the other crumbly brown rots. It may vary in color from a yellow brown to slightly reddish. Cubical cracking is common (fig. 7-2) and the shrinkage cracks are usually filled with white fungus felts.

*Fruiting body* — Fruiting bodies are commonly found associated with this rot (fig. 7-3). They are leathery to woody, perennial bracket-type structures that, when young, appear as a leathery round white fungus mass. As they develop, the upper surface turns dark gray to black; whereas, the fresh lower pore surface remains white to creamy in color. A conspicuous reddish margin develops between the two surfaces; thus, the name "red belt fungus." Fruiting bodies of this organism are among the most common ones seen on dead and fallen coniferous trees. They generally range from about 4 to 18 inches across.



F-525021
Figure 7-2. Characteristic, advanced, brown rot caused by *Fomes pinicola.*

F-700279
Figure 7-3. Commonly observed fruiting body of the red belt fungus, *Fomes pinicola,* growing on a white fir log.

# Scaly Cap Fungus

*Lentinus lepideus*

## Hosts

Pines.

## Distribution and Damage

This fungus is of worldwide distribution and in the Western United States is a heart-rot organism. It also decays dead and down wood. As a heart-rot organism, it does not appear to be limited to any particular part of the tree. It has been observed rotting roots as well as heartwood in the upper portion of the bole. It is common on pines in the high elevations and on the eastern slope of the Sierra Nevada.

## Field Identification

*Rot* — Advanced decay is dark brown, cubically cracked, almost black where exposed. Thin, white mycelial fans occur in shrinkage cracks. Rotten wood is said to have an anise or turpentine odor.

*Fruiting body* — Of all of the important brown heart rots of the Pacific Coast, this is the only one caused by a typical, mushroom-type fungus (fig. 7-4). The fruiting bodies are often large and range from 2 to 12 inches in diameter, are borne on a stalk, are leathery, and have a white gilled lower surface. The top of the cap is composed of a whitish surface overlaid with darker tan to brown scales; thus, the name, "scaly cap." The dry fruiting bodies become quite hard and brittle.

F-525022

**Figure 7-4. Mushroom-like fruiting body of the "scaly cap fungus,"** ***Lentinus lepideus.***

# Pocket Dry Rot

## *Polyporus Amarus*

## Hosts

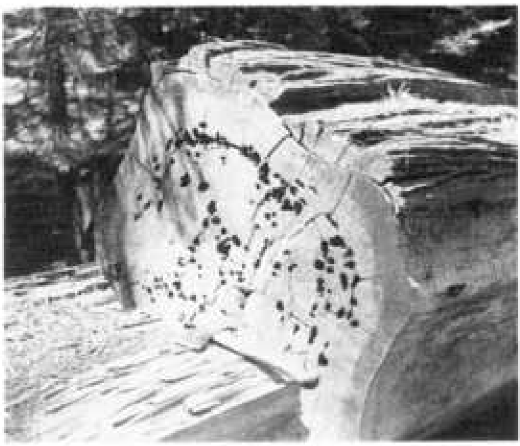
Incense-cedar.

## Distribution and Damage

*Polyporus amarus* causes a common heart rot of incense-cedar throughout its natural range. More than a third of the volume, or about 5 billion board feet, of the merchantable incense-cedar is cull from rot caused by this fungus. Pocket dry rot is most common in trees on good growing sites and less common in trees on marginal sites near the eastern limit of incense-cedar. Trees less than 150 years old are relatively free of rot, whereas in trees 200 years or older, the incidence of decay increases rapidly. Fire scars, large open knots, and branch stubs are the most common entry point for the fungus.

## Field Identification

*Rot —Polyporus amarus* produces a characteristic brown pocket rot not unlike the brown cubical rot od redwood (fig. 7-5). The initial stage of the rot appears as a brownish discoloration of the heartwood. Eventually elongated pockets, usually several times longer than wide, develop. The wood within the pockets is broken down into a dry, dark brown, crumbly residue, separated by cross and longitudinal shrinkage cracks. Although pockets may coalesce with one another, the margin between rotten wood and sound wood remains sharp. The pockets never become so numerous that the entire central cylinder of heartwood is decayed, as happens when brown cubical rot decays redwood.



F-525023

**Figure 7-5. Pocket dry rot of incense-cedar caused by *Polyporus amarus*.**

F-700280

**Figure 7-6. Fruiting body of *Polyporus amarus* on the trunk of an old-growth incense-cedar.**

*Fruiting body* — The fruiting bodies furnish certain evidence of extensive pocket dry rot. Usually one fruiting body is produced (rarely two) and then only on trees with extensive rot (fig. 7-6). When fresh they are soft, moist bracket-type structures with a yellow undersurface and tan top. They have a smooth margin and often appear somewhat hoof-shaped. Old fruiting bodies darken in color and become dry and firm. They appear annually — and only in late summer and fall. Eaten by insects, they may be destroyed in a short time. As a result, they are only occasionally seen on trees with pocket dry rot.

# "Velvet Top" Fungus — Red-Brown Butt Rot

*Polyporus schweinitzii*

## Hosts

Douglas-fir, pines, true firs, larch, spruce, incense-cedar, western red cedar, and rarely hemlock.

## Distribution and Damage

The velvet top fungus occurs throughout the world where conifers are native or grown. Hardwoods are seldom attacked. This fungus is most common on Douglas-fir along the Pacific Coast. The fungus generally enters trees through basal fire scars and is known mainly as a butt rot organism, but also is a root parasite. Although it has been reported as a trunk rot, it almost always is confined to the root system and lower 8 to 10 feet of the tree bole. Timber losses are not precisely known, but are considered high both because the valuable butt logs are badly decayed and because infected trees are predisposed to windthrow.

## Field Identification

*Rot* — Incipient decay from this fungus is not easy to recognize. Advanced decay is a typical brown rot. Rotted wood characteristically appears reddish-brown and tends to form large cubes and cracks across the grain. Thin, white resinous fungus mats may appear in the shrinkage cracks. Dry decayed wood may be easily crumbled into a fine powder.

*Fruiting body* — The fruiting bodies of this fungus may appear either on the soil around the base of an infected tree or from the butt of the tree itself. Depending on the site of development, they may be either brackets or mushroom-like in structure. Brackets tend to form on exposed wood, whereas the stalked mushroom-type fruiting bodies usually appear on the soil (fig. 7-7). The fruiting bodies have a soft velvety top that, when fresh, is usually reddish-brown in color and encircled by a yellowish margin. Concentric lines are also present on the top surface. The lower spore producing pore surface varies from dark green to light brown. The fruiting bodies are produced annually and, when old, dry up, darken, and closely resemble cow dung.

F-700281

**Figure 7-7. Fruiting body of *Polyporus schweinitzii* on the soil at the base of an infected Douglas-fir.**

# Sulphur Fungus — Brown Cubical Rot

*Polyporus sulphureus*

## Hosts

Douglas-fir, true firs, pines, hemlock, spruce, larch and western red cedar.

## Distribution and Damage

The sulphur fungus most commonly is found on hardwoods in other regions, but in the West does cause considerable rot in some conifers, particularly true firs. The organism generally enters through basal fire scars and wounds on conifers and primarily causes a butt rot. Although the sulphur fungus is not considered a major slash decay organism, it is often seen on stumps, logs, and dead trees.

## Field Identification

*Rot* — Advanced decay is similar to that caused by red-brown butt rot. Decayed wood is dark to reddish brown, cubically cracked, and is easily crumbled. Usually, white mycelial felts are present in the shrinkage cracks. These may be very thin or range up to one-quarter inch thick. Felts may also be a foot or so wide and several feet long.

*Fruiting body* – Clustered, annual, shelf-like fruiting bodies are typical of this organism (fig. 7-8). When fresh, they are soft and fleshy, with a bright yellow-orange upper surface and a bright sulphur yellow lower pore surface. Old fruiting bodies are hard, brittle, and chalky white.

F-700282

**Figure 7-8. Fresh Fruiting body of *Polyporus sulphureus* emerging from the stump of an old red fir.**

# Brown Cubical Rot

*Poria Sequoiae*

## Hosts

Coast redwood.

## Distribution and Damage

This rot is distributed throughout the natural range of coast redwood. Among the two major rots in redwood, it is the most common and causes the most cull. About 10 billion board feet of cull in redwood is attributed to heart rots of which more than 75 percent is caused by *Poria sequoiae*. Surveys have shown that by far the greatest amount of rot occurs in old-growth redwood, particularly in trees with basal fire scars or broken tops. Second-growth redwood may suffer some loss from *P. sequoiae,* but fortunately the rot is not transferred from stumps to stump sprouts.

## Field Identification

*Rot* — Initial stages of rot range from a dark brown stain of the inner heartwood to scattered pockets of brown charcoal-like "dry rot" which shrinks and cracks into cubes (fig. 7-9). In the advanced stages, the pockets of rot are so numerous that nearly the entire central and, to some degree, the outer cylinder of heartwood is rotted.

F-700283

**Figure 7-9. Pockets of brown rot in redwood caused by** *Poria sequoiae.*

*Fruiting Body* — The spore-producing structure is unlike the typical bracket or mushroom-shaped fruiting bodies produced by most of the rot fungi. Instead, the entire fruiting body develops as a thin, white mantle or crust composed of fungus strands and a spore-producing pore surface. The fruiting bodies often are no more than 2 inches long and 1 inch wide and most frequently are found in fire scars, bark crevices, and on the ends of down logs.

# White Rots

## Shoestring Fungus — Shoestring Root Rot
## Honey Mushroom — (Soft Spongy Rot)

*Armillaria mellea*

### Hosts

Most conifer species in the west.

### Distribution and Damage

*Armillaria mellea* is more commonly considered a root disease fungus rather than a rot organism. Therefore, details of the fungus, its distribution, occurrence, and structure of the fruiting body are described in Chapter 6.

### Field Identification

*Rot* — Advanced rot caused by the shoestring fungus is white or light yellow, soft and spongy, often stringy, marked by numerous black zone lines and confined to the roots and/or butt of the tree. Often the rot is accompanied by white mycelial fans (fig. 6-5) under the bark. Black rhizomorphs (shoestring-like fungal strands) usually also are present (fig. 6-4).

*Fruiting Body* — For a detailed description of the fruiting body, see Chapter 6 on root diseases.

# Indian Paint Fungus — Brown Stringy Rot

*Echinodontium tinctorium*

## Hosts

True firs, hemlock, rarely Douglas-fir and spruce.

## Distribution and Damage

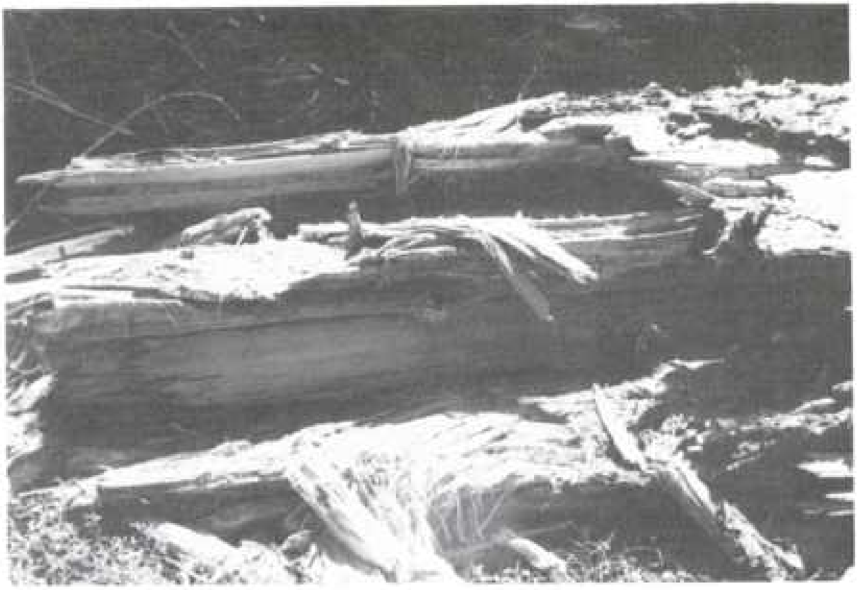
This decay fungus is distributed throughout the Western United States on firs and hemlock and is considered to be the most serious heart rot organism on these tree species. In some old-growth stands, losses of 25 to 50 percent or more of the gross board foot volume have been recorded. The Indian paint fungus may enter trees through trunk scars, dead tops, and other wounds, but most infections probably enter through branches. As a result, the rot is most common in the mid-trunk region, but it may also extend into the butt or down from the top. Trees up to 40 years old are essentially free of brown stringy rot because in trees this young, limited heartwood has developed.

## Field Identification

*Rot* — The name brown stringy rot is confusing in that the Indian paint fungus attacks both lignin and cellulose components of heartwood. The fungus is, therefore, a white rot organism.

The first noticeable evidence of rot is a yellowish to golden tan discoloration of the heartwood. The invaded wood is also somewhat softer than uninvaded heartwood at this stage. Next, the heartwood turns pale reddish-brown, and rust-red streaks appear following the grain. Wood with advanced rot becomes soft, stringy, and may vary from yellow-brown to tan to rust-red. Brown to rust-red streaks or areas are also present. Rotted wood often tends to separate along the annual rings. In the very late stages of decay, the stringy mass of rotted wood may disintegrate, leaving a hollow in the tree (fig. 7-10).

*Fruiting Body* — The fruiting bodies of the Indian paint fungus are quite distinctive and receive their name because certain Indian tribes ground the brick red interior into a powder for use as a red pigment (fig. 7-11). The woody, perennial, hoof-shaped bodies range from a few inches to more than a foot in width, and are quite common on infected trees. The upper surface is dull black and rough (fig. 7-12), whereas the undersurface is usually level but set with hard, coarse teeth or spines. The toothed surface is gray when fresh but turns black when old. Fruiting bodies develop on the bole, usually on the underside of branches or branch stubs. Heart-rot often extends about 16 feet above and 16 feet below a fruiting body. Trees with one or more fruiting bodies usually have extensive decay.



F-525024

**Figure 7-10. Brown, stringy rot of white fir caused by** *Echinodontium tinctorium.*

F-700284

**Figure 7-11. Reddish interior of the fruiting body of** *Echinodontium tinctorium.*

F-525025
**Figure 7-12. Black, woody fruiting body of *Echinodontium tinctorium* on white fir.**

# Fomes Root and Butt Rot

*Fomes Annosus*

## Hosts

Occurs on most conifer species in the West.

## Distribution and Damage

This organism occurs throughout the coniferous forests in the West. Although it is primarily known as a root disease organism, it also acts as an important butt and trunk rot on some species. *F. annosus* is particularly common on true firs in California and on hemlock in the Pacific Northwest and is considered a damaging butt rot organism in old-growth stands. The fungus commonly enters through fire scars, dead or broken tops, and other wounds. The rot column, although usually in the butt and root systems, may occur anywhere in the heartwood. The fungus spreads from one tree to another by root grafting or from infected roots contacting non-infected roots.

## Field Identification

*Rot* — Incipient decay from Fomes root and butt rot is not readily recognized. Discoloration may or may not be present, and heartwood remains firm and hard. In the advanced stage, the decayed wood is white, spongy, and may contain elongated white pockets (fig. 6-2). No rhizomorphs are formed as they are with a similar decay caused by *Armillaria mellea*.

*Fruiting Body* – The fruiting bodies of *F. annosus* vary considerably in shape and size. Their shape is indefinite. They may appear as small, round, button-shaped structures growing under or protruding from the bark at the base of trees or as rather conspicuous irregularly shaped bracket-like bodies on the butts and roots of trees. Often they occur deep within hollow stumps of true firs and may develop to become almost a foot in width. When fresh, they are dark brown to gray on the upper surface and creamy white to pale orange on the lower pore surface (fig. 6-1).

# Juniper Pocket Rot

*Fomes Juniperinus*

## Hosts

Western junipers.

## Distribution and Damage

This fungus is found on western juniper throughout its natural range in the Western United States. The extent of decay in juniper stands throughout the Far West is not known. However, studies in stands of western juniper in Modoc County, Calif. have shown that about 40 percent of the trees 12 inches and greater in basal diameter were infected with juniper pocket rot. Consequently, utilization of western juniper for pencil stock is uneconomical.

## Field Identification

*Rot— Fomes juniperinus* may occur as either a butt or a trunk rot, depending on the location of the entrance court for the fungus. Incipient decay first appears as a yellowish discoloration. Wood with advanced decay contains numerous large pockets, lined with yellowish-white fibers, and fungus mats and strands. These pockets often join to form fairly long tubes of stringy rot.

*Fruiting Body* — Fruiting bodies (fig. 7-13) are fairly common in the Far West and when present indicate extensive heart rot. The upper surface of the woody hoof-shaped fruiting bodies is dark brown to nearly black and usually contains numerous deep cracks. The lower pore surface is light brown, and the interior is reddish-brown.

F-700285
**Figure 7-13. Woody, perennial, fruiting body of** *Fomes juniperinum.*

# Red Ring Rot or White Pocket Rot

*Fomes Pini*

## Hosts

Douglas-fir, pines, true firs, larch, spruce, hemlock, western red cedar, and rarely incense-cedar.

## Distribution and Damage

Red ring rot occurs throughout the coniferous forests of the world, and in the West is considered to be the single most damaging heart rot organism. Coastal Douglas-fir is the tree most commonly infected. Other coniferous trees species along the coast as well as conifers in the mountains of the West are also attacked. Millions of board feet of timber a year are lost or degraded as a result of rot caused by this organism.

Red ring rot attacks second-growth as well as old-growth trees. Nearly all infections become established through living and dead branches or branch stubs. Open wounds rarely act as entrance points for this fungus. Thus, red ring rot may be one of the most serious heart rot problems in future forest stands.

## Field Identification

*Rot* — Incipient decay appears as a discoloration of the heartwood. In pines, a pink to reddish color is present. Pronounced reddish-purple to olive discoloration appears in Douglas-fir.

Wood with advanced decay is often reddish and contains sharply margined small spindle-shaped pockets containing white, soft, fibers (fig. 7-14). Mostly heartwood is affected, but sapwood is also invaded. Dark colored zone lines may also be observed in decayed wood. In cross section, the pockets may be evenly distributed throughout the wood (soft pines) or appear in rings (Douglas-fir, hard pines). The ring-like attack of heartwood is the result of the fungus attacking certain groups of annual rings and more readily destroying early wood rather than late wood.

F-525026

**Figure 7-14. White pocket rot of Douglas-fir caused by *Fomes pini*.**

*Fruiting Body* — The perennial, woody fruiting bodies are the best indicators of decay. But they vary considerably in size, shape, and texture. One should be aware of this variability in identifying *F. pini*. Fruiting bodies may range from about 2 to 10 inches in width and be thin and bracket-like or thick and hoof-shaped (fig. 7-15). The lower pore surface is usually a rich, rusty brown, the pores ranging from nearly round to maze-like. The upper surface is darker brown or dark gray, and is usually marked with several concentric furrows.

Often a velvety margin separates the two surfaces. On living trees, the fruiting bodies nearly always arise from knots or branch stubs. Sometimes only punky knots bearing the inner portion of the fruiting body remain on the tree. These punky knots may subsequently be overgrown with new wood, becoming swollen knots that are the only symptom of decay.

F-525027
**Figure 7-15. Typical bracket-like fruiting bodies of *Fomes pini* on Douglas-fir.**

# Coral Fungus — Yellow Pitted Rot

*Hericium abietis*

## Hosts

True firs, Engelmann spruce, hemlock.

## Distribution and Damage

This fungus is an important decay organism of true firs in the Pacific Northwest, particularly in the mountains of eastern Oregon and Washington. It also occurs in the Rocky Mountains and in northern California but is rare elsewhere along the Pacific Coast. The rot may develop in the butt or upper portions of living trees, or in stumps, fallen trees, and snags. The coral fungus probably enters living trees through wounds and dead branches.

## Field Identification

*Rot* — The advanced stage of this rot is similar to that caused by red ring rot but the elongate pockets formed are empty of noticeable white fibers. The color of the wood does not change noticeably.

*Fruiting Body* — The fruiting bodies are soft, creamy white, coral-like, and characterized mainly by the presence of numerous "spines" or "teeth" which produce spores (fig. 7-16). The fruiting bodies are short-lived and not readily recognized when shriveled and dry.

F-700286

**Figure 7-16. Fruiting body of *Hericium abietis*, the cause of yellow pitted rot.**

# Laminated Root Rot

*Phellinus (Poria) Weirii*

## Hosts

Douglas-fir and western red cedar are the conifer species most frequently damaged. For additional hosts attacked, see Chapter 6 on root disease.

## Distribution and Damage

This fungus occurs throughout the Pacific Northwest. Although *Phellinus weirii* is known mainly as a root disease organism, it does decay tree roots and butts. Heavy losses occur not only from tree mortality but also from blowdown as a result of root decay.

## Field Identification

*Rot* — Early decay by this organism appears as a red-brown stain in the outer heartwood. As the decay develops the wood softens, small pits appear and the annual rings separate to form the characteristic laminated rot (fig. 7-17). At this stage the rotted wood is yellow to buff colored with dark brown mycelial felts often found between the laminations and in shrinkage cracks.

*Fruiting body* — For a description of the fruiting body, see Chapter 6 on root disease.

F-700287

**Figure 7-17. Laminated rot of Douglas-fir caused by** *Phellinus weirii.*

# Yellow Cap Fungus — Mottled Rot

*Pholiota adiposa*

## Hosts

Red fir, white fir, grand fir.

## Distribution and Damage

This fungus is found on both hardwoods and conifers in the United States, but in the West it is primarily a problem on true firs (Abies). In California and parts of Oregon, it is considered to be a major heart rot organism in old-growth true fir stands. Young, unwounded trees are seldom infected. Fire scars, other basal wounds, and dwarf mistletoe bole cankers are the sites of infection for mottled rot. As a result, most of the rot occurs in the lower bole, but has been found to extend 50 to 60 feet above the ground.

## Field Identification

*Rot* — The fungus produces a mottled appearance in the wood in the advanced stage of rot. Early decay appears as a light cream to yellowish discoloration in heartwood. As the rot progresses the areas darken and brownish streaks develop, forming small widely scattered holes or pockets resembling insect burrows.

Yellowish-brown fungus strands fill the holes and shrinkage cracks. These strands may be best observed if the wood is split along the grain. Older trees with decay of long standing usually have a hollow butt.

*Fruiting body* — Other than shoestring root rot, mottled rot is the only major white rot of conifers caused by a gill bearing, mushroom-like fungus (fig. 7-18). The yellow cap fungus fruits in the fall, usually after the first rains. The fresh fruiting structures consist of a yellowish central stalk and a cap that varies from yellow to yellowish brown on the upper surface and yellow on the lower gill surface. The tops of the caps are sticky and slightly scaly. The mushrooms often occur in clusters and may appear on the trunk or from the base of infected trees. They are also commonly seen on stumps, down trees, and on the ends of cull logs. Old fruiting bodies dry and shrivel and turn black. They often persist for a year or more in this condition.

F-700288

**Figure 7-18. Mushroom-like fruiting bodies of *Pholiota adiposa* on white fir.**

# False Velvet Top Fungus — Red Root and Butt Rot

*Polyporus tomentosus*

## Hosts

Pines, spruce, larch, hemlock, Douglas-fir, true firs.

## Distribution and Damage

The fungus occurs on conifers throughout the West but is most commonly found on hosts in the Pacific Northwest and the Rocky Mountains. It appears to be less often found in the drier, arid regions of the Pacific Southwest.

## Field Identification

*Rot* — The advanced stage of this rot closely resembles that caused by the red ring rot fungus. Many narrow pockets filled with white fibers occur in the heartwood. Affected wood usually becomes stained dark reddish-brown to tan but retains its structural integrity as in the case with wood affected by red ring rot. This fungus causes primarily a root and butt rot and is seldom found more than a few feet above the ground in tree trunks.

*Fruiting body* — The fruiting bodies of this fungus resemble those produced by the velvet top fungus but are much smaller (usually about 2 to 3 inches in diameter) and lighter in color. The upper surface is brown to tan, zonate and slightly hairy in texture. The lower surface contains pores and is usually light brown. The fruiting bodies almost always occur on the ground in small clusters where they arise from diseased roots. Occasionally they occur at the base of a tree.

# White Ring Rot

*Poria Albipellucida*

## Hosts

Coast redwood, western red cedar.

## Distribution and Damage

Except for brown cubical rot, white ring rot is the only other rot of any consequence associated with native stands of redwood. Whereas brown cubical rot is fairly evenly distributed throughout the natural range of redwood, white ring rot increases in severity from south to north. For instance, less than 10 percent of old-growth trees in Sonoma

County, Calif. were attacked by this fungus, but in Del Norte County, Calif. nearly 75 percent of old-growth trees contained white ring rot. Western red cedar along the Pacific Coast is also often attacked by this fungus, and it is believed that the incidence of rot in redwood is correlated with the amount of western red cedar in the stand. Entrance courts for this fungus are wounds, mainly fire scars and dead or broken tops. Like brown cubical rot, white ring rot does not move into stump sprouts from rotted stumps.

## Field Identification

*Rot* — Incipient rot looks like normal heartwood except for a dark brown discoloration. As the decay progresses, the heartwood softens and turns lighter brown. Wood with advanced decay is soft and cinnamon-brown and often separates along the annual rings. Minute, elongated pits occur in the wood surfaces between these separations. These pitted surfaces may become somewhat hairy with whitish wood fibers as the rot continues (fig. 7-19). Wood in the final stage of decay appears as a stringy, fibrous mass.

*Fruiting body* — Fruiting bodies of this organism have never been found associated with decayed wood of redwood. The fungus was identified solely from laboratory cultures obtained from rotted wood. Fruiting bodies are found on western red cedar slash in the Pacific Northwest.

F-525028

**Figure 7-19. White ring rot *(Poria albipellucida)* along the checked surface of a redwood log.**

# Heart Rots of Minor Importance

*Fomes roseus,* the cause of brown top rot in Douglas-fir, true fir, spruce, and some pines, occurs occasionally in northwestern California and in the Pacific Northwest. As the name implies, the rot often occurs in the uppermost part of the bole. This fungus is most common on dead trees and wood in service, but can cause a brown cubical rot in the heartwood of Douglas-fir. Wood in the advanced stage of decay is soft, yellow to yellowish-brown in color and breaks into irregular shaped cubes. The fruiting bodies are bracket-like, woody, have a pinkish rose colored lower pore surface and a rough black zoned upper surface (fig. 7-20).

*Polyporus basilaris* causes a brown cubical pocket rot in the butts of Monterey cypress *(Cupressus macrocarpa).* It occurs in natural stands in California and nearly everywhere Monterey cypress has been planted along the Pacific Coast. Trees 65 years and older are highly defective, 80 percent and more with rot. Trees less than 26 years old are practically rot-free. One to several fruiting bodies may be present and these usually arise from branch stubs. Entrance of the fungus is thought to be through dead branches. Fruiting bodies are usually small (1 to 2 inches across) and leathery, bracket-like and vary from grayish brown to black in color.

*Ganoderma oregonense,* commonly called the lacquer fungus because of the shiny, reddish, lacquer-like upper surface of the fruiting body, primarily decays dead timber, but occasionally causes a soft, spongy white rot of living trees (fig. 7-21). The distinctive annual,

F-700289

**Figure 7-20. Fruiting body of *Fomes roseus,* the brown top rot fungus.**

F-700290

**Figure 7-21. White spongy rot of red fir caused by** *Ganoderma oregonense.*

F-700291

**Figure 7-22. Large distinctive fruiting body of** *Ganoderma oregonense.*

bracket-type fruiting bodies have a cream colored lower pore surface and are produced in the fall and often grow to be a foot or more across (fig. 7-22). The lacquer fungus attacks Douglas-fir, spruce, hemlock,

F-700292

**Figure 7-23. Small, leathery fruiting bodies of the pouch fungus *Polyporus volvatus*, on a white fir log.**

and some pines along the Pacific Coast, and true firs throughout their natural range in California. Red fir is the most commonly attacked fir species.

*Pleurotus ostreatus*, the oyster mushroom, occasionally causes a white, flaky rot of the sapwood and heartwood of conifers in the West, but is most common on hardwoods. Infection usually occurs through open wounds and the fungus has been observed invading true firs at the site of old open dwarf mistletoe bole infections. The white, fleshy, shelf-like mushrooms are smooth on the upper surface with gills on the lower surface, and often arise in clusters. The gills on the lower surface characteristically extend down along the stalk.

*Polyporus anceps* or red rot often occurs in ponderosa, Jeffrey, and Coulter pines in southern California. It is rare elsewhere along the Pacific Coast, but is common and damaging on pines in the Southwest and Rocky Mountains. This fungus acts as both a decomposer of dead wood and as a heart rot. In living trees, the fungus frequently enters through broken tops causing considerable rot of the upper boles. It can also enter through bole wounds and large dead limbs. Advanced decay is a white pocket rot—not unlike that caused by the red ring rot organism *Fomes pini*. Wood infected by red rot does not remain firm, but tends to crumble and disintegrate when handled. Fruiting bodies are rarely found on living trees, but occur mostly on the underside of down logs or on slash. They appear as white to light brown colored crusts of irregular shape on down trunks and branches. Detection of the rot in living trees is difficult.

*Polyporus volvatus*, the pouch fungus, is not a heart-rotting fungus but causes a greyish white rot of the sapwood of most conifers in the

West. It is only included because it occurs so frequently in the forest and is often mistaken for a heart rot organism. For the most part, it only occurs on dead trees and snags within 1 to 2 years after the tree's death. But, it has been observed on dead portions of living trees and on Douglas-fir weakened by bark beetle infestation. The small, leathery white fruiting bodies are produced in abundance within a short time after the tree is attacked (fig. 7-23). One of their distinguishing features is that the lower spore bearing surface is covered by a fungus sheath except for a single hole through which insects enter, feed, and then exit and move on to spread the fungus. This unique adaptation to spread by beetles and other insects accounts for the rapidity with which it invades dead and dying trees.

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# GLOSSARY

**Aerial Shoot** — Stem-like portion of dwarf mistletoe outside the host bark whose primary function is to reproduce.
**Alternate Host** — One or the other of two unlike hosts of a heteroecious fungus, i.e., some rust fungi.
**Annual Canker** — A canker that occurs only during one period of time of the year or season, usually caused by adverse environmental conditions or organisms.
**Apothecium(ia)** — A cup or saucerlike sexual fruiting body that produces ascospores.
**Ascocarp** — A sexual or perfect fruiting body of the Ascomycete, which produces its spores within an ascus.
**Ascospores** — A spore produced in an ascus (see ascus).
**Ascus(i)** — A sac-like cell of the perfect stage of the Ascomycetes in which ascospores—usually eight—are produced.
**Asexual Stage** — A stage in the life cycle of a fungus in which spores are produced without a previous sexual fusion; also called imperfect stage.
**Autoecious Life Cycle** — A fungus that completes its life cycle on one host, e.g., some rust fungi.
**Basal Shoot Scar** — See basal cup.
**Basal Cup** — The cup-like remnant on the bark of an infection that remains visible long after the disintegration of an aerial shoot.
**Biotic Factors** — The living organisms in an ecosystem and their relationship with other organisms.
**Bicolored** — Two colors (relating to the fruit of dwarf mistletoe which are bicolored).
**Blight** — A loose term for a disease causing rapid death or dieback.
**Bole** — A tree stem once it has grown to substantial thickness—roughly capable of yielding saw timber; similar to trunk stem.
**Bracket Type Fungus** — Laterally attached, shelf-like fungus fruiting bodies occurring on trees; mostly of the wood decay type.
**Broom** — See witches-broom.
**Brown Rot** — A light to dark brown decay of wood that is friable and rectangularly checked in the advanced stage, caused by fungi that attack mainly the cellulose and associated carbohydrates; residue is chiefly lignin.
**Burl** — A hard, woody, abnormal outgrowth in a tree, more or less rounded in form. Usually resulting from the entwined growth of a cluster of adventitious buds—sometimes from an old wound.
**Butt Rot** — A rot characateristically confined to the butt or lower trunk of a tree.

**Canker** — A definite, relatively localized, necrotic lesion primarily of the bark and cambium.

**Cellulose** — A complex carbohydrate occurring in most all plant material. A major component of wood.

**Colonize** — To establish an infection within a host or part of a host.

**Concolorous** — Of the same color as.

**Confluent** — Running into one another, merging.

**Conk** — The large, often bracket-like fruiting bodies of wood destroying fungi (Basidiomycetes).

**Cubical Cracking** — The characteristic of woods in an advanced stage of brown rot to break up into distinct cubes.

**Cull Factor** — A calculated percentage of the amount of merchantable wood lost from a tree as a result of decay or other defect.

**Decay** — The decomposition of wood by fungi

**Decline** — The gradual reduction in health and vigor as a tree is in the process of dying slowly.

**Decomposer** — Organism that physically and chemically breaks down dead organisms into simpler compounds and elements.

**Defect** — Any imperfection in a tree that reduces the volume of sound wood or lowers its durability, strength, or utility value.

**Dieback** — The progressive dying, from the tip downward, of twigs, branches, or tops.

**Discoloration** — A change in hue or color.

**Disease** — The alteration of the function or the form of a plant from normal.

**Disease Cycle** — The chain of events in the development of a disease.

**Dry Rot** — A decay of the brown rot type, caused by specialized fungi able to conduct moisture from an available source and extend their attack to wood previously too dry to decay.

**Duff** — The litter and partially decomposed litter on the forest floor.

**Early Wood** — The less dense, larger-celled portion of an annual growth ring formed during the early part of the growing season.

**Elliptical** — Shaped like an ellipse, oblong with regularly rounded ends.

**Endemic** — A disease which is at its usual normal balanced level within a region to which it is indigenous. Not epidemic or rampant.

**Entrance Courts** — The point of invasion of a disease organism into its host.

**Environment** — The sum total of all the biotic (living) and abiotic (non-living) factors affecting an individual's surroundings.

**Epidemic Disease** — A disease that occurs periodically, widely, and rapidly, and reaches injurious levels.

**Exudate** — Matter which oozes out or is secreted out.

**Facultative Parasite** — An organism normally saprophytic but capable of changing to a parasitic life.

**Fade** — To change foliage color slightly in the early process of dying. Usually changes occur from a dark green toward a lighter gray-green.

**Flagging** — Displaying dead brown branches known as flags among the rest of the living crown.

**Flags** — Conspicuous dead branches with foliage remaining as a result of rapid killing by adverse abiotic conditions or disease agents.

**Form** — A description below the subspecies or variety level but which is still distinguished on morphological grounds.

**Fruiting Body** — Any of a number of kinds of reproductive structures which produces spores.

**Fungus** — One of a group of organisms considered by some authorities to be lower plants which lack chlorophyll.

**Fungus Mat** — Dense, leathery mass of fungus mycelium often formed in decayed wood by certain wood rotting fungi.

**Fusiform Swelling** — A swelling on a host branch or stem that is typically widest near the middle and tapers toward each end. Syn. spindle-shaped swelling.

**Galls (Burls)** — Pronounced swellings on woody plants caused by certain insects and disease organisms.

**Germinate** — The beginning of growth by a seed or spore.

**Gill Fungi** — Those fungi whose fruiting bodies are mushroom shaped and which bear gill-like plates on the underside of the cap.

**Gills** — Blade-like, spore-bearing structures on the lower surface of the fruiting bodies of certain fungi.

**Globose** — Spherical.

**Hard Pine** — Any pines of the subgenus *Pinus* (Diploxylon).

**Heart Rot** — A decay characteristically confined to the heartwood.

**Heartwood** — The inner layers of wood that in the growing tree have ceased to contain living cells and in which the reserve materials (e.g., starch) have been removed or converted into more durable substances.

**Heteroecious Life Cycle** — A fungus that must pass different stages of its life cycle on unlike hosts, i.e., some rust fungi.

**Hoof-Shaped** — Appearing like a hoof; e.g., the bracket-type fruiting bodies of certain wood decay fungi that are flat on the bottom and rounded on the sides and top.

**Host** — The plant on or in which a pathogen exists.

**Host Range** — All the hosts that a particular pathogen attacks.

**Host Specific** — Disease organisms that attack only certain species of hosts.

**Hysterothecium(ia)** — A specialized fruiting body of needle cast fungi which is usually elongate, covered, and opens at maturity by a long slit.

**Immune** — Unable to be attacked by an organism.

**Incidence** — Rate of occurrence.

**Incipient Rot** — The early stage of wood decay in which the wood is invaded and may show discoloration but is not otherwise visibly altered.

**Incipient Decay** — See incipient rot.

**Infection** — The act of a pathogen establishing itself on or within a host.

**Infection Site** — The area in which the pathogen first established itself on or in the host.

**Infest** — To be present in such numbers within an area as to be a source of danger.
**Inner Bark** — The active layer of tissues (phloem and cambium) between the wood (xylem) and the suberized bark.
**Inoculum** — The spores or tissues of a pathogen which infect a host or crop.
**Inoculum Potential** — The general mass of the pathogen (including spores and tissues) and its relative virulence which are available for infection.
**Late Wood** — The denser, smaller celled portion of an annual growth ring formed during the latter part of the growing season.
**Life Cycle** — The stage or series of stages in fungi between one spore form and the development of the same spore again.
**Lignin** — A substance impregnating the cell wall in woody tissue; along with cellulose, it is the principal component of wood.
**Litter** — See duff.
**Microsclerotium** — A tiny (microscopic) sclerotium.
**Mortality** — The loss from death.
**Mycelial Fans** — Similar in structure to mycelial felts but fan-shaped.
**Mycelial Felt** — A mass of fungus filaments that are arranged in a flat plane and resemble a thin felt-like paper or cloth.
**Mycelial Pads** — Small mats of compacted mycelia that are often formed by fungi on or in the host.
**Mycelial Strands** — A mass or group of fungus filaments that appear as visible strands to the naked eye.
**Mycelium(ia)** — A mass of hyphae that forms the vegetative filamentous body of a fungus.
**Necrosis** — Death of plant cells usually resulting in darkening of the tissue.
**Necrotic Spot (Area)** — A dead area on a living plant. Often caused by biotic and abiotic diseases.
**Needle Cast** — A disease of conifers in which the needles are killed and shortly thereafter fall from the tree.
**Needle Complement** — The normal or usual number of needles that a conifer of a particular species will bear.
**Needle Spotting** — A needle disease characterized by isolated circular or elongate lesions.
**Obligate Parasite** — A parasite incapable of existing independent of live host tissue.
**Parasite** — An organism living on and nourished by another living organism.
**Parasitic** — Living on or in another organism and deriving nourishment therefrom.
**Pathogen** — An organism which causes a disease.
**Pendant** — Hanging, pendulous.
**Perennial** — Continuing growth from year to year.
**Perennial Canker** — The recurrent yearly killing back and healing over of the bark and cambial tissue of woody plants by certain disease organisms.

**Perithecium(ia)** — A closed, flask-like sexual fruiting body containing asci and ascospores produced by certain Ascomycetes.
**Pocket Rot** — A characteristic pattern of rot caused by certain fungi. The rot occurs in distinct, scattered pockets within the heartwood of a tree rather than in a distinct column.
**Pore Surface** — The surface of the fruiting body of certain wood decaying fungi (polyporaceae) that consists of small openings or pores.
**Predispose** — To make susceptible
**Predisposition** — The effect of one or more environmental or biotic factors which makes a plant vulnerable to attack by a pathogen.
**Primary Host** — See principal host.
**Principal Host** — The main host for a particular disease organism. This term is used particularly with regard to the main host species infected by dwarf mistletoes.
**Pustule** — Blisters caused by certain disease fungi, often maturing into the spore-bearing structures of the disease organism.
**Pycnidium(ia)** — An asexual type of fruiting body, typically flask-like, that produces asexual spores or conidia.
**Resinosis** — The unnatural and profuse flow or accumulation of resin from conifers injured or attacked by insects and disease.
**Resistant** — Able to withstand without serious injury attack by an organism or damage by a non-living agency but not immune from such attacks.
**Rhizomorphs** — A specialized thread- or cord-like structure made up of parallel hyphae with a protective covering.
**Root Crown** — The upper-most portion of the root system where the major roots join together at the base of the stem.
**Root Grafting** — The union of the roots of two different trees as a result of physical contact.
**Rot** — The physical and chemical deterioration of wood caused by wood rotting fungi.
**Rot Column** — The vertical column of rotted wood within the heartwood of a tree invaded by heart rot fungi.
**Saprophyte** — An organism using dead organic material as food.
**Sapwood** — The outer layers of wood which in the growing tree contain living cells and reserve materials.
**Secondary Host** — A host species attacked less commonly than the principal host.
**Sexual Stage** — The stage in the life cycle of a fungus in which spores are formed after sexual fusion. Syn. perfect stage.
**Scale-Like Leaves** — A scale-like structure that is morphologically a leaf often reduced in size (as bud scale, various bracts).
**Sclerotium** — A firm, frequently rounded, often black mass of hyphae often acting as a resting body.
**Shoot Scar** — See basal cup.
**Soft Pine** — Any pines of the subgenus *Strobus* (Haploxylon).
**Spindle-Shaped Swelling** — See fusiform swelling.
**Spores** — The final reproductive structure of the fungi and other lower plants.
**Sporulation** — The act of producing and liberating spores.

**Stain** — The dark brown to black discolorations of wood caused by the presence of certain fungi; not to be confused with wetwood.

**Susceptible** — Unable to withstand attack by an organism or damage by a non-living agency without serious injury.

**Symptoms** — The noticeable evidence of disturbances in the normal development and life processes of the host plant.

**Teeth** — See toothed surface.

**Toothed Surface** — The tooth-like texture of the spore-bearing surface of certain wood decay fungi, e.g., indian paint fungus. See teeth.

**Upward Spread** — See vertical intensification.

**Vertical Intensification** — The spread upward of dwarf mistletoe within a tree. Syn. upward spread.

**Virulent** — Vigorously pathogenic.

**Wetwood** — A discolored, water-soaked condition of the heartwood of some conifers presumably caused by bacterial fermentation. Often associated with distinctive odor, gas production, and an exudation called slime flux.

**White Rot** — Decay caused by fungi that attack all chief constituents of wood and leave a whitish or light colored residue. Wood is often fibrous or spongy in texture.

**Witches-Broom** — An abnormally profuse, dense mass of host branches and foliage. Syn. broom.

**Wilt** — The collapse of a plant or part of a plant due to a loss of cell turgidity.

**Xerophytic** — Adapted to dry conditions.

**Xylem** — The woody tissue of the stem, branches, and roots.

**Zone Lines** — Narrow, dark brown or black lines in a decayed wood caused by fungi.

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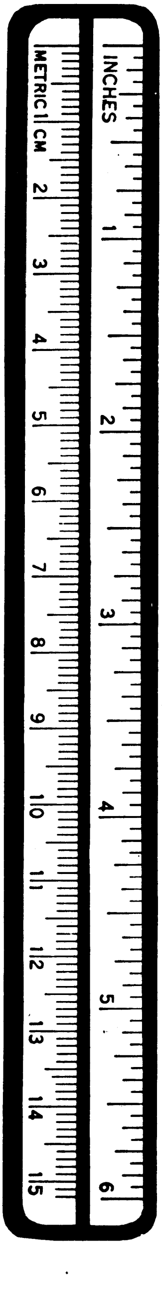
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