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Field Guide to the Common Diseases and Insect Pests of Oregon and Washington Conifers

Forest Service

Pacific Northwest Region

Quick Tab to Insect & Disease Sections

Stem and Root

Branch and Terminal

Foliage

Abiotic or Noninfectious Diseases

Field Guide to the Common Diseases and Insect Pests of Oregon and Washington Conifers

Revised Edition

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Figure 11l, p. 23
Figure 13b, p. 26
Figure 13c, p. 26
Figure 13d, p. 26
Figure 13f, p. 26
Figure 13g (slightly altered), p. 27
Figure 13l, p. 27
Figure 13m (slightly altered), p. 27
Figure 100i, p. 233

This field guide is

dedicated to

Leon Pettinger

(June 22, 1927 to September 20, 1994),

Entomologist,

Forest Pest Management,

who started it all,

many years ago.

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This field guide was inspired by the excellent work done by our colleagues throughout western North America. There is no doubt that we have built on the foundation established with the Pacific Northwest Region's *Forest Disease Management Notes,* the *Field Guide to Diseases and Insect Pests of Idaho and Montana Forests,* and *Common Tree Diseases of British Columbia.* In this case, imitation is truly indicative of flattery.

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INTRODUCTION

Phytophagous ("plant-eating") insects and tree pathogens (organisms that cause diseases of trees) are important components of coniferous forests in Washington and Oregon. They are most commonly known for causing individual tree-level impacts, such as growth reduction, breakage, deformity, and mortality. However, insects and pathogens do have significant effects on forest structure, species composition, and succession at stand and landscape levels. Insects and pathogens can influence the development and quality of wildlife habitat, watershed values, visual character, nutrient cycling, commodity production, and human safety.

This field guide has been prepared to provide forest resource managers with a basic tool for quick field identification of diseases and insects that are commonly found affecting conifers in the Pacific Northwest. It does not attempt to describe or list all insects and pathogens found affecting coniferous trees, only those most commonly encountered. This field guide should be used in combination with other resources such as the books *Western Forest Insects* (Furniss and Carolin 1977) and *Diseases of Pacific Coast Conifers* (Scharpf 1993). Written descriptions, identification keys, comparative tables, photographs, and line drawings are used to illustrate and emphasize key characteristics that will help the user identify the common insects and pathogens during field reconnaissance.

HOW TO USE THIS BOOK

First, users of this field guide should familiarize themselves with the steps of diagnosing conifer diseases and insect damage (see "Be Systematic," p. 3). If identity is not obvious based on observations, the user should work through the flow charts provided on pages 5 and 6 to ascertain the tree part or parts primarily affected. Once the affected tree parts are known, the subsequent, more detailed flow charts provided on pages 7-12 should be used to narrow the field of consideration to a particular causal group or agent. Next, the detailed descriptions, drawings, and photographs provided in the bulk of this publication should be used to confirm the identification. This systematic approach will undoubtedly prove more efficient than thumbing through the guide and simply viewing the included photographs.

Causal agent descriptions are grouped by functional category (e.g., bark beetles, root diseases, etc.), within sections corresponding to one of the three major tree parts with which they are most associated: 1) stem and root, 2) branch and terminal, and 3) foliage. An additional section of abiotic or noninfectious diseases is also provided. Descriptions are arranged alphabetically within each functional category except for juniper mistletoe and incense-cedar rust, where, in the authors' judgment, identification is better facilitated by a non-alphabetic placement. Measurements are expressed in both metric and the nearest "functional" (but often less precise) English conversions.

A reference list is associated with each agent or group of agents described. It is not meant to be all-inclusive; rather, it is a short list of key references likely to provide the interested user with general knowledge regarding the agent's biology, ecological role, and management. "General" references are compilations that include information for a broad array of agents. These publications may be consulted for additional information regarding the agents included in this text. The user is referred to "general" references when specific references for an agent are lacking or unavailable.

Plant pathologists and entomologists are available to assist resource managers with identification of insects and pathogens encountered in the forests. At the back of this field guide, a list of offices providing this assistance is included along with instructions for shipping samples.

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DIAGNOSIS

Identifying the agents associated with tree damage and mortality requires practiced observational skills. The person making the identification must rely on accurately assessing specific symptoms, signs, and patterns (Fig. 1a).

Causes of tree damage

Many organisms and abiotic factors cause tree damage and mortality.

Table 1–Causes of tree damage and mortality.

BIOTIC			ABIOTIC		
Insects	**Pathogens**	**Wildlife**	**Human-origin**	**Weather**	**Other**
Bark beetles	Root disease fungi	Bears	Herbicides	Drought	Fire
Wood borers	Dwarf mistletoes	Ungulates	Air Pollution	Wind	Poor soil
Defoliators	Canker-causing fungi	Rodents	Displaced soil, construction	Frost	Nutrient imbalances
Terminal and shoot borers	Stem decay fungi	Sapsuckers	Soil compaction	Flooding	Landslides
Root feeders	Other brooming agents		Poor planting technique	Winter desiccation	Avalanches
Sucking insects and mites	Foliar pathogens		Off-site seed source	Temperature extremes	
				Lightning	
				Snow, ice	

Primary agents vs. secondary agents

Insects and pathogens are sometimes divided into two categories, primary and secondary, depending upon their ability to cause tree mortality in the absence of other predisposing factors. Primary agents frequently kill the trees they affect, acting alone or in concert with other agents or factors. Secondary agents may cause tree damage or predispose trees to attack by other agents, but seldom cause tree mortality on their own.

Complexes are common

Frequently more than one causal factor contributes to tree mortality and certain combinations are commonly found in association with one another. Some common associations include root diseases and bark beetles, bark beetles and wood borers, canker-causing fungi and rodents, and off-site seed source plantings and foliar pathogens.

SYMPTOMS
Expressions of the host

- Sparse foliage
- Yellow foliage
- Resin flow
- Pitch tubes
- Swellings
- Branch dieback
- Crown dieback

SIGNS
Expressions of the agent

- Fruiting body on a needle
- Conk on a bole
- Insect galleries
- Chewed or webbed needles
- Fungal mycelia

PATTERNS
Within and among trees

- Portion of the tree
- Windward or exposed side
- Age of affected needles
- Tree species
- Tree age
- Mortality progresses slowly over time in the stand
- Mortality has occurred within a short time period

CONTEXT
The setting for the observed damage

- Geographic location
- Topographic location
- Stand history
- Weather history
- Setting
- Forest characteristics

Figure 1a Components of diagnosis.

Diagnosis is based on symptoms, signs, patterns, and context

Symptoms are how the host expresses the disease or insect invasion. Common symptoms include discoloration of foliage, loss of foliage, branch dieback, excessive resin flow at the root collar, presence of pitch tubes, or pitch streaming on the bole.

Signs are expressions of the agent itself, such as a fungal fruiting body on a needle, a conk on the tree bole, bark beetle gallery patterns, or chewed and webbed needles.

Patterns of damage on **individual trees** and **within groups of trees** will provide clues to the agent or agents involved. Note the portion of the tree that is affected (Fig. 1b), such as the branches, top, bottom, south side or whole tree, or determine the age of foliage affected. Distinguish among damage to older foliage, new foliage, foliage in only a portion of the crown, a sharp demarcation between dead and living foliage, or all foliage. Is a certain tree species or particular age class within the stand affected? Did groups of trees die within a relatively short period of time or has mortality progressed slowly among a group of trees over many years?

Context describes factors such as **geographical location, weather patterns, and information on past activities** on the site. Geographic location (e.g. western coastal lowlands), topographic location (elevation, aspect, floodplain, ridgetop), site history (drought, windthrow events, management activities, seed source), setting (natural, intensively managed, urban), timing (foliar discoloration in fall versus spring), and forest characteristics (pure or mixed species, structural stage, stand density) may be critical to diagnosing the cause of damage or mortality in forest trees.

Be systematic

If the observer is aware of more than just the affected tree or tree part and uses a systematic approach, diagnosis will steadily become easier.

1. Observe the damage.
2. Note symptoms and their pattern of distribution among affected trees.
3. Examine symptomatic, dying, and dead trees for signs of causal agents.
4. Note patterns of damage distribution and symptom development over time.
5. Know the site. What is the context of the damage?
6. Assemble the clues and identify potential causal factors.
7. Evaluate relative importance of primary versus secondary agents, common associations among damaging agents, and known relationships of site, stand, and agents in the area.
8. Arrive at diagnosis.
9. When in doubt, ask your local forest entomologist or pathologist.

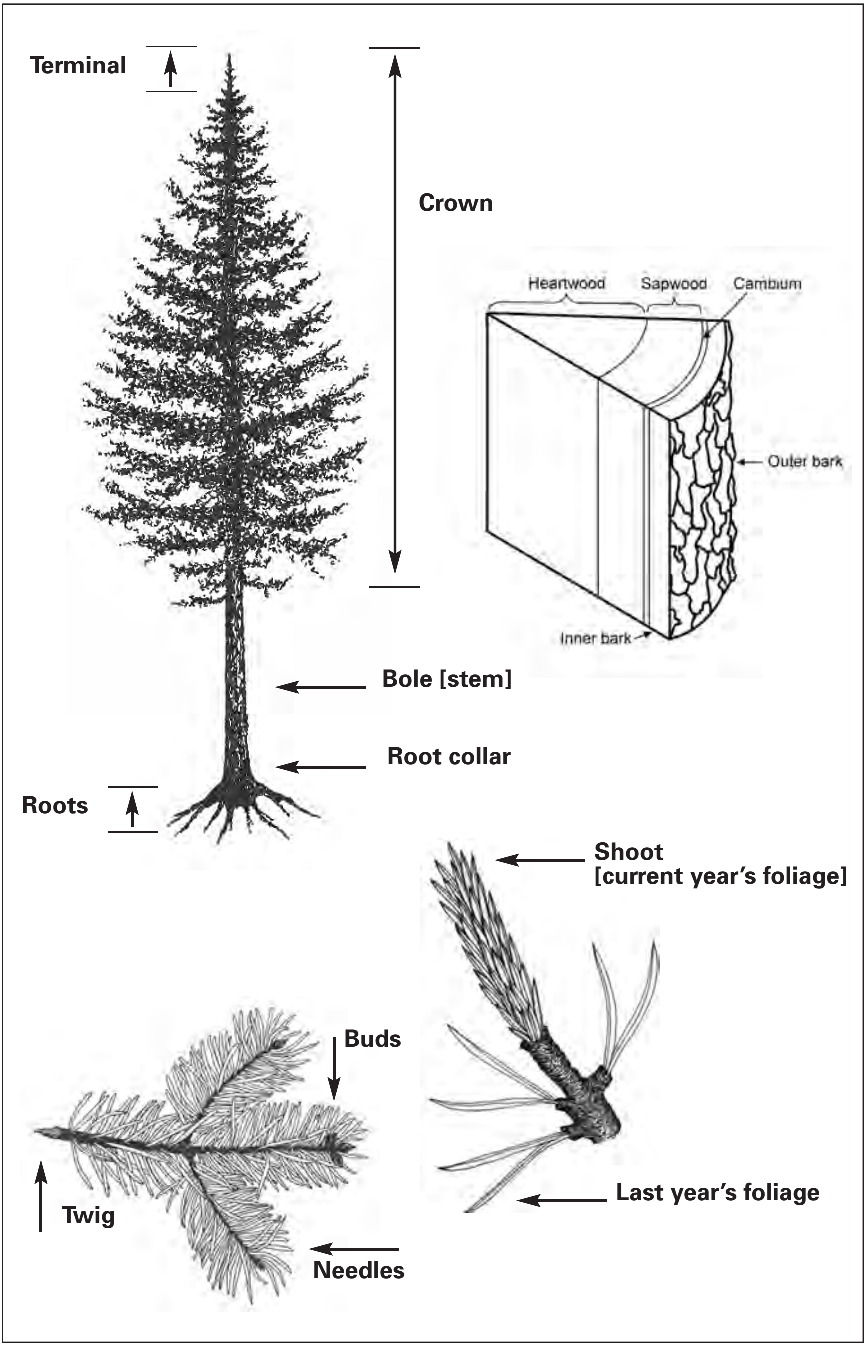


Figure 1b–Parts of a tree.

Figure 2 Tree is Alive Key

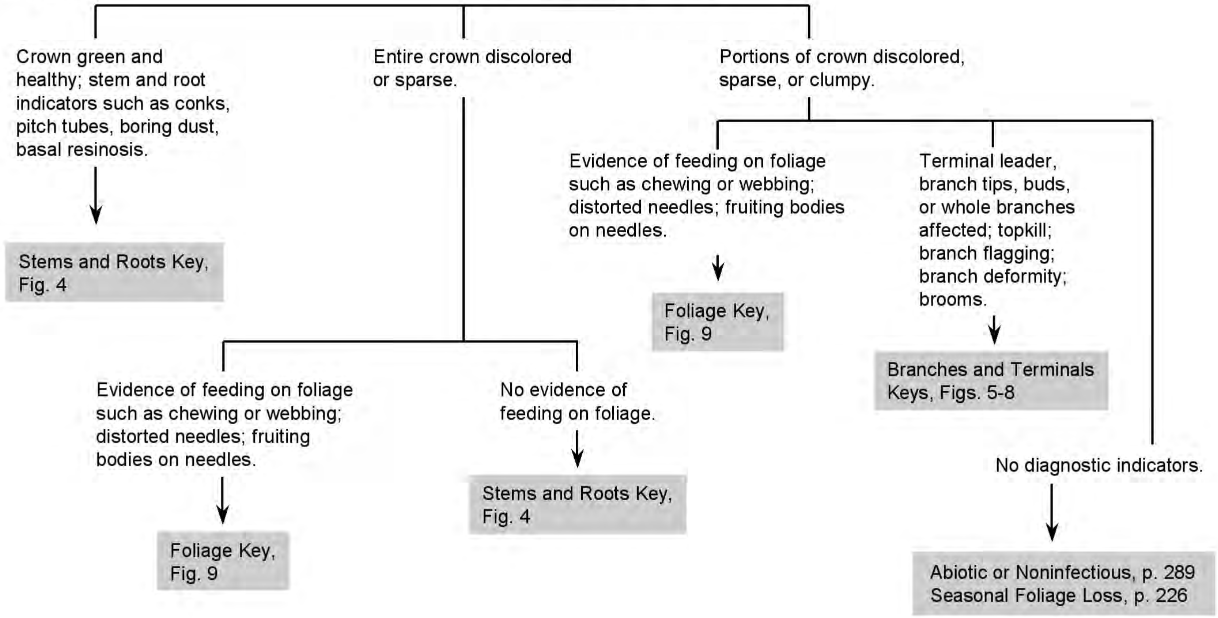


Figure 3 Tree is Dead Key

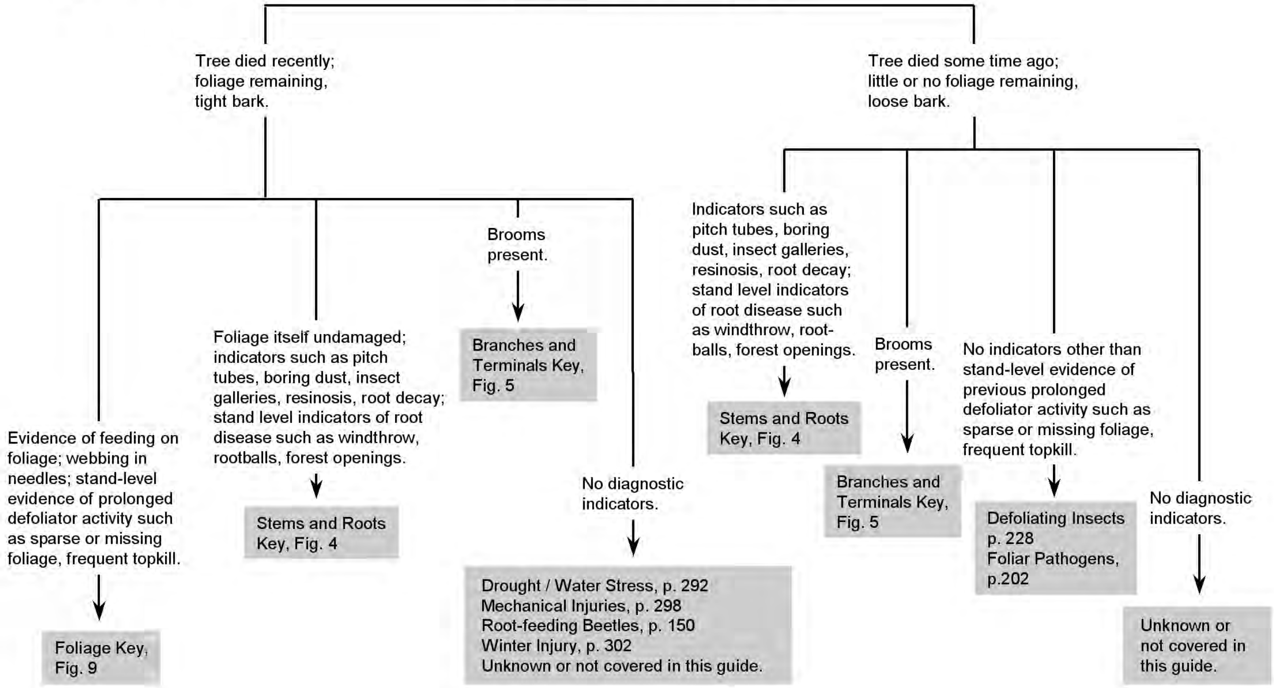


Figure 4 Stems and Roots Key

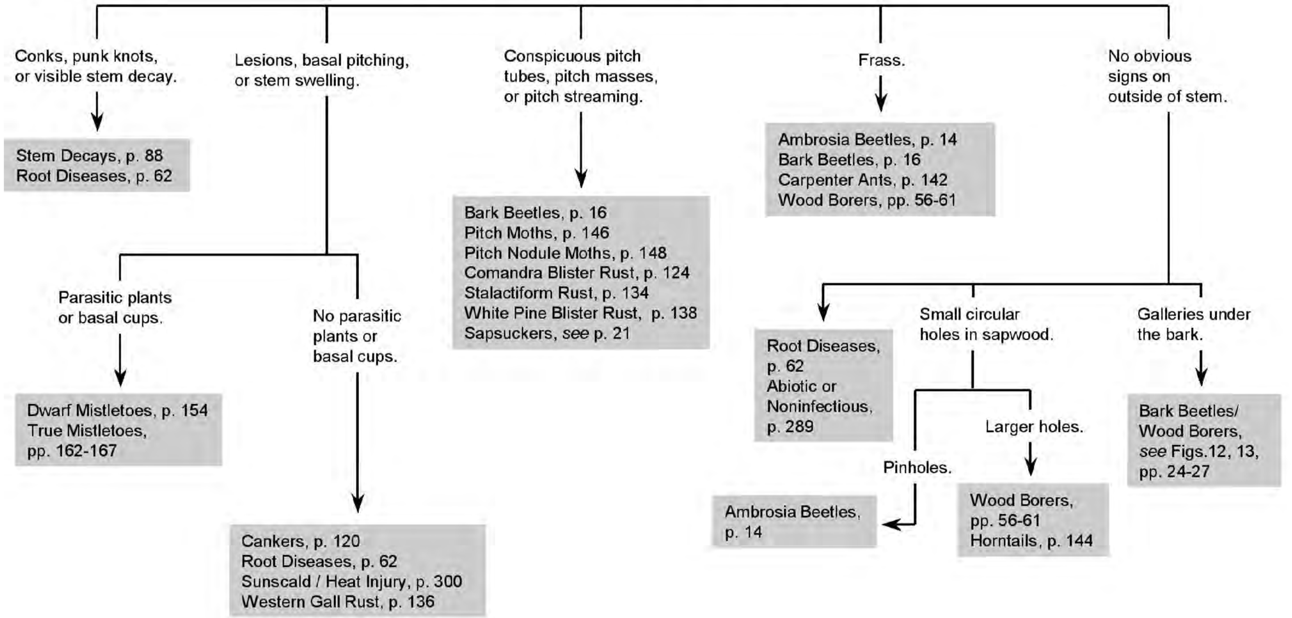


Figure 5 Branches and Terminals Key

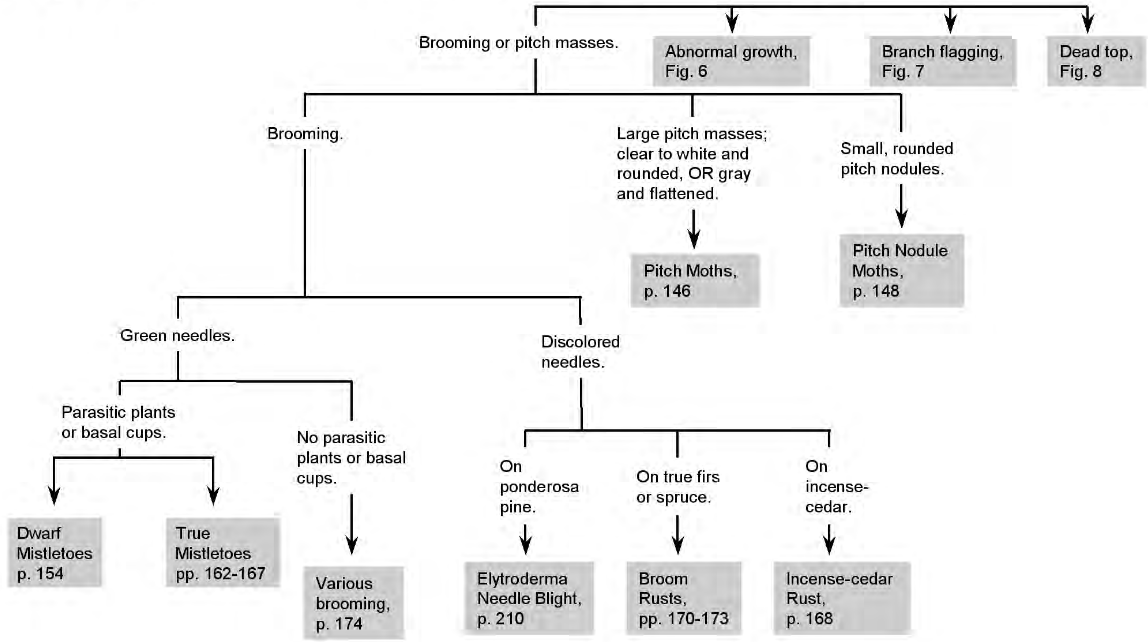


Figure 6 Branches and Terminals Key

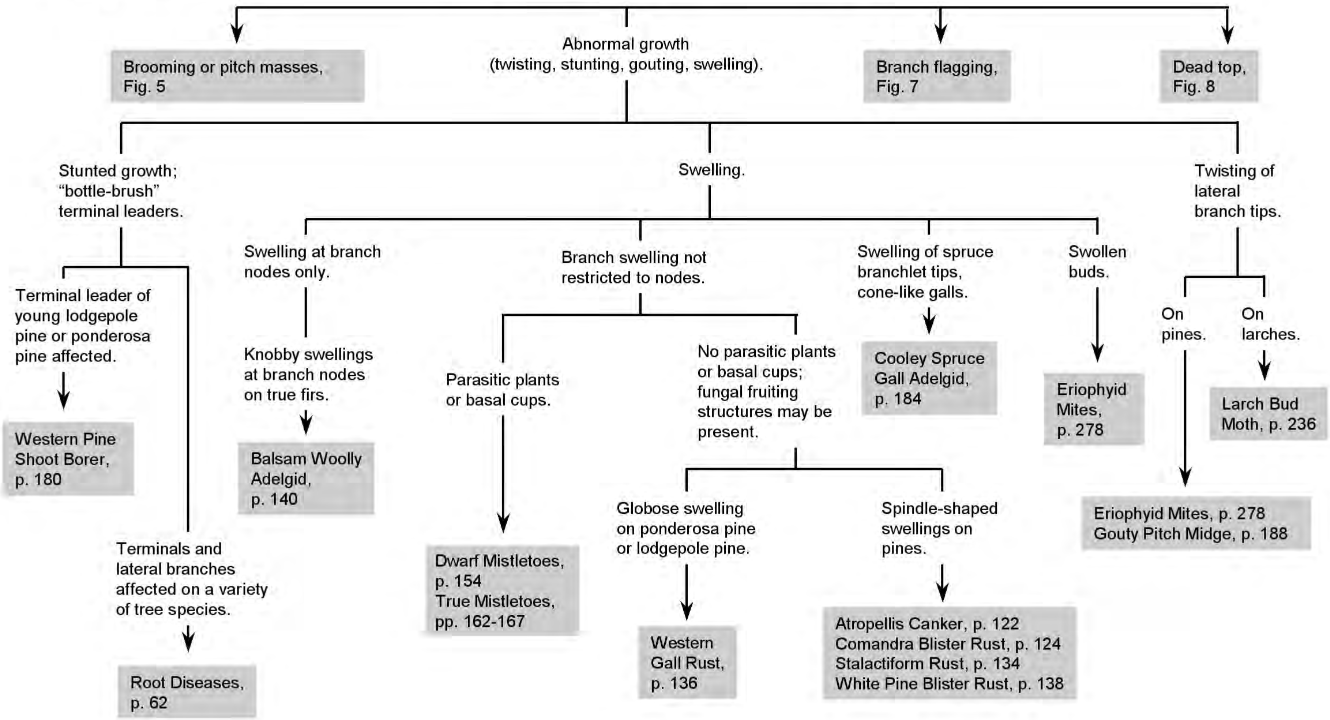


Figure 7 Branches and Terminals Key

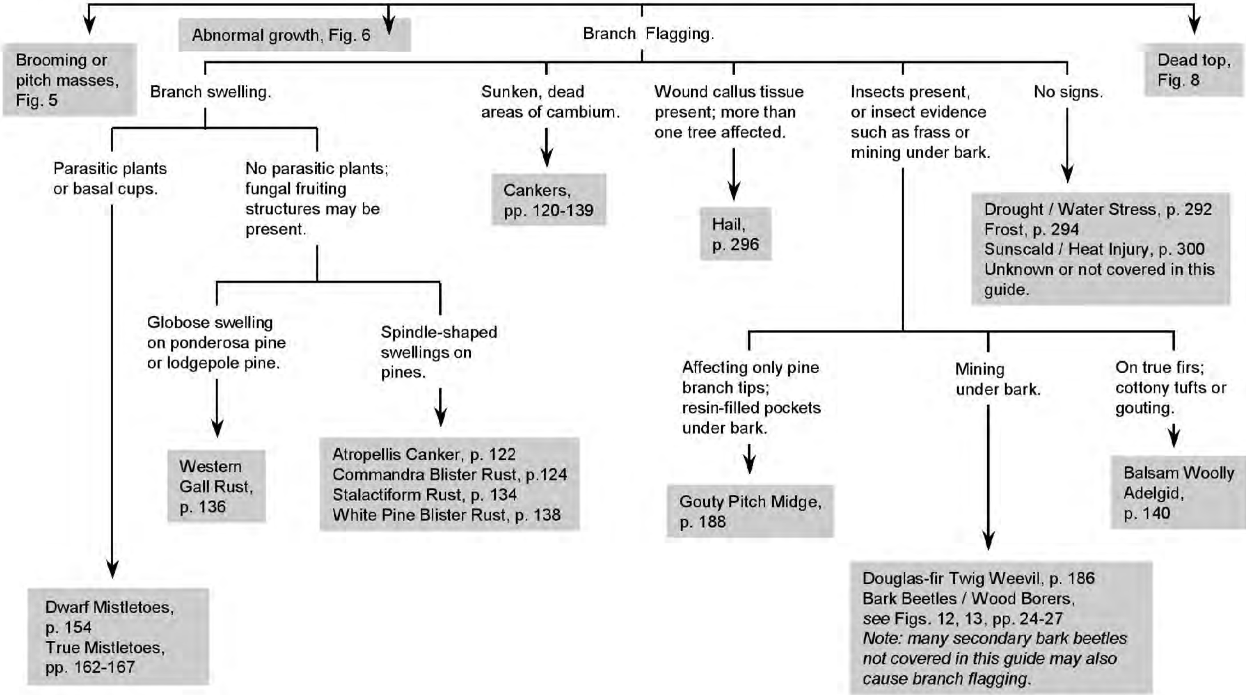


Figure 8 Branches and Terminals Key

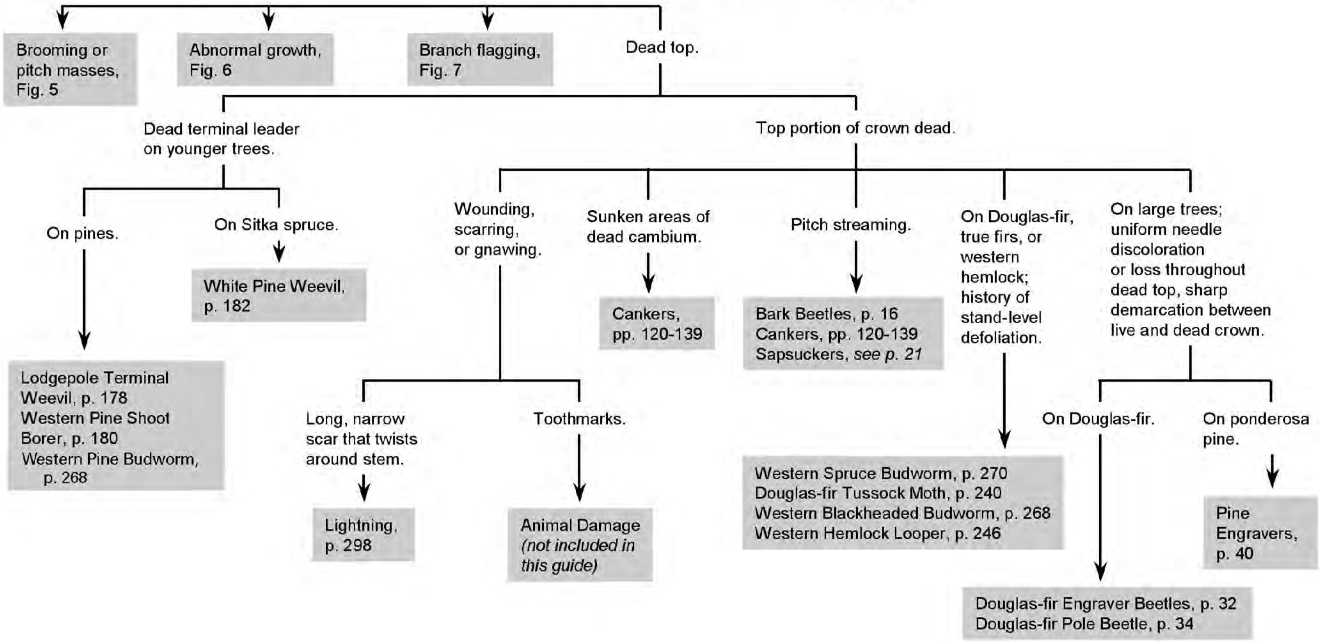
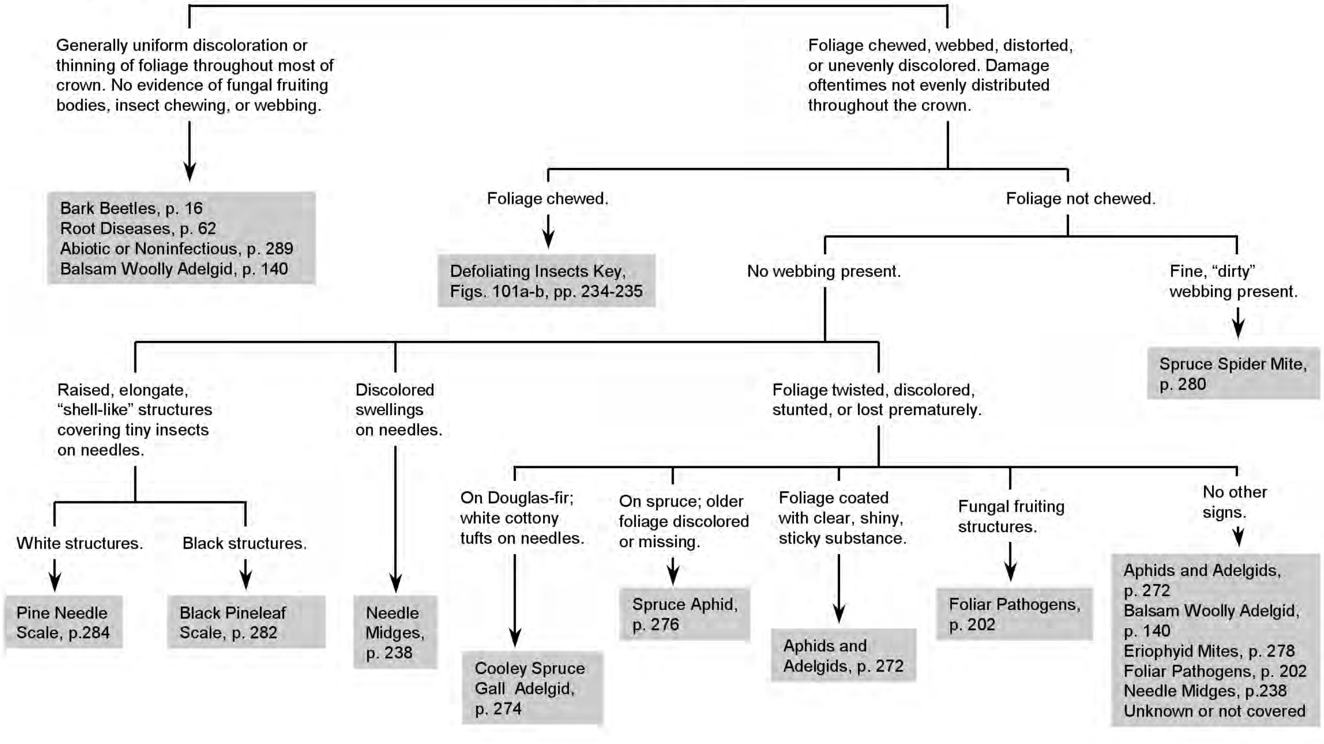


Figure 9 Foliage Key



Stem and Root

AMBROSIA BEETLES

Many species, including those in genera *Gnathotrichus, Monarthrum, Treptoplatypus, Trypodendron,* and *Xyleborus*.

Hosts: True firs, spruces, Douglas-fir, hemlocks, larches, pines, and western redcedar (least preferred).

Distribution and Damage: Ambrosia beetles are found throughout Oregon and Washington. *Trypodendron lineatum, Gnathotrichus sulcatus,* and *G. retusus* are considered the most damaging and common ambrosia beetles in this region. Adult ambrosia beetles bore into nearly dead and recently dead trees and logs cut within the past 2 to 3 years, causing pinhole defects and dark staining in the outer wood. Ambrosia beetles do not feed on wood, but construct tunnels in it where they rear their young and cultivate the symbiotic "ambrosia" fungi on which they feed. Although some species extend their tunnels into heartwood, most species inhabit the sapwood.

Identification: Ambrosia beetles cause tiny, perfectly round pinholes 0.5 to 1.5 mm (1/64 to 1/16 in) in diameter on the sapwood surface (Fig. 10a). These entrance holes lead into primary tunnels that are oriented perpendicular to the axis of the tree bole. Branching off horizontally from the primary tunnels and following generally along the growth rings are secondary tunnels (brood galleries) (Fig. 10b). These secondary tunnels are often lined with short perpendicular niches called "larval cradles." Black fungal stains frequently surround tunnels and pinhole entrances.

Entrance points are marked on the outer bark surface by piles of fine, granular, white to very pale yellow boring dust (Fig. 10c). The boring dust created by ambrosia beetles is unlike that created by bark beetles and wood borers, which is darker yellow to reddish orange in color, and often coarser in texture (Fig. 10d). The color difference is due to the boring substrate; ambrosia beetles penetrate into the whitish sapwood, while bark beetles and wood borers excavate primarily in the more deeply colored inner bark.

Ambrosia beetle larvae are small, white legless grubs with brown head capsules. Adults are small, cylindrical in cross-section, shiny brown to black beetles that range from 2 to 5.5 mm (1/16 to 1/4 in) long. The three most common and damaging species typically are about 3.5 to 3.7 mm (a little over 1/8 in) long. Some species have yellowish stripes or yellow legs.

Agents Producing Similar Symptoms and Signs: Ambrosia beetles may be confused with bark beetles and wood borers. However, fine, white boring dust and pinhole entrances to tunnels leading straight into the tree bole are diagnostic.

Severity: Ambrosia beetles primarily attack nearly dead and recently killed trees, and recently cut logs. They do not cause tree mortality. Their activity, however, can significantly lower the quality and value of wood used for lumber. In addition, the ability of some species to survive and develop in green lumber causes import, export, and quarantine problems and additional associated costs. Damage caused by ambrosia beetles is greater in the wetter coastal areas than in the drier interior regions.

References: 10

- *Fine, whitish boring dust in bark crevices.*
- *Pinhole entrances to tunnels boring straight into sapwood.*

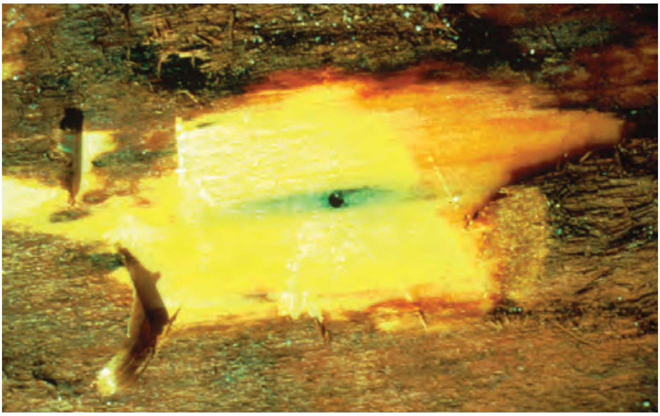


Figure 10a–Ambrosia beetle pinhole entrances on sapwood are often surrounded by dark fungal stains.

Figure 10b—Ambrosia beetle, *Trypodendron* sp., galleries in ponderosa pine sapwood.

Figure 10c—Fine whitish boring dust of ambrosia beetles at the base of a ponderosa pine tree.

Figure 10d—Side-by-side view of ambrosia beetle boring dust (left) and bark beetle boring dust (right).

Bark Beetles

Bark beetles spend most of their lives between the bark and sapwood of trees. They have four life stages: egg, larva, pupa, and adult. Most species take one year to complete their life cycle. Those that cause the most harmful effects to living trees colonize the main stem. In general, bark beetles are most successful at colonizing and reproducing in trees of lower-than-normal vigor.

Bark beetles may be grouped into two general categories relating to their ability to cause tree mortality: primary and secondary. Primary bark beetles are capable of killing trees of normal or near normal vigor, while secondary bark beetles usually colonize only dead, dying, or severely weakened trees, or live in twigs and branches. When primary bark beetle population levels are low, they, like many of the secondary bark beetle species, live almost exclusively in diseased, weakened, or stressed trees. However, when populations are high, primary bark beetles also colonize trees of more normal vigor. Conditions that precipitate bark beetle population increases to outbreak levels vary according to species. Drought, severe defoliation, stand age, overcrowding, windthrow events, winter damage, and fire injury are conditions associated with population increases of various primary bark beetle species and subsequent beetle-caused mortality of healthy trees.

Bark beetle adults use volatile scents called pheromones to communicate location and occupancy. Trees tend to be killed in groups during bark beetle outbreaks due to the aggregating effects of attractive pheromones (Fig. 11a).

Tree and Bark Beetle Interactions

Adult bark beetles are strong fliers. Once they land on a new host, the adults tunnel through the bark to construct galleries in the cambial area (Fig. 1b) in which they feed and lay their eggs. They almost always carry spores of staining fungi that germinate and grow in the host's sapwood region, restricting the flow of water and nutrients in the tree. Spores of the saprophytic pouch fungus, *Cryptoporus volvatus*, are also frequently carried into trees by bark beetles and wood borers. *Cryptoporus* fruiting bodies, which appear within 1 to 2 years at holes created in the bark by beetles, are good indicators of previous bark beetle or wood borer activity (Figs. 11b, 53a-c).

As adult beetles begin egg gallery (Figs. 11c, d) construction, they push boring dust (Fig. 11e) out of the entrance hole. It collects in bark crevices and

Figure 11a—Bark beetles tend to kill groups of trees. These ponderosa pines were killed by mountain pine beetle.

Figure 11b—Fruiting bodies of the pouch fungus, *Cryptoporus volvatus,* indicate previous activity of bark beetles or wood borers in a tree.

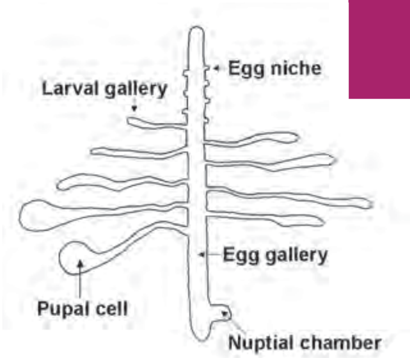


Figure 11c—Illustration of a bark beetle gallery, showing typified features and a longitudinal orientation.

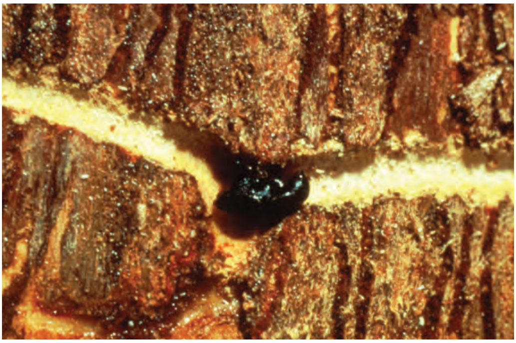


Figure 11d—Adult fir engraver in transversely oriented egg gallery.

Figure 11e—Pile of boring dust at Douglas-fir beetle entrance hole.

around the base of the tree, or mixes with pitch produced by the tree. Eggs are laid singly or in groups along the walls of the egg galleries. When the larvae hatch, they mine out initially at right angles to the egg galleries. Their tunnels are called larval galleries. Larval galleries increase in width along their length, reflecting larval growth, whereas egg galleries remain the same width along their entire length.

Trees react to tunneling beetles by producing flows of pitch, which repel or engulf the beetles and their progeny. Pitch flows are responsible for the formation of pitch tubes (Fig. 11f), found only on pines and spruces, and pitch streamers (Fig. 11g), which are found on a number of host species. The production of pitch is positively correlated with the vigor of the tree. A healthy tree's natural defense mechanisms, however, may be overcome by massive beetle attacks. Trees completely girdled by beetle galleries are killed. The growth of staining fungi introduced by the attacking beetles may stop or reduce water movement to such an extent that trees not physically girdled by bark beetles die as well. The balance of several factors determines the fate of a tree attacked by bark beetles during the period of attack, including the vigor of the tree, the number of attacking beetles, and the degree to which the beetles utilize the entire circumference of the tree.

In pines, the success or failure of mountain pine beetle or western pine beetle attack may be inferred for an individual tree by examining the color and number of pitch tubes. White to clear pitch tubes contain no boring dust, and indicate the beetles were unsuccessful in constructing egg galleries (Fig. 22d). Pink to reddish pitch tubes represent a mixture of boring dust and pitch, and usually indicate that beetles successfully constructed egg galleries (Fig. 22c). In some instances, a tree may be so severely stressed or weakened that it is unable to produce much pitch in response to the beetle attacks. When this happens, no pitch tubes are formed. These are often referred to as "blind attacks."

Bark Beetle Identification

Bark beetle activity causes specific patterns of damage within a stand and on an individual tree. For the most part, beetle signs are fairly obvious and relatively durable, making it possible to detect previous infestations for many years. Bark beetle infestations frequently occur in combination with other mortality agents, especially root disease, so one should always inspect both the tree bole and the roots to get an accurate picture of factors contributing to tree mortality on a site.

Figure 11f—Pitch tubes caused by the mountain pine beetle.

Figure 11g—Pitch streamers on Engelmann spruce bole resulting from spruce beetle attacks.

Patterns of Damage

Within a stand
Bark beetle infestation typically results in the occurrence of groups of dead or dying trees composed of the same or closely related species and a similar range of diameter sizes. Mortality of all trees in the group usually occurs at about the same time (Fig. 11a). Trees that die at the same time have approximately the same amount of chlorotic, yellow, orange, red, or dropped foliage, and similar bark tightness and retention.

Within a tree
Bark beetle infested trees generally die within a relatively short time span. Recent bark beetle-killed trees (that are unaffected by other damage agents) are characterized by a full complement of uniformly discolored foliage (Fig. 11h). Needles are entire. Bark beetles typically cause the death of a whole tree, the top portion of a tree crown, or, more rarely, single branches. "Strip attacks" occur when beetle infestation is restricted to one side of the tree.

Signs of Occurrence

On the tree

1) Woodpecker activity on pines or spruces that has flaked off considerable amounts of bark (Figs. 11i, 27b).
2) Pouch fungus (common on Douglas-fir, pines, and true firs) (Fig.11b).
3) Pitch exudations, in the form of pitch tubes or pitch streamers, which originate from nonlinearly arranged points on the tree bole (Figs. 11f, g, 15c). Do not confuse with pitch exudations caused by sapsuckers (Fig. 11j).
4) Yellow to reddish boring dust in bark crevices or around the base of the tree (Figs. 11e, 14a, 15b).
5) Gallery patterns under the bark, either on the sapwood or the inner bark (Figs. 13a-n).

   Note: Wood borer galleries sometimes obscure bark beetle gallery patterns (Fig. 28a).

Distinguishing Bark Beetle Species

The following features distinguish bark beetle species from one another:

Host preferences
Each bark beetle species is specific to one or a few tree species. In addition, most bark beetles exhibit preferences for certain bole diameters, or locations on the bole. These preferences aid identification.

Galleries
The pattern formed by the egg and larval galleries of each bark beetle species is unique to that species, and when used in conjunction with the preferred host tree species, is one of the most useful features for bark beetle species identification (Figs. 12, 13a-n). Important distinguishing features include the vertical or horizontal orientation of the egg gallery in relation to the axis of the stem, the length and number of egg galleries in a single gallery pattern, the overall pattern of the larval galleries, the presence or absence of frass in the egg gallery, and the presence or absence of a nuptial chamber.

Figure 11h—Bark beetle-killed trees usually die rapidly, and with a full complement of foliage. Note color change in these grand fir trees, from current-year fader (left) to previous-year mortality (right).

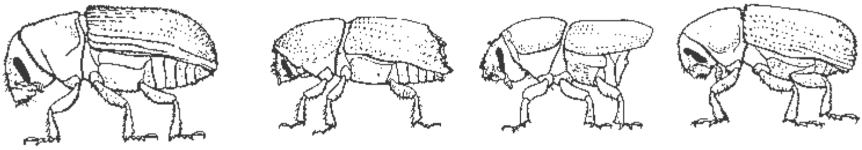
Figure 11i—Spruce boles infested with spruce beetle. Foraging woodpeckers frequently flake bark off of spruces and pines infested with bark beetles.

Figure 11j—Sapsucker holes tend to form a linear horizontal pattern across the bole. Pitch streamers originating from sapsucker holes are sometimes confused with those caused by bark beetles, which arise from a random pattern of point sources on the bole.

Body characteristics
The larvae of all bark beetle species have a very similar appearance: small, white, legless, slightly "c" shaped, with brown head capsules (Fig. 11k). Pupae are usually cream-colored to white. Due to the similarity among species, larval and pupal characteristics are not useful for distinguishing species in the field. New, or "callow," adult beetles are a golden to very light brown color. Mature bark beetle adults are generally dark brown, reddish brown, or black. Adults of the major genera may be distinguished on the basis of shape and coloration of the abdomen (Fig. 11l). Adult body shape characteristics are not emphasized as an identifying feature in this guide because beetles are not always present when field determinations are made, and because successful field determinations are more easily made using other indicators, such as host tree species and gallery pattern.

References: General

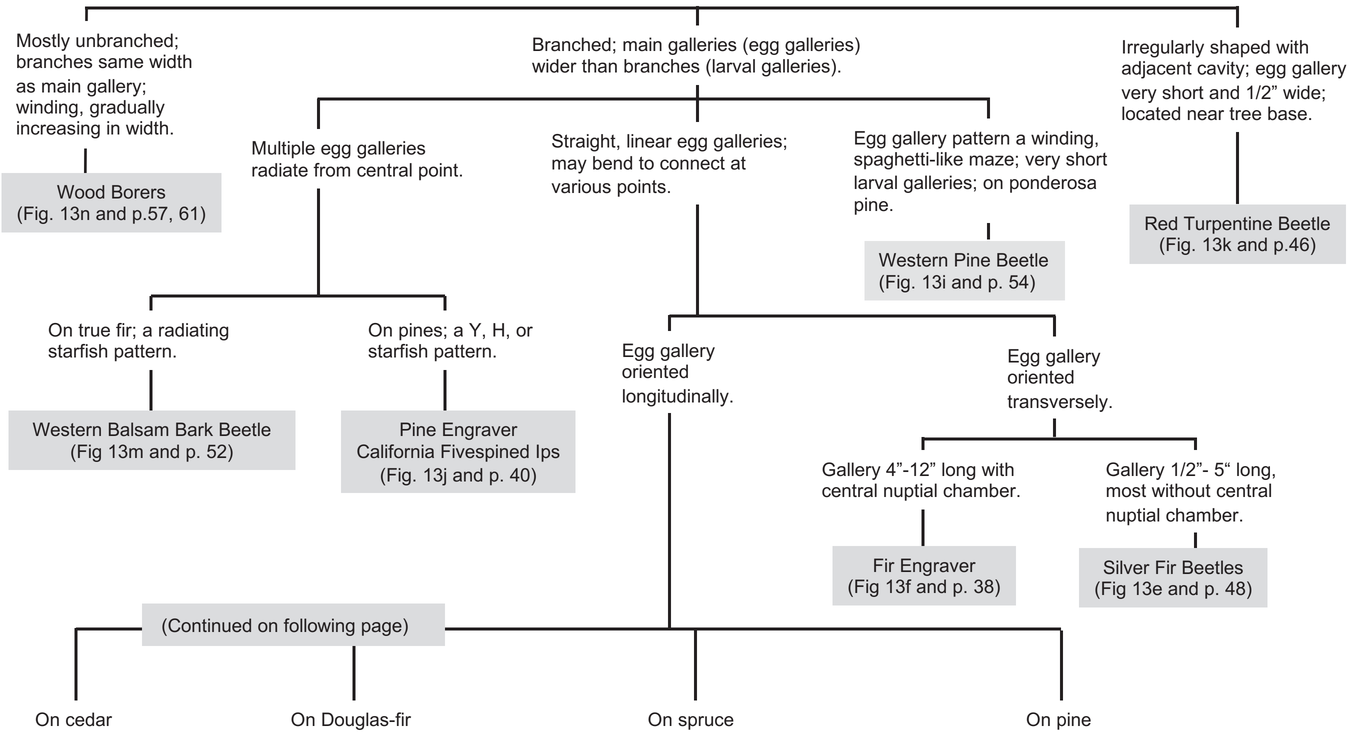
Figure 11k—Mountain pine beetle larva.



Dendroctonus pseudotsugae	*Ips pini*	*Scolytus ventralis*	*Phloeosinus sequoiae*

Figure 11l—The shape of a bark beetle's posterior is a useful identification aid. Representative types include "rounded" (*Dendroctonus* spp.), "dish-shaped depression with spines" (*Ips* spp.), "sawed-off" (*Scolytus* spp.) and "rounded with tubercles" (*Phloeosinus* spp.).

Figure 12 Bark Beetle Galleries Key



- On cedar
  - **Cedar Bark Beetles** (Fig. 13a and p. 28)
- On Douglas-fir
  - Long egg galleries on large-diameter stems; larval galleries extend fanlike on alternating sides of egg gallery.
    - **Douglas-fir Beetle** (Fig. 13b and p. 30)
  - Short egg galleries on small-diameter stems; well-defined nuptial chamber at basal end of gallery.
    - **Douglas-fir Engraver** (Fig.13c and p. 32)
  - Short egg galleries on small-diameter stems; slight crook at gallery midpoint.
    - **Douglas-fir Pole Beetle** (Fig. 13d and p. 34)
- On spruce
  - **Spruce Beetle** (Fig. 13l and p. 50)
- On pine
  - Egg gallery very short and 1/2” wide; irregularly shaped, with adjacent cavity; located near tree base.
    - **Red Turpentine Beetle** (Fig. 13k and p. 46)
  - Egg gallery long, straight, sometimes slightly sinuous.
    - Parallel egg galleries do not connect; have slight crook at basal end; frass in fresh galleries.
      - On Jeffrey pine
        - **Jeffrey Pine Beetle** (Fig. 13g and p. 42)
      - On other pines
        - **Mountain Pine Beetle** (Fig. 13g and p. 44)
    - Parallel egg galleries bend to connect at various points; nuptial chambers present; no frass in fresh galleries.
      - **Emarginate Ips** (Fig. 13h and p. 36)

Figure 12 Bark Beetle Galleries Key

(Continued from previous page)

BARK BEETLE GALLERY PATTERNS

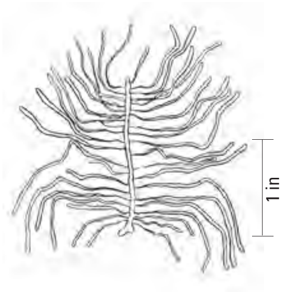


Figure 13a—Cedar bark beetle

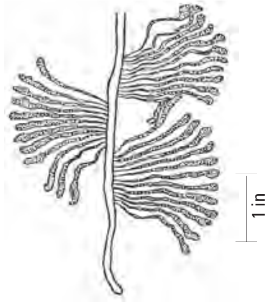


Figure 13b—Douglas-fir beetle[1]

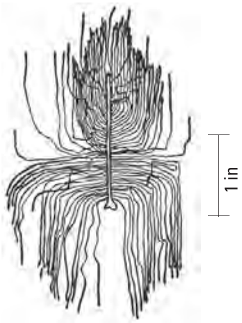


Figure 13c—Douglas-fir engraver[1]

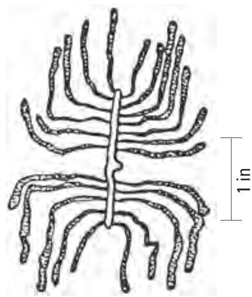


Figure 13d—Douglas-fir pole beetle[1]

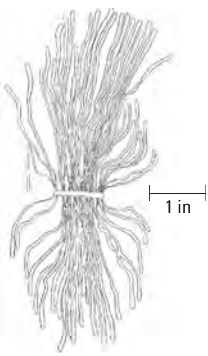


Figure 13e—Silver fir beetle

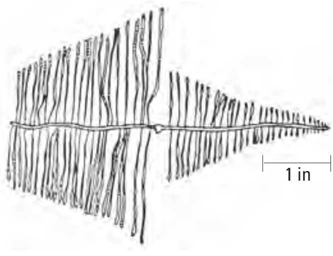


Figure 13f—Fir engraver[1]

[1]Reprinted with permission from OSU Book Stores, Inc.

BARK BEETLE GALLERY PATTERNS

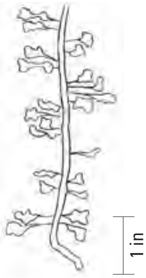


Figure 13g—Mountain pine beetle,[1] Jeffrey pine beetle

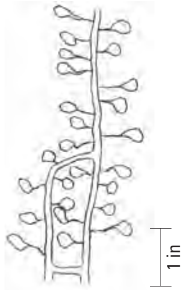


Figure 13h—Emarginate ips

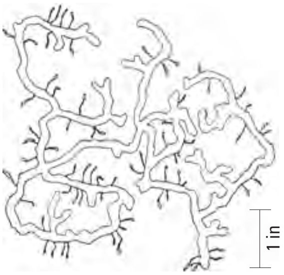


Figure 13i—Western pine beetle

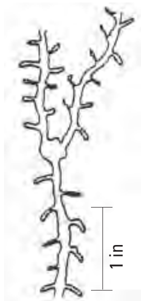


Figure 13j—Pine engraver, California five-spined ips

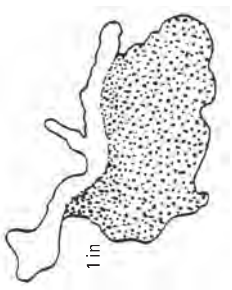


Figure 13k—Red turpentine beetle

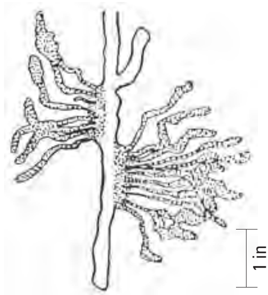


Figure 13l—Spruce beetle[1]

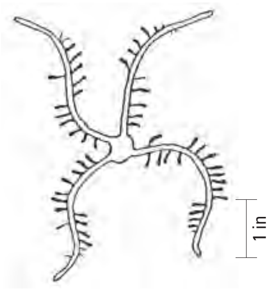


Figure 13m—Western balsam bark beetle[1]

Figure 13n—Wood borers

CEDAR BARK BEETLES

Phloeosinus spp.

Hosts: Cedars, cypress, western juniper, coast redwood, and giant sequoia. One *Phloeosinus* species is reported to occur occasionally on Engelmann spruce and noble fir.

Distribution and Damage: Cedar bark beetles are found throughout Oregon and Washington. They most commonly are associated with weakened, felled, or dying trees where they attack stems, branches, and tops. Apparently healthy trees are sometimes attacked and killed when outbreaks develop during periods of drought. Newly emerged adults feed on the twigs of healthy trees, often causing them to break and die.

Identification: *Phloeosinus* spp. are the only bark beetles that attack cedars and cedar-like trees. Look for dying and dead host trees with orange-red boring dust in bark crevices (Fig. 14a) or with numerous egg galleries under the bark. The egg gallery is often quite short (19 to 25 mm or 3/4 to 1 in), but may sometimes extend for as long as 15 cm (6 in). It is free of frass with an enlarged entrance chamber at the lower end (Figs. 13a, 14b, c). Egg galleries tend to be longitudinally oriented and straight, but sometimes are randomly oriented and irregularly shaped (Fig. 14d). Eggs are placed in uniformly spaced niches along either side of the egg gallery, and the larval galleries extend outward in a regular pattern. Adults are tiny, 2 to 4 mm (1/16 to 1/8 in) long, reddish brown to black, and often shiny. Their posteriors are rounded, and armed with small bumps called tubercles (Fig. 11l). When diagnosing the cause of twig mortality on otherwise healthy hosts, look for chewed stem surfaces, hollowed-out twigs, and other evidence of adult beetle feeding at the point of dieback.

Agents Producing Similar Symptoms and Signs: The effects of Port-Orford-cedar root disease and other root diseases may be confused with those of *Phloeosinus* spp. Egg galleries under the bark will be present if cedar bark beetles are involved. Other agents that cause twig dieback include foliar diseases such as cedar leaf blight, and natural dieback of older foliage in autumn.

Severity: Cedar bark beetles are generally secondary, attacking trees injured or weakened by root disease or other agents. They may become more aggressive and kill otherwise healthy trees during periods of drought.

References: General

- *Bark beetle galleries on cedar or cedar-like trees.*
- *Look for root disease!*

Figure 14a—Fine orange-red boring dust on dying Port-Orford-cedar indicates infestation by cedar bark beetles.

Figure 14b and c—Typical cedar bark beetle galleries are short and longitudinal, with an enlarged entrance chamber at the lower end.

Figure 14d—Cedar bark beetle galleries sometimes are randomly oriented and irregularly shaped.

DOUGLAS-FIR BEETLE

Dendroctonus pseudotsugae Hopkins

Hosts: Douglas-fir. Western larch is occasionally attacked, but brood is successfully produced only in freshly downed trees.

Distribution and Damage: *D. pseudotsugae* is found throughout Oregon and Washington. It causes tree mortality and, occasionally, patches of cambium mortality from strip attacks. Standing trees less than 30.5 cm (12 in) dbh are seldom killed in areas west of the Cascade Mountains crest. East of the crest, it is not unusual to observe mortality of trees as small as 20.3 cm (8 in) dbh.

Identification: Douglas-fir beetles often kill trees in groups (Fig. 15a). Substantial amounts of coarse, rounded, red-orange boring dust in bark crevices or on the ground around a tree usually indicate a recent successful attack (Fig. 15b). No pitch tubes are formed, but clear resin "pitch streamers" may exude from attacks high on the stem (Fig. 15c). Unlike boring dust, pitch streamers are not reliable indicators of successful attack. Egg galleries are straight or slightly sinuous, packed with frass, and may extend longitudinally 12.5 to 46 cm (5 to 18 in) (Figs. 13b, 15d). Eggs are laid in groups on alternating sides of the gallery. Each group of larval galleries radiates away from the egg gallery in a somewhat fan-shaped pattern. Most individuals overwinter in the galleries as adults, though some large larvae also may be present. Adults are about 6 mm (1/4 in) long, are black with red-brown elytra, and have rounded posteriors (Fig. 11l).

Agents Producing Similar Symptoms and Signs: Root diseases also may produce groups of dead Douglas-fir trees. Attacks by secondary bark beetles or wood-borers may also produce boring dust in bark crevices; this dust usually differs by being of a different texture or color than that made by Douglas-fir beetle. Pitch exudations on the upper bole may be caused by a variety of agents, e.g., sapsucker feeding often produces pitch streamers from a linear series of horizontal holes on the bole (Fig. 11j). Gallery size and pattern distinguish the Douglas-fir beetle.

Severity: The Douglas-fir beetle normally breeds in felled, injured, windthrown, or diseased (especially root-diseased) trees. At times, though, populations increase to epidemic levels and kill apparently healthy trees over large areas. Outbreaks in the coastal Douglas-fir region usually develop as a result of extensive windthrow, kill a substantial number of trees the year following windthrow, and subside quickly over the two years subsequent to the first pulse of standing tree mortality. Outbreaks east of the Cascade Mountains crest may develop following extensive windthrow, defoliator outbreaks, or extended drought, and usually last from two to four years. Those that last longer often occur during a drought period and may kill many of the older Douglas-firs in some stands, sometimes up to 80 percent.

References: 32

- *Longitudinal egg gallery with larval galleries extending in groups from alternating sides.*
- *Red-orange boring dust in bark crevices.*
- *Pitch streamers high on stem.*
- *Look for root disease!*

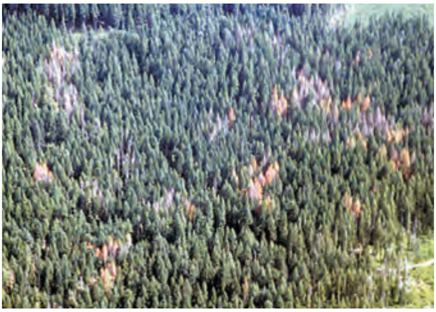


Figure 15a—Grouped mortality of Douglas-fir caused by the Douglas-fir beetle.

Figure 15c—Pitch streamers on Douglas-fir caused by Douglas-fir beetle attacks.

Figure 15b—Red-orange boring dust of Douglas-fir beetle on down tree.

Figure 15d—Douglas-fir beetle galleries. Note fan-shaped pattern of larval galleries that originate in groups on alternate sides of the egg gallery.

DOUGLAS-FIR ENGRAVER BEETLES

DOUGLAS-FIR ENGRAVER *Scolytus unispinosus* LeConte
AN ENGRAVER BEETLE *Scolytus monticolae* (Swaine), previously included in the species *S. tsugae* (hemlock engraver) by some authors; *S. monticolae* and *S. tsugae* are now regarded as separate species.

Hosts: Douglas-fir, occasionally on other conifers.

Distribution and Damage: Douglas-fir engraver and *S. monticolae* are found throughout Oregon and Washington. They kill individual branches, small trees, and the tops of large trees, commonly attacking logging slash, weakened or recently dead young trees, and larger trees stressed by drought or other agents. These beetles are very common on trees with root disease and on trees colonized by the Douglas-fir beetle.

Identification: Both species produce similar galleries, with *S. unispinosus* having a more variable pattern. Egg galleries score the sapwood. They are longitudinal and relatively short, ranging from 2.5 to 8.9 cm (1 to 3-1/2 in) long (Figs. 13c, 16a). The egg galleries may be two-branched, extending in opposite directions from a central notch (*S. unispinosus, S. monticolae*), or unbranched, extending in one direction (*S. unispinosus*) from an enlarged chamber or notch. Egg galleries of *S. monticolae* are slightly wider than those of *S. unispinosis*. Larval galleries may fan out from the egg gallery in a regular fashion (*S. unispinosis*) or tend to branch off at right angles for a short distance before diverging, with the upper galleries turning up and the lower galleries turning down (*S. monticolae*). Generally there is one generation per year, although *S. unispinosus* sometimes has two generations at low altitudes in western Oregon. Winter is spent in the larval stage. Adult beetles of both species are variable in size, averaging about 2 to 3 mm (1/16 to 1/8 in) in length, are shiny, dark brown to black, and have “sawed-off” rear ends (e.g. Fig. 11l). *S. unispinosis* adults have a single rearward projecting spine or bump on their rear ends.

Agents Producing Similar Symptoms and Signs: Douglas-fir pole beetle produces nearly identical symptoms, and the galleries of all three species are quite similar and frequently found intermingled. However, Douglas-fir engraver and *S. monticolae* galleries score the sapwood, while those of the Douglas-fir pole beetle are merely lightly etched. Unlike the Douglas-fir pole beetle, adults of the Douglas-fir engraver and *S. monticolae* are shiny and appear “sawed-off.” Douglas-fir canker diseases cause similar symptoms in young trees and in the small-diameter, thin-barked portions of larger trees. Root diseases also cause mortality in young Douglas-fir plantations, and young trees attacked by these beetles should be closely inspected for signs of root disease. On stressed sites and during droughty periods, several agents may work together to cause symptoms.

Severity: Douglas-fir engraver beetles are usually secondary, occurring in association with moisture stress or other agents, especially root disease, cankers, Douglas-fir pole beetle, and Douglas-fir beetle. During periods of drought, large populations sometimes develop in logging slash, then kill nearby young Douglas-fir trees. Topkill and branch-kill in larger Douglas-fir trees also is more prevalent during droughty periods (Fig. 16b).

References: 50, 58

- *Short, longitudinal egg gallery that scores the sapwood.*
- *Galleries occur on small tree boles, and on tops and limbs of larger trees.*
- *Look for root disease!*

Figure 16a—Douglas-fir engraver (*S. unispinosis*) galleries. Note the longitudinal egg gallery that scores the sapwood and the short, compact pattern.

Figure 16b—Douglas-fir engraver beetles and Douglas-fir pole beetle (p. 34) can cause topkill of mature Douglas-fir trees, especially during droughty periods.

DOUGLAS-FIR POLE BEETLE

Pseudohylesinus nebulosus (LeConte)

Hosts: Douglas-fir is the principal host.

Distribution and Damage: Douglas-fir pole beetle is found throughout Oregon and Washington. It causes small-tree mortality and topkill of larger trees. This beetle commonly attacks thin-barked portions of logging slash, windthrown trees, and the tops and branches of larger trees. It also attacks saplings and pole-sized trees infected by root disease fungi or stressed by competition, drought, or thinning shock.

Identification: Egg galleries are short (2.5 to 5 cm or 1 to 2 in), longitudinal, and usually two-branched from a central notch, or entrance chamber (Figs. 13d, 17). The sapwood surface may be slightly etched but is not scored; gallery patterns are deeply engraved on the bark underside. Larval galleries tend to turn upward to follow the grain above the notch and downward below it. They sometimes wander erratically or are unusually long. Adult beetles are brown, slender, and quite small, about 3 mm (1/8 in) long. They have a rounded posterior, and are densely covered with scales, which gives them a dull, soft appearance. Adults overwinter under the bark in small, excavated niches. Depending on location, there are 1 to 2 generations per year.

Agents Producing Similar Symptoms and Signs: Douglas-fir canker diseases also cause topkill and branch flagging in young trees. Root disease in young plantations can be confused with Douglas-fir pole beetle, and young trees infested with this beetle should be inspected for signs of root disease. Douglas-fir engraver beetles produce nearly identical symptoms and their similar-appearing galleries frequently are found intermixed with Douglas-fir pole beetle, however, the absence of sapwood scoring distinguishes Douglas-fir pole beetle galleries. Adults of the Douglas-fir pole beetle are dull instead of shiny and do not have the "sawed-off" appearance of Douglas-fir engraver beetles. Several agents may work together to cause symptoms during droughty periods, and on stressed sites.

Severity: Douglas-fir pole beetle is a secondary bark beetle that is associated with slash and trees under stress. Topkill and branch flagging in larger Douglas-firs caused by *P. nebulosus* is most prevalent during droughty periods (Fig. 16b).

References: 88

- *Short, longitudinal egg gallery that does not score the sapwood.*
- *Egg galleries two-branched from a central notch.*
- *Galleries occur on small tree boles and on tops and limbs of larger trees.*
- *Look for root disease!*

Figure 17—Douglas-fir pole beetle galleries lightly etch the sapwood. Note central notch and larval galleries that turn up near the top of the egg gallery and down near the bottom.

EMARGINATE IPS

Ips emarginatus (LeConte)

Hosts: Ponderosa pine, lodgepole pine, western white pine, sugar pine, and Jeffrey pine.

Distribution and Damage: The emarginate ips is found throughout Oregon and Washington. It causes or contributes to tree mortality and is commonly found in association with western pine beetle, mountain pine beetle and Jeffrey pine beetle.

Identification: Yellow or reddish boring dust in the bark crevices or on the ground near the base of a tree is the only outward indication of attack. Egg galleries are 0.6 to 1.2 m (2 to 4 ft) long, longitudinal, free of packed boring dust, and each has a nuptial chamber. Gallery patterns vary. Commonly, several egg galleries run nearly parallel, bending to connect at various points (Figs. 13h, 18a). Nuptial chambers may be present at these junctions. Sometimes the egg galleries are straight and unconnected, and difficult to distinguish from Jeffrey or mountain pine beetle galleries except by the absence of packed boring dust and presence of nuptial chambers (Fig 18b). Pupal cells at the ends of the larval galleries are oval and conspicuous. Adult beetles are less than 6 mm (1/4 in) long, dark brown, cylindrical and shiny, with a "dished-out" concavity at the rear end that is surrounded on either side by 3 or 4 spines (Fig. 11l).

Agents Producing Similar Symptoms and Signs: The gallery pattern of the emarginate ips is easily confused with those of the mountain pine beetle and Jeffrey pine beetle and may occur intermingled with their galleries. Presence of a nuptial chamber, sharp bends and connections, and the absence of packed boring dust in the egg gallery are distinguishing features.

Severity: Emarginate ips is usually secondary. Although it sometimes acts alone as a tree killer, it most frequently is found in association with mountain pine beetle, western pine beetle, and Jeffrey pine beetle.

References: General

- *Long, longitudinal gallery patterns on tree bole with:*
  - *-nuptial chambers*
  - *-abrupt bends and connections*
  - *-no packed frass*
- *Yellow-red boring dust in bark crevices.*

Figure 18a—Typical pattern of emarginate ips galleries showing parallel galleries that bend to connect at various points and conspicuous oval pupal cells.

Figure 18b—Emarginate ips galleries often look very similar to those of mountain and Jeffrey pine beetles, but lack packed boring dust and have sharp bends.

FIR ENGRAVER

Scolytus ventralis LeConte

Hosts: Primarily grand fir, white fir, and Shasta red fir, occasionally subalpine fir and other *Abies* species.

Distribution and Damage: Fir engraver is found throughout Oregon and Washington. Adult beetles attack standing green trees pole-sized and larger, causing mortality, topkill, and branch flagging. Some trees may survive repeated "patch" attacks for many years (Fig. 19a). The fir engraver also colonizes freshly cut logs and recent windthrows.

Identification: The egg gallery pattern is transverse and branches outward in opposite directions from a central notch, or nuptial chamber (Figs. 13f, 19b). It deeply scores the sapwood for a distance of 10 to 30 cm (4 to 12 in), and often remains visible on the tree for many years following death. Larval galleries run up and down the bole at right angles to the egg gallery. Red-brown boring dust on the bole marks new attack sites during summer months. Dying firs fade yellow green to orange (Fig. 11h), eventually turning dark red to maroon. Adult beetles are shiny, black, and about 3 mm (1/8 in) long (Fig. 11d). The posterior end of the adult's abdomen has a "sawed-off" appearance when viewed from the side (Fig. 11l). A multitude of buckshot-sized emergence holes is sometimes apparent on the bark of trees killed by the fir engraver (Fig. 19c).

Agents Producing Similar Symptoms and Signs: Root diseases, silver fir beetles, and western balsam bark beetle can be confused with fir engraver. The fir engraver's distinctive transverse egg gallery pattern, longer gallery length, and unique adult shape distinguish it from associates.

Severity: Fir engraver activity is strongly associated with root disease, drought, and defoliation. Fir engraver epidemics often occur during and following periods of protracted drought. During outbreaks, significant mortality may occur over large areas.

References: 25

- *Transverse egg gallery pattern with central notch.*
- *Galleries occur on tree bole and large branches.*
- *Look for root disease!*

Figure 19a—Dead portion of tree bole caused by fir engraver "patch" attack. Egg galleries are still visible on old dead wood.

Figure 19b—Transverse egg gallery pattern of the fir engraver.

Figure 19c—"Buckshot" exit holes in grand fir bark made by emerging fir engraver adults.

IPS in SMALL-DIAMETER PINE STEMS

CALIFORNIA FIVESPINED IPS *Ips paraconfusus* Lanier
PINE ENGRAVER *Ips pini* (Say)

Hosts: Most commonly found in ponderosa, lodgepole, and Jeffrey pines, but may occur in almost any species of pine.

Distribution and Damage: *I. pini* occurs throughout Oregon and Washington, but is most common east of the Cascade Mountains crest. *I. paraconfusus* is found in western Oregon, southwestern Washington, and the Columbia River Gorge. Both species commonly attack pine slash of any diameter, and kill small trees 5 to 20 cm (2 to 8 in) in diameter and the tops of larger trees. During outbreaks, larger trees may be killed.

Identification: Typical mortality scenarios include: 1) grouped mortality of small trees in the vicinity of fresh windfall or logging slash (Fig. 20a), and 2) large trees with the upper 1/2 to 1/3 of the crown killed (Fig. 20b). Reddish-orange boring dust in small mounds around entrance holes, in bark crevices, and on the ground around infested trees indicates attack (Fig. 20c). Both species have at least 2 generations each year. Foliage begins fading within a few weeks after successful attacks.

Egg galleries are free of tightly packed frass and usually longitudinal, extending for 13 to 25 cm (5 to 10 in). The typical gallery pattern of California fivespined ips resembles an inverted '"Y" with an enlarged nuptial chamber at the center (Fig. 20d), while the gallery of the pine engraver is more variable, appearing as Y-, H-, or star-shaped with a centrally located nuptial chamber (Figs. 13i, 20e). Larval galleries extend laterally 2.5 to 5.0 cm (1 to 2 in) from the egg galleries and are packed with frass. Also present may be mazelike feeding galleries lightly etched onto the sapwood surface, produced when masses of adults infest living trees during late summer and mine extensively without producing brood. Adult beetles are cylindrical, dark reddish brown to black, and about 4 mm (1/8 to 3/16 in) long. A dish-shaped depression with four (*I. pini*) or five (*I. paraconfusus*) spines along each side is located on the posterior end of the wing covers (Fig. 11l).

Agents Producing Similar Symptoms and Signs: Mortality caused by root diseases or other bark beetles and topkill caused by comandra blister rust, dwarf mistletoe, or animal damage may be confused with *I. pini* and *I. paraconfusus*. *Ips* beetles are distinguished by their gallery patterns, distinct adult body shape, and by the rapid nature of the tree mortality and top dieback that they cause.

Severity: Fresh pine slash, windfalls, and trees weakened by wildfire or drought are frequently attacked. Populations may increase rapidly in fresh down material during spring and early summer and then attack standing trees. Outbreaks seldom extend beyond the current season but may last longer when consecutive years of drought, damaging storms, or wildfires occur. During prolonged *I. paraconfusus* outbreaks, large trees may be killed by the successive crown attacks of multiple generations. Western pine beetle frequently attacks and kills ponderosa pines recently topkilled by *I. paraconfusus*.

References: 51, 78

Figure 20a—Pine engraver and California fivespined ips outbreaks are commonly associated with freshly cut slash. Note grouped mortality of small trees in background.

- *Y-, H-, or star-shaped gallery pattern.*
- *Galleries occur on boles of small trees and tops and limbs of larger trees.*
- *Dead patches of small trees adjacent to freshly cut slash or windfalls.*
- *Larger trees with dead upper crowns.*

Figure 20c—Down log with boring dust from pine engraver attacks.

Figures 20d and e—Inverted Y-shaped (left) *Ips paraconfusus* and H-shaped (right) *Ips pini* galleries. Pine engraver and California fivespined ips galleries are characterized by a central nuptial chamber and usually 3 to 5 (*I. pini*) or 3 (*I. paraconfusus*) branches.

Figure 20b—Ponderosa pine topkill caused by pine engraver.

JEFFREY PINE BEETLE

Dendroctonus jeffreyi Hopkins

Hosts: Jeffrey pine.

Distribution and Damage: Jeffrey pine beetle is found in southwestern Oregon. It causes tree mortality, preferring trees 30.5 cm (12 in) or more in diameter, and almost never infests trees less than 10 cm (4 in) dbh. *D. jeffreyi* frequently attacks trees previously infested by California flatheaded borer, *Melanophila californica* or pine engraver, *Ips pini*.

Identification: Jeffrey pine beetle often kills trees in groups. Pitch tubes, gallery pattern, and insect appearance and behavior are nearly identical to those of mountain pine beetle. Egg galleries are long, longitudinal, and straight to slightly sinuous (Figs. 13g, 21). They often have a noticeable J-shaped crook at the bottom that is more pronounced than that caused by mountain pine beetle. The galleries slightly etch both inner bark and sapwood surfaces. They are packed tightly with frass, and may extend upward for 76 cm (30 in) or more. Larvae are present in the galleries during fall and winter. Most pupate in late spring and adults emerge in midsummer to attack new trees. Mature adults are black with rounded posteriors, and are about 5 mm (3/16 in) long. Infested trees fade within a year from yellow green to red brown. Woodpeckers feeding on larvae often flake off pieces of bark all the way to the inner wood. Host identification in combination with gallery pattern is the best way to identify the Jeffrey pine beetle.

Agents Producing Similar Symptoms and Signs: Emarginate ips, root diseases, and other secondary bark beetles may be confused with Jeffrey pine beetle. Pitch tube presence, color, and size, and gallery pattern are distinguishing features.

Severity: Jeffrey pine beetle breeds in scattered lightning-struck, diseased, recently windthrown, and other slow-growing, low vigor trees when populations are low. It does not breed in down trees or slash. It is often associated with trees having high severity dwarf mistletoe infections in the Siskiyou Mountains. During outbreaks, apparently healthy trees are often killed in groups of up to 20 or 30 individuals.

References: 80

- *Conspicuous pitch tubes.*
- *Long, straight, longitudinal egg galleries on Jeffrey pine bole.*

Figure 21—Jeffrey pine beetle galleries look almost identical to those of the mountain pine beetle; however, they are found only on Jeffrey pine.

MOUNTAIN PINE BEETLE

Dendroctonus ponderosae Hopkins

Hosts: All native and introduced species of pines.

Distribution and Damage: Mountain pine beetle causes tree mortality throughout Oregon and Washington. Strip attacks may also occur. Trees less than 10 cm (4 in) dbh are seldom attacked.

Identification: Mountain pine beetle often kills trees in groups. The most obvious indication of attack is the occurrence of cream-colored to reddish pitch tubes about 25 mm (1 in) in diameter on the attacked tree's bole (Figs. 22a, c, d). However, severely stressed trees may not produce enough pitch for "classic" pitch tube formation. In such cases, small spots of pitch or a complete absence of pitch may characterize the attack. Orange-red boring dust on bark and around the base of infested trees may also indicate attack.

Egg galleries are long, longitudinal, and straight to slightly sinuous, with a slight crook or "J" at the basal end (Figs. 13g, 22b). They are packed tightly with frass, and may extend upward for 76 cm (30 in) or more. The galleries slightly etch both inner bark and sapwood surfaces. In white pine and sugar pine, egg galleries tend to be more winding, to the point of being broadly "S-shaped" (Fig. 22e). Larvae are present in the galleries during fall and winter. Most individuals pupate in late spring and adults emerge in midsummer to attack new trees. Mature adults are black with rounded posteriors, and are about 5 mm (3/16 in) long. Infested trees turn yellowish green, fading within a year to straw yellow or reddish brown (Fig. 22f). Woodpeckers feeding on larvae often flake off pieces of bark all the way to the inner wood.

Agents Producing Similar Symptoms and Signs: Western pine beetle on ponderosa pine, root diseases, emarginate ips, and other secondary bark beetles may be confused with mountain pine beetle. Presence, color, and size of pitch tubes, as well as gallery pattern distinguish the mountain pine beetle.

Severity: When population levels are low, the mountain pine beetle tends to attack injured, diseased, and low vigor trees. Populations do not build up in slash. During outbreaks, the mountain pine beetle attacks apparently healthy trees and can cause extensive tree mortality over large geographical areas. Stand susceptibility to mountain pine beetle is strongly correlated with high stocking levels and tree age.

References: 33

- *Conspicuous pitch tubes.*
- *Long, straight, longitudinal egg galleries on pine bole.*

Figure 22a—Pitch tubes on bole of lodgepole pine caused by mountain pine beetle.

Figure 22b—Mountain pine beetle galleries are typically long and straight, each with a slight crook at the basal end.

Figure 22c—Pitch tubes that are creamy to pink in color usually indicate successful attack.

Figure 22d—Clear to white pitch tubes often indicate unsuccessful attack. Note posterior of pitched-out beetle on pitch tube surface.

Figure 22e—Broadly "S–shaped" egg galleries often occur on sugar pine and western white pine.

Figure 22f—Ponderosa pine fading in color following successful current-year attack by mountain pine beetle *(photo taken in October).*

RED TURPENTINE BEETLE

Dendroctonus valens LeConte

Hosts: All pine species, infrequently other conifers.

Distribution and Damage: Red turpentine beetle is found throughout Oregon and Washington. This beetle seldom kills trees because the number of attacks is usually insufficient to cause mortality, however, it does weaken trees and occasionally acts alone as a mortality agent. Frequently associated with fire injury and mechanical injury caused by partial cutting, road building, or construction, red turpentine beetle also is common on root-diseased trees and freshly cut stumps.

Identification: Attacks usually occur in the basal 1 to 2 m (3 to 6 ft) of the bole. Two types of pitch tubes are characteristic: 1) very large, 5 to 8 cm (2 to 3 in) across, pinkish, amorphous masses of resin and frass (Fig. 23a), and 2) small, less than 13 mm (1/2 in) across, dark red-brown tubes that are granular-looking and resinous (Fig. 23b). Egg galleries are short and longitudinal, about 13 mm (1/2 in) wide, irregular in shape, packed with a reddish, pitchy frass, and may extend below the ground line (Figs. 13k, 23c). Larvae feed gregariously, producing large cavities adjacent to the egg gallery. Unlike other western bark beetle species, red turpentine beetles construct no individual larval galleries. Adults are a distinctive reddish-brown color, have rounded posteriors, and are the largest beetles in the genus *Dendroctonus,* averaging nearly 10 mm (3/8 in) in length (Fig. 23d).

Agents Producing Similar Symptoms and Signs: Other bark beetles on pine that produce pitch tubes, and pitch moths may be confused with red turpentine beetle. Pitch tube size, appearance, and location on the lower bole; gallery pattern; and size of beetle are distinguishing characteristics.

Severity: Red turpentine beetles typically attack injured, weakened, or dying trees. Ordinarily they are not very aggressive and do not become epidemic. At times they weaken trees enough to predispose them to fatal attack by other bark beetles. During periods of drought, or through repeated attacks, these beetles sometimes kill scattered individual trees.

References: 65

- *Pitch tubes concentrated on the basal 1 to 2 m (3 to 6 ft) of tree bole.*
- *Large resinous pitch masses OR small, granular, resin-soaked pitch tubes.*
- *Short, wide, irregular galleries with adjacent larval feeding chamber.*

Figure 23a—Pitch tubes of the red turpentine beetle usually occur near the base of the tree. Note characteristic large size of pitch tubes.

Figure 23b—The red turpentine beetle sometimes creates small, resinous, granular pitch tubes.

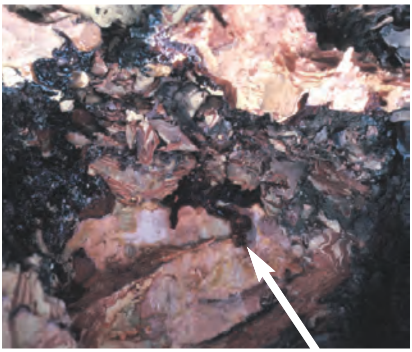


Figure 23c—Red turpentine beetle galleries are short, irregularly shaped, and packed with reddish, pitchy frass.

Figure 23d—Adults of the red turpentine beetle are reddish brown and have rounded posteriors.

SILVER FIR BEETLES

SILVER FIR BEETLE *Pseudohylesinus sericeus* (Mannerheim)
FIR ROOT BARK BEETLE *Pseudohylesinus granulatus* (LeConte)

Hosts: Pacific silver fir is the only host species that has been affected by a serious outbreak of silver fir beetle and fir root bark beetle; both beetles also have been recorded on grand fir, Douglas-fir, and western hemlock. In addition, the silver fir beetle is found on subalpine fir, Shasta red fir, and Sitka spruce, and the fir root bark beetle on ponderosa pine.

Distribution and Damage: Silver fir beetles are found throughout Oregon and Washington. They usually attack windthrown, felled, diseased, injured, and severely suppressed trees, causing mortality. More than one year of recurrent attacks is commonly required for a mature tree to be killed. The broods often develop in a patchlike fashion, killing the cambium in localized areas but not extensively enough to girdle the tree in a single season. Occasionally silver fir beetle will kill patches of Pacific silver fir several acres in size (Fig. 24a). Crowns of dying trees may become yellow in July and red by August, or the needles may drop off without appreciably changing color.

Identification: Reddish boring dust may be evident around the base of attacked trees in May and August. Adult beetles make two types of galleries. In the fall, new adults of both species emerge and tunnel into tree boles near their bases, constructing short, irregular feeding galleries in which the beetles hibernate but do not lay eggs. In spring and again in late summer, overwintered adults emerge and initiate construction of galleries in which they lay eggs. Egg galleries of both species are transverse, and range from 1 to 13 cm (1/2 to 5 in) long (Figs. 13e, 24b, c). *P. sericeus* galleries may be unbranched or two-branched, and may or may not have a well-defined nuptial chamber. Larvae mine at right angles to the egg gallery. In mature trees, each species tends to attack a different portion. The fir root bark beetle prefers the thicker bark found in the basal portion of the tree, invading from a few inches below the ground line to a height of about 4.5 m (15 ft). The silver fir beetle may be found all along the bole but occurs most frequently in the thinner-barked portions of the upper bole and branches. Adults of both species have rounded posteriors and look quite similar, differing mainly in size (Fig. 24d). The fir root bark beetle is about 6 mm (1/4 in) long, while the silver fir beetle is only about 3 mm (1/8 in) long. New adults of both species are mottled with brown and white scales that later rub off, leaving the beetles with shiny, dark, reddish-brown to black surfaces.

Agents Producing Similar Symptoms and Signs: Root diseases, fir engraver, western balsam bark beetle, and other secondary bark beetles can be confused with silver fir beetles, which are distinguished by their gallery patterns. Silver fir beetle galleries look quite similar to those of the fir engraver, but tend to be shorter and more variable.

Severity: Normally silver fir beetles are secondary, and commonly associated with root diseases. In the 1950's, both beetle species simultaneously became epidemic, acting together on Pacific silver fir and killing large numbers of trees.

References: 6

- *Short, somewhat variable, transverse egg gallery patterns.*
- *Galleries occur on tree bole and large branches.*

Figure 24a—Patch of Pacific silver fir killed by silver fir beetles.

Figure 24b—Galleries of the silver fir beetle. Note transverse egg gallery.

Figure 24c—Fir root bark beetle galleries.

Figure 24d—Adult fir root bark beetle (left) and silver fir beetle (right).

SPRUCE BEETLE

Dendroctonus rufipennis (Kirby)

Hosts: Engelmann spruce, Sitka spruce, Brewer spruce.

Distribution and Damage: The spruce beetle is found throughout Oregon and Washington. It causes tree mortality, most commonly in areas east of the Cascade Mountains crest. Strip attacks may also occur. Except during outbreaks, trees smaller than 30.5 cm (12 in) dbh are infrequently attacked.

Identification: Look for red-brown boring dust on bark, in bark crevices, and around the tree base (Fig. 25a). Sometimes, reddish pitch tubes are formed. Occasionally, resin may stream from the entrance holes of unsuccessful attacks (Fig. 11g). Infested green trees often drop up to 30 percent of their older needles during the spring following the summer of attack (Fig. 25b). Woodpeckers feeding on larvae often flake off pieces of bark from the tree bole (Fig. 11i). The egg gallery is longitudinal with a slight crook at the basal end, filled with frass, and averages about 13 cm (5 in) long (Figs. 13l, 25c). Larval galleries are grouped on alternating sides of the egg gallery. They meander somewhat randomly, frequently crossing one another and converging into common feeding areas. At their bases, widened chambers where the newly hatched larvae fed gregariously are evident alongside the egg gallery. Gallery patterns often are more evident on the bark underside than the sapwood surface. Adult beetles are dark brown to black with reddish elytra, measuring about 6 mm (1/4 in) long. This insect has a 2-year life cycle with larvae developing in the galleries for two summers.

Agents Producing Similar Symptoms and Signs: Secondary bark beetles and wood borers may also produce boring dust on spruce trees. Gallery patterns distinguish the spruce beetle.

Severity: Spruce beetles are normally present in small numbers in weakened or windthrown host trees, fresh stumps, and large pieces of slash. West of the Cascade Mountains crest, mortality caused by this beetle appears to be very limited. East of the Cascade Mountains crest, epidemics may develop following windthrow events or during periods of drought. During outbreaks, standing trees of all ages and diameters except for seedlings and small saplings may be attacked. The larger diameter trees are preferred. Outbreaks may continue for several years until most of the large spruce trees in the outbreak area are killed (Fig. 25d).

References: 48

- *Red-brown boring dust, green needle drop, woodpecker activity.*
- *Longitudinal egg gallery on spruce bole, most clearly seen on inner bark.*
- *Larval galleries criss-cross and randomly converge into common feeding areas.*

Figure 25a—Red-brown boring dust at the base of a spruce attacked by spruce beetle.

Figure 25b—Green needle drop caused by spruce beetle.

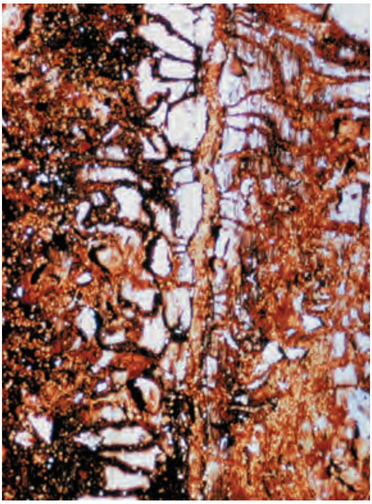


Figure 25c—Spruce beetle gallery showing alternate-sided grouping of larval galleries and areas of gregarious larval feeding.

Figure 25d—Outbreaks of the spruce beetle can result in widespread mortality of large spruce trees.

WESTERN BALSAM BARK BEETLE

Dryocoetes confusus Swaine

Hosts: Subalpine fir is the principal host; occasionally found in other true firs, Engelmann spruce, and lodgepole pine.

Distribution and Damage: Western balsam bark beetle is found throughout Oregon and Washington. Attacks result in branch flagging, top killing, and tree mortality (Fig. 26a). More than half of the mortality caused by this beetle is believed to result from a lesion-causing fungus, *Ceratocystis dryocoetidis,* carried on the beetle. Initial beetle attacks, though often pitched out by the tree, may successfully introduce the fungus. Establishment of *C. dryocoetidis* in the phloem facilitates subsequent beetle attacks. Trees may die without further beetle activity when coalescing lesions caused by the fungus girdle the tree bole.

Identification: Recent western balsam bark beetle attacks are difficult to detect using external indicators. Boring dust and entrance holes on the lower boles of standing trees may be evident in August, although field observations indicate that the majority of attacks often occur above 2 m (6 ft). Abundant pitch flow is usually considered an indication that attacking beetles were pitched out. Fir foliage changes from green to brick red during the year following a successful beetle attack. This red foliage may be retained for up to five years. The gallery pattern consists of a central nuptial chamber with several curving egg galleries radiating outward in a random, starfishlike pattern (Figs. 13m, 26b, c). Total diameter of the "starfish" pattern is approximately 7.5 to 10 cm (3 to 4 in), with individul egg galleries ranging in length from 3.8 to 7.5 cm (1-1/2 to 3 in), and having widths of about 2 mm (1/16 in). Adults range from 3 to 5 mm (1/8 to 3/16 in) long, with dark brown, shiny bodies. The western balsam bark beetle's posterior is slightly flattened instead of being evenly rounded, and has no spines. The front of the female beetle's head is densely covered with a brush of short, reddish-yellow hairs; the front of the male's head is sparsely covered with longer, reddish-yellow hairs.

Agents Producing Similar Symptoms and Signs: Root diseases, fir engraver, silver fir beetle, and some secondary bark beetles that also form radiating gallery patterns may be confused with western balsam bark beetle. The size and radiating pattern of the gallery made by this beetle is diagnostic.

Severity: Western balsam bark beetle frequently occurs in association with drought, winter injury, and a complex of other organisms including the fungus *C. dryocoetidis,* balsam woolly adelgid (Fig. 26d), root diseases, defoliators, and other bark beetles. Trees may be repeatedly strip attacked and die slowly over a period of several years, or quickly killed in one season. Though only a small percentage of a stand is attacked during normal years, in some areas high beetle populations may persist for many years until most of the older subalpine firs are dead.

References: 57

- *"Starfish" gallery pattern.*
- *Galleries occur on tree bole and large branches.*
- *Look for root disease!*

Figure 26a—Subalpine fir killed by the western balsam bark beetle.

Figure 26b—The gallery pattern of the western balsam bark beetle looks like a starfish.

Figure 26c—Old western balsam bark beetle galleries on a subalpine fir snag.

Figure 26d—The abnormal crown shape of this dead subalpine fir indicates that this tree was infested by balsam woolly adelgid before being successfully attacked by the western balsam bark beetle.

WESTERN PINE BEETLE

Dendroctonus brevicomis LeConte

Hosts: Ponderosa pine.

Distribution and Damage: Western pine beetle is found throughout Oregon and Washington. It causes tree mortality, usually preferring large diameter trees, but may attack trees as small as 15 cm (6 in) dbh.

Identification: Reddish boring dust on the bark and around the base of the tree indicates recent attack. Small, inconspicuous, reddish pitch tubes less than 1 cm (about 1/2 in) wide may or may not be present (Fig. 27a). Initial attacks on standing trees occur at midbole and subsequent attacks fill in above and below. Woodpecker activity is strongly associated with western pine beetle infestation; look for lighter areas on the tree bole where bark is “shaved,” (Fig. 27b), and for pieces of bark accumulated on the ground around the tree base. Generally, woodpeckers feeding on western pine beetle do not penetrate the bark all the way to the sapwood like they do when feeding on other pine beetle species, because western pine beetle larvae tunnel away from the cambium when quite small, completing most of their development in the outer bark. The frass-packed egg galleries of western pine beetle are long, and wind both laterally and longitudinally as they cross and recross in a spaghetti-like pattern (Figs. 13i, 27c). Larval galleries radiate away from the egg gallery for a short distance, and then appear to stop abruptly at the point where larvae tunnel outward into the corky outer bark. Gallery patterns often are more evident on the bark underside than the sapwood surface. Adults are dark brown to black and about 6 mm (1/4 in) long, with rounded posteriors.

Agents Producing Similar Symptoms and Signs: Mountain pine beetle, *Ips* spp. or other secondary bark beetles, and root diseases may be confused with western pine beetle. The serpentine egg gallery pattern is diagnostic.

Severity: Western pine beetle populations usually fluctuate at low levels, breeding in declining mature, windthrown, diseased, or otherwise weakened trees. During periods of extended drought, however, populations may increase rapidly, become aggressive, and kill apparently vigorous host trees over large areas. Outbreaks are most commonly associated with large old growth and overcrowded second growth stands. At least two generations occur annually in most of Oregon and Washington.

References: 12, 60

- *Reddish boring dust.*
- *Small, inconspicuous pitch tubes.*
- *Spaghetti-like, winding egg gallery pattern.*
- *Galleries occur on ponderosa pine bole, more clearly seen on inner bark.*

Figure 27a—Western pine beetle pitch tubes are small and inconspicuous.

Figure 27b—Woodpeckers frequently "shave" off large patches of outer bark on trees colonized by the western pine beetle.

Figure 27c—Serpentine egg gallery pattern of the western pine beetle, most clearly seen on the inner bark. Note short larval gallery patterns.

FLATHEADED WOOD BORERS (METALLIC WOOD BORERS)

Many species, Family Buprestidae

Hosts: All conifers are hosts of one or more flatheaded wood borer species.

Distribution and Damage: Various species of flatheaded wood borers are found throughout Oregon and Washington. Larvae make extensive galleries under the bark that may also continue into the sapwood or heartwood. They contribute to mortality of trees weakened from other causes and create defect in solid wood products sawn from infested trees and logs.

Identification: Flatheaded wood borers commonly occur in dead and dying sapling-size and larger trees and cut logs. Reddish boring dust is sometimes present in bark crevices. Larval galleries are irregular, long, and randomly sinuous, often gradually increasing in width, and are tightly packed with fine boring material (Figs. 13n, 28a). This boring dust is often packed in concentric crescents like the ridges on a fingertip (Fig. 28b). There are no associated egg galleries, because adults lay their eggs on the outer bark surface or in bark or wood crevices without boring into the tree. The larval stage may last from nearly 1 to 4 or more years. Larvae range in size up to about 32 mm (1-1/4 in) long. They are cream-colored, legless, flattened, and typically shaped like horseshoe nails (Fig. 28b), with a distinctly enlarged head region and long slender abdomen. Emerging adults leave oval exit holes. Adults are flattened, somewhat torpedo shaped, and often brightly colored metallic beetles (Fig. 28c, Table 2). Their antennae are much shorter than their body lengths.

Agents Producing Similar Symptoms and Signs: The larvae of roundheaded borers, horntails, some weevils, and bark beetles often occupy the same habitats as flatheaded wood borer larvae and may appear quite similar. As flatheaded wood borer larvae develop, their body size, shape, boring material characteristics, and gallery patterns distinguish them from other bark-and-wood-inhabiting insects.

Severity: Flatheaded wood borers are generally secondary. Most species are non-aggressive, attacking only dead and dying trees. They are frequently found in trees infested or killed by bark beetles or root disease. Like roundheaded wood borers and horntails, they are especially abundant in recently burned areas, and play important roles in cycling woody material back to the soil and as a woodpecker food resource. However, some species can cause significant tree mortality or damage (Table 2). In southwestern Oregon, and during droughty periods in the Willamette Valley, the flatheaded fir borer behaves very aggressively, attacking and killing Douglas-firs and true firs on drier sites such as valley fringe areas that were historically occupied by oaks (Fig. 28d). Additionally, several species, including the golden buprestid and western cedar borer, cause important economic damage in trees and logs destined for poles and other sound wood products.

References: 17, 18, 89

- *Long, randomly winding galleries that gradually increase in width.*
- *Gallery branches same width as main gallery.*
- *Galleries tightly packed with fine, rounded boring material.*

Figure 28a—A maze of flatheaded wood borer galleries nearly obscures the western pine beetle galleries on the inner bark of this ponderosa pine.

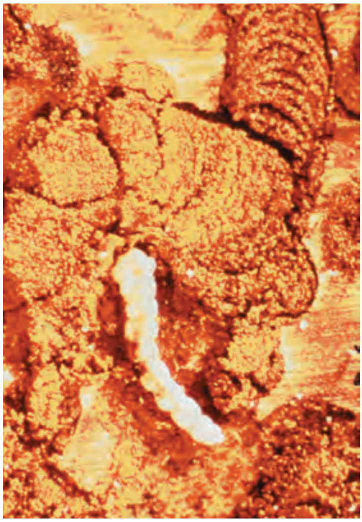


Figure 28b—Characteristic flatheaded wood borer larva and winding larval gallery of tightly packed fine boring material.

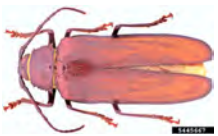
Figure 28c—Typical adult buprestid. Note antennae shorter than body and overall torpedo shape.

Figure 28d—Low elevation, dry site Douglas-fir mortality caused by flatheaded fir borer in southwestern Oregon.

Table 2—Important Buprestidae found on conifers in Oregon and Washington.

Common Name Genus, species	Host	Life Cycle and Damage	Adult Beetle Description	Damage Severity
Golden buprestid *Buprestus aurulenta* 	Primarily Douglas-fir and ponderosa pine, also spruces and true firs	Flat masses of eggs are laid in fire-injured or mechanically injured trees and on exposed lumber in lumberyards or structures. Larvae mine throughout the wood until pupation, damaging wood used for construction. Life cycle takes several years in the forest, up to 50 years in buildings. New adults cut large exit holes through the wood surface when they emerge.	Iridescent green or blue green with copper margins on the wing covers and a coppery underside; 12 to 20 mm (1/2 to 3/4 in) long.	Not usually associated with tree mortality. Larval mining causes defect in structural lumber and emerging adults damage finished wood surfaces in buildings.
Flatheaded fir borer *Phaenops drummondi* 	Douglas-fir, true firs, western hemlock, spruces, western larch	Larvae bore in the inner bark, girdling and killing the tree. Life cycle normally takes one year, but can last up to four years.	Bronze-black with usually 3 small yellow spots on each wing cover; wing covers sometimes have three ridges; about 11 to 19 mm (7/16 to 3/4 in) long.	Sometimes aggressively attacks and kills Douglas-fir and true firs on drier sites in southwestern Oregon and Oregon's Willamette Valley, especially during droughty periods.
Western cedar borer *Trachykele blondeli* 	Primarily western redcedar, also junipers, *Cupressus* spp., and possibly incense-cedar	Pupation occurs in the fall and adults emerge the following spring to lay eggs under bark scales on branches of living trees. Larvae bore from branches to the bole where they mine primarily in the heartwood. Life cycle takes two or more years.	Bright emerald green with a golden sheen and several dark spots; 11 to 17 mm (7/16 to 11/16 in) long.	Not associated with tree mortality, but may cause severe degrade and cull in trees cut for shingles, poles, and other sound wood products.

Table 3—Important Cerambycidae found on conifers in Oregon and Washington.

Common Name Genus, species	Host	Life Cycle and Damage	Adult Beetle Description	Damage Severity
Oregon fir sawyer *Monochamus scutellatus oregonensis* 	Douglas-fir, pines, spruces and true firs	Larvae mine though the wood until pupation, damaging wood used for construction. Life cycle takes one year.	Shiny black with a distinct white spot between the wing covers at their base, may have scattered patches of faded white on the elytra; 18 to 27 mm (3/4 to 1-1/4 in) long.	Not usually associated with tree mortality. Larvae mine in injured, dying, fire-scorched, and recently felled trees, sometimes causing serious degrade of wood for sound wood products.
Ponderosa pine bark borer *Acanthocinus princeps* 	Ponderosa pine	Large white larvae feed on inner bark of injured and recently killed trees, pupating in nestlike cells between the bark and wood. Life cycle takes one year.	Gray and black striped; stripes slightly v-shaped with feathered edges. Antennae very long and striped gray and black, with tufts of hair at the lower joints; About 14 to 24 mm (1/2 to 1 in) long.	Commonly found in trees killed by the western pine beetle.
Ponderous borer *Trichocnemis spiculatus* 	Primarily Douglas-fir and ponderosa pine	Adults lay eggs in the bark crevices of dead trees and stumps. Thick-bodied larvae grow to a huge size (60 to 70 mm, or 2-3/8 to 2-3/4 in long) as they bore in the sapwood and heartwood. Life cycle takes several years. Modern chain saw inspired by their mandibles and boring action.	Uniformly reddish brown; antennae generally shorter than body; very large; 42 to 65 mm (1-5/8 to 2-1/2 in) long.	Commonly found mining at the bases of pines killed by the western pine beetle, causing them to fall more quickly. Boring speeds wood deterioration and causes degrade of wood cut for sound wood products.

ROUNDHEADED WOOD BORERS (LONGHORNED BEETLES)

Many species, Family Cerambycidae

Hosts: All conifers are hosts of one or more roundheaded wood borer species.

Distribution and Damage: Roundheaded wood borers are found throughout Oregon and Washington. Larval mining creates long, meandering galleries under the bark that may extend into the sapwood or heartwood. They contribute to mortality of trees weakened by other causes, and cause defects that severely degrade solid wood products sawn from infested trees and logs.

Identification: Roundheaded wood borers commonly occur in dead and dying sapling size and larger trees and cut logs. Larval galleries are irregular, long, and randomly sinuous, often gradually increasing in width (Fig. 13n), and are loosely packed with coarse, angular boring material (Figs. 29a, b). No egg galleries are associated with wood borer galleries because the adults lay their eggs in bark crevices or in slits cut into the bark without boring into the tree. The larval stage may last from nearly 1 to 4 or more years. Larvae are cream-colored, lack noticeable legs, and can be cylindrical or flattened, slender or thick and robust, usually with the head region slightly wider than the rest of their bodies (Fig. 29c). Mature larvae can be very large, up to 38 mm (1-1/2 in) long. Emerging adults leave broadly oval to nearly circular, cleanly cut exit holes. Adult beetles vary greatly in size, but can be quite large, with many being over 25 mm (1 in) long. They sometimes are very colorful, and usually have antennae that are longer than their bodies (Figs. 29d, e; Table 3).

Agents Producing Similar Symptoms and Signs: The larvae of flatheaded wood borers, horntails, some weevils, and bark beetles often occupy the same habitats as roundheaded wood borer larvae and can have a similar appearance. As roundheaded wood borer larvae develop, their body size, shape, boring material, and gallery pattern distinguish them from other bark and wood inhabiting insects. Native Oregon fir sawyer adults are commonly mistaken for similar-appearing and rarely encountered, yet occasionally introduced immigrant species such as Asian longhorned borer or citrus longhorned borer. Oregon fir sawyers, however, have a distinct white spot in the middle of their back at the base of their elytra that is absent on the immigrant species (Fig. 29e, Table 3).

Severity: Most roundheaded wood borers are secondary agents. They breed in dead, dying, or severely stressed trees and are especially abundant in recently burned areas. They play important roles in cycling woody material back to the soil and as a woodpecker food resource. Although roundheaded wood borers sometimes contribute to tree mortality, none of our native species are considered to be major conifer pests. However, those that bore into sapwood and heartwood lower the economic value of trees and logs utilized for wood products.

References: 89, 92

- *Long, randomly winding galleries that gradually increase in width.*
- *Gallery branches same width as main gallery.*
- *Galleries loosely packed with coarse, angular boring material.*

Figure 29a—The winding larval galleries of roundheaded wood borers are filled with coarse, angular boring material.

Figure 29b—Close-up of splinterlike boring material and frass of a roundheaded wood borer.

Figure 29c—Roundheaded wood borer larva, *Trichocnemis spiculatus* (ponderous borer).

Figure 29d—The amethyst borer, *Semanotus amethystinus*, is frequently associated with topkill and mortality of drought-stressed cedars.

Figure 29e—Typical adult cerambycid characteristics are shown in this photo of a male Oregon fir sawyer. Note elongate body shape, and antennae longer than body.

Root Diseases

Root diseases commonly found in Oregon and Washington are caused by several species of fungi and one Oomycete. Some root disease pathogens are favored by conditions associated with low tree vigor. Others are able to cause infection regardless of tree vigor. Some are quite host specific, while others have large host lists. Susceptibility to root diseases may also vary with host age or with geographic location.

Root diseases are often difficult to detect because of the subtle nature of their effects. Trees tend to die slowly, especially when older. Mortality may occur in centers or pockets or as individual dead trees scattered through a stand.

Tree and Root Disease Interactions

The predominant mode of spread for most root disease pathogens occurs underground when the roots of susceptible uninfected trees directly contact infected roots of diseased trees. Spore spread, insect vectors, short distance growth of fungi through the soil, or movement of infection propagules in soil or water may be involved in some cases.

Root disease pathogens may kill the cambium, decay root wood, plug water conducting tissue, or cause some combination of these effects. Tree death may be a direct result of root disease infection or may occur when trees with decayed roots fall or are predisposed to bark beetle attack.

Many root diseases are considered to be diseases of the site; inoculum may remain viable in the wood of infected roots or in the soil for many years or even decades.

Patterns of Damage

Within a stand
Several stages of tree decline and death usually occur in root disease pockets (Figs. 30a-e). Older dead trees are often broken off at the stem or near groundline (Fig. 30c). Recent mortality is frequently mixed with trees exhibiting crown symptoms such as chlorosis, reduced growth, and presence of distress cone crops (Figs. 30k-o). Downed trees often occur in a “jackstraw” pattern (Figs. 30c, f). Large structural roots of downed trees may be partially or totally decayed leaving a “root ball” (Fig. 30g). Mortality may be associated with cut stumps (Fig. 30h) or be concentrated along roadsides and skid trails. Within pockets, brush species may be abundant and conifer regeneration may occur (Fig. 30a). The pattern of mortality may be “doughnutlike,” a slowly expanding circle with symptomatic trees at the margin of the pocket and the oldest mortality at the center or, more likely, the pattern may be “amoeboid,” with stages of mortality and infection relatively mixed in small pockets or lobes in the stand.

Scattered individual tree mortality is typical for some site and root disease combinations. Root disease of this nature often goes undetected because of its subtlety. Scattered mortality may also be found in combination with distinct pockets on some sites.

Some root disease conditions are recognized because of the absence of trees rather than obvious current mortality. The lack of adequate regeneration around stumps may result from root disease.

Root disease symptoms may not be visible until trees reach the age where their root systems are able to contact inoculum. It may take up to 15 years before root disease effects are visible in plantations. While stands remain young, root disease signatures may be limited to scattered mortality or relatively small non-stocked pockets associated with stumps or snags remaining from the previous stand (Fig. 30d).

Bark beetle activity is often an indicator of root disease since bark beetles infest disease-weakened trees preferentially. It is important to examine trees for indicators of root disease when investigating areas where bark beetles are or have been active.

Within a tree
Aboveground symptoms of root disease include decreased growth, crown deterioration, and chlorosis (yellowing) (Table 4, Figs. 30j-m). Needles fade in color from bright green to pale green to yellow to red.

Crowns of some small root-diseased trees or trees infested by bark beetles rapidly fade to reddish brown. Needles fade or are lost from infected trees over their entire crowns; the pattern of loss is usually from inside to outside and from bottom to top, but this may be quite subtle. Shortened terminal growth and smaller-than-normal needles often are symptoms of root disease. A sharp demarcation between dead and dying needles and bright healthy needles within a crown is not symptomatic of root diseases.

Many root diseased trees produce “stress” or “distress” cone crops (Figs. 30n, o). Cones may be produced earlier in the tree’s life than normal, generally are smaller, and have fewer viable seeds than otherwise healthy cones.

Another symptom of root disease may be production of excessive resin flow or “basal resinosis” in the lower portion of the stem and at the root collar (Fig. 30i). In certain species, brown leachate, a watery resin-flow that emerges from and soaks the bark, may be visible on stems (Fig. 32a).

Signs of Occurrence

On the tree
Root disease symptoms may be confused with those caused by local wind events, sucking or defoliating insects, nutrient deficiencies or other impacts to root systems. To determine if root diseases are involved in tree decline or death, roots and root collars of dead or declining trees should be examined for diagnostic stains, decays, or fruiting structures (Table 4). This may involve excavation of roots on several sides of a tree, removal of bark, and chopping into the root wood. Stumps may also need to be examined in the same manner. Timing may be critical. For some root diseases, important indicators may disappear within a few years after trees have died.

Distinguishing Root Disease Pathogens

Diagnostic features

While a few of the root diseases may be accurately identified by a single diagnostic feature, it is often necessary to use combinations of distinguishing features in order to make an accurate identification for others (Table 4). It is also possible to have more than one root disease present at a time on a given tree.

Host preferences

The host may also help identify the root disease pathogens. Several root diseases have wide host ranges while others are quite host specific (Table 5). For those with wide host ranges, the likelihood of identifying root disease pathogens is higher on moderately and severely damaged tree species than on those hosts that are seldom damaged. Host preference may also differ by locality.

Root Disease Severity Rating

During stand examinations and inventories, individual trees are often given a root disease severity rating based on diagnostic decay or tree reaction in combination with the presence or lack of crown symptoms (Fig. 30p). The following rating scale is used throughout the Pacific Northwest:

Root Disease Severity Rating

Severity 1: A live tree within 30 feet of known root disease.

Severity 2: A live tree with diagnostic decay or tree reaction without crown symptoms.

Severity 3: A live tree with diagnostic decay, other root disease indicators and a symptomatic crown OR a dead tree with diagnostic decay or root disease indicators.

Figure 30p—Root disease severity rating for individual trees.

References: 34, 37, 38, 42, 63, 71, 77, 84, 91

Figure 30a—Hardwood shrubs often fill in openings where root diseases have killed groups of conifers.

Figure 30c—Root disease centers frequently have substantial accumulations of down wood.

Figure 30d—Root disease mortality is usually not evident in plantations until trees are 10 to 20 years old.

Figure 30b—Several stages of tree decline and death, often in close proximity, are typical stand-level symptoms of root disease.

Figure 30e—Several stages of tree decline and death caused by root disease.

Figure 30f—Down wood in root disease pockets is usually oriented in a random or "jackstraw" pattern.

Figure 30g—All large roots of this tree have been decayed by a root pathogen resulting in formation of a "root ball."

Figure 30h—Stumps often serve as foci for root disease centers.

Figure 30i—Resin flow at the base of a tree (basal resinosis) is often a symptom of root disease.

Figure 30j and k—Yellow (chlorotic) foliage is a common root disease symptom.

Figure 30l and m—Foliage on root diseased trees may be sparse as well as chlorotic.

Figure 30n and o—"Stress" cones may be produced on young infected trees.

Table 4—Symptoms and signs of five important forest tree root diseases in Oregon and Washington.[1]

Symptoms and Signs	Laminated root rot	Armillaria root disease	Heterobasidion root disease	Black stain root disease	Port-Orford-cedar root disease
Reduced height growth	√	√	√	√	
Chlorotic foliage	√	√	√	√	√
Slow loss of foliage	√	√	√	√	
Distress cones	√	√	√	√	
Slow cone decline	√	√	√	√	
Rapid tree death[2]				√	√
Dead tree, no foliage loss[2]					√
Abundant basal resin flow		√		√	
Cinnamon stain in inner bark					√
Black stain in sapwood				√	
Roots rotted	√	√	√		
Windthrown live trees	√		√		
Insect galleries under bark	√	√	√	√	√
Fleshy golden yellow mushroom on tree base		√			

Table 4–Symptoms and signs of five important forest tree root diseases in Oregon and Washington (cont.).[1]

Symptoms and Signs	Laminated root rot	Armillaria root disease	Heterobasidion root disease	Black stain root disease	Port-Orford-cedar root disease
Thick mycelial fans		√			
Rhizomorphs		√			
Leathery conks			√		
Setal hyphae	√				
Ectotrophic mycelium	√				
Creamy leathery pustules on roots			√		
Laminated decay with pits and setal hypae	√				
Laminated decay with pits on one side of sheet			√		
Yellow stringy decay, papery when dry		√			
White stringy decay			√		

[1] Table modified after Hadfield et al. 1986.

[2] Young trees with root disease may die rapidly with foliage intact.

Table 5—Relative susceptibility of conifers in Oregon and Washington to damage by five common root diseases.[1]

Hosts	Laminated root rot	Armillaria root disease	Heterobasidion root disease	Black stain root disease	Port-Orford-cedar root disease
Douglas-fir Westside	1[2]	2[3]	3	1	4
Douglas-fir Eastside	1	1	3	3	4
Ponderosa pine	3	2	2	3	4
Jeffrey pine	3	2	2	3	4
Lodgepole pine	3	2	2	3	4
Knobcone pine	3	2	3	3	4
Western white pine	3	2	3	3	4
Sugar pine	3	2	3	3	4
Whitebark pine	3	3	3	4	4
Grand fir	1	1	1	4	4
White fir	1	1	1	4	4
Noble fir	2	2	2	4	4
Pacific silver fir	2	2	1	4	4
Subalpine fir	2	2	2	4	4
Shasta red fir	2	2	2	4	4
Western hemlock	2	2	2[4]	3	4
Mountain hemlock	1	2	1	3	4
Western larch	2	3	3	4	4

Table 5–Relative susceptibility of conifers in Oregon and Washington to damage by five common root diseases (cont).[1]

Hosts	Laminated root rot	Armillaria root disease	Heterobasidion root disease	Black stain root disease	Port-Orford-cedar root disease
Subalpine larch	3	3	3	4	4
Engelmann spruce	2	2	3	4	4
Sitka spruce	3	2	3	4	4
Brewer spruce	3	2	3	4	4
Western redcedar	4[5]	2	3	4	4
Incense-cedar	4	3	3	4	4
Port-Orford-cedar	4	3	3	4	1
Pacific yew	3	3	4	4	2

[1] Table modified after Hadfield et al. 1986.
[2] 1 = severely damaged
2 = moderately damaged
3 = seldom damaged
4 = not damaged
[3] Westside Douglas-fir is moderately damaged up to age 25 to 30, susceptibility then decreases.
[4] Western hemlock is not severely damaged until it exceeds 150-years-old.
[5] Western redcedar east of the Cascade Mountains may have butt rot caused by laminated root rot.

ARMILLARIA ROOT DISEASE

Pathogen: *Armillaria ostoyae* Romagn. Herink

Hosts: All conifers. Susceptibility and damage vary by location.

Distribution and Damage: *A. ostoyae* is found throughout Oregon and Washington. On highly susceptible hosts, the fungus causes severe root and butt decay, growth loss, and mortality. In general, grand fir, and white fir east of the Cascades are most susceptible. They are readily infected and killed. In northwestern Washington, Douglas-fir is readily killed. In southcentral Washington, ponderosa pine is often infected and can be severely impacted. In Oregon west of the Cascades Mountains crest, the disease is most common in Douglas-fir plantations less than 30 years old or where conditions occur that stress individual trees such as poor planting, planting of off-site stock, soil displacement, or soil compaction. White fir and Shasta red fir on compacted soils or in previously salvaged areas, and off-site ponderosa pine are readily killed in southwestern Oregon. In general, western larch, incense-cedar, Alaska yellow-cedar and Port-Orford-cedar are resistant. In local situations, other species or species combinations may be affected. This disease needs to be evaluated on a site by site basis since the host preference and virulence may differ significantly in nearby areas. Bark beetles often attack *A. ostoyae*-infected trees.

Identification: Aboveground symptoms of Armillaria root disease are typical of those for all root diseases. Heavy resin flow and soaking at the base of trees is commonly associated with this disease (Figs. 30i, 31a). White mycelial sheets, often shaped like fans, form between the wood and bark and take the place of the cambium of lower stems and roots (Figs. 31b, c). Fans are thick and peel away from wood or inner bark like “latex paint” (Fig. 31d). Fans often leave an impression on the bark after they disintegrate (Fig. 31e). Incipient decay is water-soaked wood with small straw-colored flecks; advanced decay is a wet, yellow, stringy rot (Fig. 31f). Rhizomorphs, black to reddish-brown shoestrings of fungal mycelia, form on roots and under bark. Golden-brown “honey-colored” mushrooms may be produced at the base of infected trees and stumps in late summer and fall (Fig. 31g).

Caution: Other species of *Armillaria* occur as saprophytes and are often found on stumps, severely weakened trees, or suppression-related mortality. To distinguish *A. ostoyae* from these, look for tree reaction, such as resin flow and soaking, and for mycelial fans that are thick and substantial and that often extend above the root collar.

Agents Producing Similar Symptoms and Signs: Armillaria root disease may be confused with other root diseases. The white mycelium is often confused with that of *Perenniporia subacida*. Thick mycelial fans present between the bark and wood (not within the wood itself) are diagnostic of *A. ostoyae*. Roots of bark beetle-infested trees should be examined for the presence of the fungus. Fruiting bodies may be confused with those of *Pholiota* species.

Severity: Armillaria root disease can be very severe locally. The disease may create large openings where highly susceptible species never attain large size.

References: 34, 79, 91

- *Thick white/cream mycelial fans.*
- *Tree reaction such as basal resinosis.*
- *Look for bark beetles!*

Figure 31a—Resin soaking at the bases of trees is often a symptom of Armillaria root disease.

Figure 31b—Removing bark reveals a white to cream-colored mycelial fan.

Figure 31c—Mycelial fans are found between the bark and the wood.

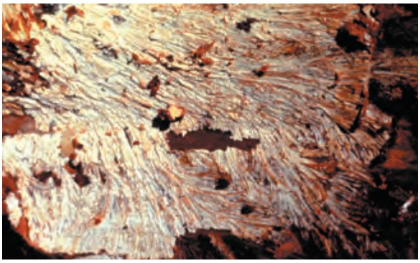


Figure 31d—Mycelial fans of *A. ostoyae* are thick and often can be peeled off of wood like coats of dried latex paint.

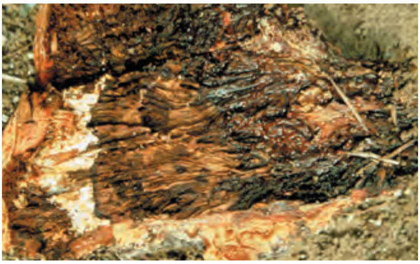


Figure 31e—As they get older and begin to deteriorate, mycelial fans may leave impressions in the bark.

Figure 31f—Advanced decay of *A. ostoyae* is a wet, yellow, stringy rot.

Figure 31g—*A. ostoyae* produces mushrooms in the fall.

BLACK STAIN ROOT DISEASE

Pathogen: *Leptographium wageneri* (Kendr.) M.J. Wingfield

Hosts: Douglas-fir, western hemlock, mountain hemlock, lodgepole pine, ponderosa pine, knobcone pine, western white pine, and sugar pine. The disease is most common on westside Douglas-fir under 30 years old and ponderosa pine of all ages. Black stain root disease is found only occasionally on the other hosts listed.

Distribution and Damage: *L. wageneri* is found throughout Oregon and Washington. It causes growth reduction and mortality. Bark beetles often attack *L. wageneri*-infected pines. The disease is most often associated with ground disturbance along roads, skid trails and on compacted soils.

Identification: Aboveground symptoms are typical of those for all root diseases. However, the dark brown to purplish stain in the sapwood of roots, root crowns, and lower stems is diagnostic (Figs. 32a-c). Stain will be most apparent in older sapwood. In cross-section, the stain is usually limited to one or two growth rings and very rarely extends radially into the wood (Fig. 32d). Stain is most readily visible on living trees that exhibit crown symptoms or on recently killed trees; it may disappear when trees have been dead for several years. Heavy resin flow and resin soaking at the base of trees are often associated with black stain root disease.

Agents Producing Similar Symptoms and Signs: Black stain root disease may be confused with other root diseases, bark beetles, and animal damage in plantations. The diagnostic sapwood stain distinguishes it.

Severity: Black stain root disease is most severe in Douglas-fir plantations in western Oregon and in pine stands on the southern edge of the Blue Mountains. In other areas, black stain root disease is less common and usually kills small numbers of trees. In severely affected areas, it is widely distributed and causes substantial mortality. It is being encountered with increasing frquency killing newly-planted Douglas-fir seedlings in the Oregon coast range. Mortality caused by black stain root disease also has been found associated with the pruned Douglas-fir in older plantations, particularly if the pruning treatment was done in spring and the slash was burned on site.

References: 34, 42, 47

- *Black to purplish stain in xylem.*
- *Difficult to identify in older mortality.*
- *Look for bark beetles!*

Figures 32a and b—Cutting through the bark reveals purple to black longitudinal staining in the xylem of affected trees.

Figure 32c—Staining will fade within a few years after host death. Diagnosis is most successful on symptomatic or recently-killed trees.

Figure 32d—In cross-section, stain occurs in circles or arcs. Stain is usually found in the outer rings of the xylem and does not extend into the center of the tree.

HETEROBASIDION ROOT DISEASE

PREVIOUSLY KNOWN AS ANNOSUS ROOT DISEASE

Pathogen: *Heterobasidion occidentale* Ostrosina and Garbelotto (previously known as *H. annosum* "fir type") and *H. irregulare* Garbelotto & Ostrosina (previously known as *H. annosum* "pine type")

Hosts: Most conifers. Susceptibility and damage vary greatly by tree species and location.

Distribution and Damage: *H. occidentale* causes severe root and butt decay, extensive tree mortality and growth loss of grand and white fir east of the Cascades and in Southwest Oregon. Substantial butt rot can also be caused in older spruces, hemlocks, and other true fir species throughout their ranges. Regeneration of these species may occasionally be killed. *H. irregulare* often infects and kills ponderosa pine and associated western juniper on drier sites east of the Cascades. Other pine species and western larch are killed on rare occasions. In some locations east of the Cascades, Douglas-fir may also be severely damaged by *H. irregulare*. Bark beetles are commonly found infesting trees infected by *Heterobasidion* spp.

Identification: Signs and symptoms of the two *Heterobasidion* spp. are similar on their respective hosts. The diseases are often difficult to detect; many infected trees do not show aboveground symptoms. Dead and dying trees with stained roots are often found adjacent to stumps with typical *Heterobasidion* species decay and conks. On pine sites, substantial openings where regeneration is dead or missing are often centered on large (greater than 45 cm (18 in) diameter) pine stumps. Fruiting bodies of *Heterobasidion* spp. occur inside hollows in stumps, on the wood/bark interface of stumps, or in the root crotches below the duff (Figs. 31a-d). Conks are perennial with woody or leathery dark to chestnut-brown upper surfaces, white poreless margins, and creamy-white undersurfaces with small, rounded, regular pores (Fig. 31c). "Button conks," small cream-colored, "popcorn-like" pustules of corky fungal tissue (pores visible), are sometimes found on the root collars of infected seedlings or within stumps (Fig. 31d). Incipient decay is a light brown to reddish stain in outer heartwood of lower stems and roots; wood is firm. In advanced decay small elongated white pockets coalesce to form a white stringy to laminated decay (Figs. 31e, f). Small black flecks are often seen (Fig. 31e). Elongated pits occur on only one side of the laminae (Fig. 31g).

Agents Producing Similar Symptoms and Signs: Heterobasidion root disease may be confused with other root diseases. *Heterobasidion* spp. have distinctive fruiting bodies and the laminated decay has no associated setal hyphae. Wood decay may be confused with decay caused by *Echinodontium tinctorium, Perenniporia subacida,* or *Ganoderma tsugae.*

Severity: Most damage associated with Heterobasidion root disease occurs in true fir stands that have been entered for harvest one or more times and in entered pine stands in dry plant associations. *H. occidentale* causes substantial amounts of decay and associated stem breakage in older mountain hemlock and western hemlock stands.

References: 1, 34, 64, 77

- *Diagnostic fruiting bodies.*
- *Laminated decay **without** setal hyphae.*
- *Check for bark beetles!*

Figure 33a—*Heterobasidion* spp. fruiting bodies are often found inside of stumps.

Figure 33b—Woody, shelflike conks have dark upper surfaces and a white to cream-colored margin.

Figure 33c—Pore layers of *Heterobasidion* spp. fruiting bodies are white to cream colored with small, somewhat rounded pores.

Figure 33d—Conks may also occur under the duff or in root crotches of affected trees. Small "popcorn" or "button" conks are shown.

Figure 33e—Small, elongated white pockets of *Heterobasidion* spp. decay coalesce to form a white spongy decay interspersed with black flecks.

Figure 33f—In advanced stages, *Heterobasidion* spp. can delaminate wood.

Figure 33g—Delaminated wood may be pitted on one side. No setal hyphae are present.

LAMINATED ROOT ROT

Pathogen: *Coniferiporia sulphurascens* (Pilát) L. W. Zhou & Y. C. Dai (previously known as *Phellinus weirii*)

Hosts: All conifers. Susceptibility and damage vary by species.

Distribution and Damage: In Oregon, *C. sulphurascens* is present on and west of the Cascade Mountains and north of the Crooked River on the east side of the Cascade crest. It is found throughout the forested portions of Washington. The fungus causes severe root and butt decay, growth loss and mortality. Douglas-fir, mountain hemlock, grand fir, and white fir are readily infected and often killed. Western hemlock, western larch, Pacific silver fir, subalpine fir, noble fir, Shasta red fir, Engelmann spruce and Sitka spruce are often infected but rarely killed. These species frequently exhibit butt decay. Lodgepole pine, ponderosa pine, Jeffrey pine, western white pine, sugar pine, whitebark pine, and western redcedar are seldom infected and almost never killed. Incense-cedar, Port-Orford-cedar, and Alaska yellow-cedar are almost never infected. Bark beetles often infest *C. sulphurascens*-infected trees.

Identification: Aboveground symptoms are typical of those caused by most root diseases. Down trees with "root balls" and trees broken at or near ground level are common in laminated root rot pockets (Fig. 34e). Incipient decay is a brown to reddish-brown stain seen most often in sapwood (Fig. 34f). Stain is often crescent shaped or semicircular in cross-section (Fig. 34f). Advanced decay is a laminated yellow pocket rot (Figs. 34a, b). Wood separates at the growth rings with small, regular, elliptical pits on both sides of the laminae (Figs. 34a, b). Rusty-red, whiskery fungal hyphae called "setal hyphae" occur between layers of decayed wood (Fig. 34b). Setal hyphae may coalesce to form mats of reddish-brown "velvet." White, buff-colored, pinkish or grayish superficial (ectotrophic) mycelium can be found on the bark surface of roots, particularly on younger trees or younger portions of roots (Fig. 34c). On large roots with thick bark, ectotrophic mycelium can be found within bark crevices (Fig. 34d). Gray-brown to cinnamon-brown flat fruiting bodies may be found on the undersides of windthrown infected trees; they are infrequently observed and are of limited use for diagnosis.

Agents Producing Similar Symptoms and Signs: Laminated root rot may be confused with the stem decay red ring rot or with other root diseases, especially Heterobasidion root disease that also causes a laminated decay. Setal hyphae combined with pitted, delaminated wood are diagnostic of *C. sulphurascens*.

Severity: Laminated root rot frequently creates substantial-sized openings in stands where highly susceptible species such as Douglas-fir, white fir, grand fir, and mountain hemlock never attain large size. The disease is particularly severe on and west of the Cascade Mountain crest in Oregon and Washington, and in the Oregon Coast range.

References: 34, 38, 63, 84

Figure 34a—Decayed wood separates at the annual rings like the pages of a book.

- *Laminated decay with pits on both sides of laminae.*
- *Presence of setal hyphae.*
- *Ectotrophic mycelium on root bark or within bark fissures.*
- *Look for bark beetles!*

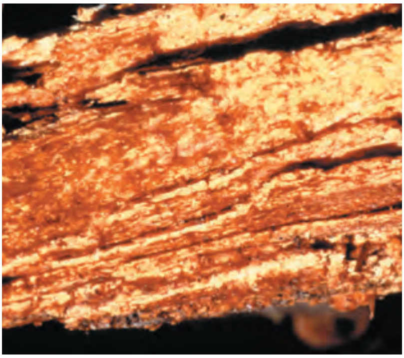


Figure 34b—*Coniferiporia sulphurascens* decays small holes or pits in the wood. Reddish-brown whiskery setal hyphae are found between wood sheets.

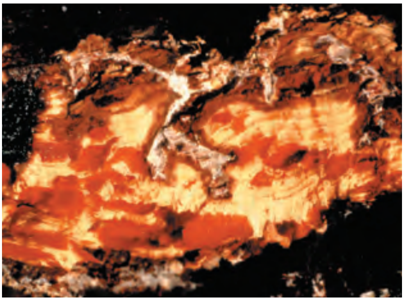


Figure 34d—In older trees with thick bark, ectotrophic mycelium may be found in bark crevices instead of on the bark surface.

Figure 34c—White, buff-colored, pinkish or grayish superficial (ectotrophic) mycelium grows on root surfaces.

Figure 34e—Physical decay of roots results in windthrown trees exhibiting "root balls."

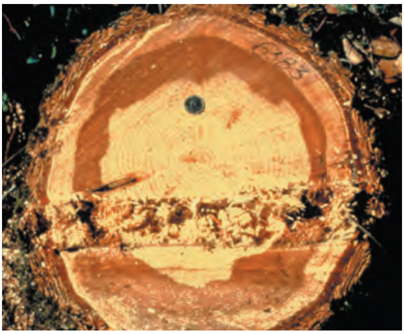


Figure 34f—A brown to reddish-brown stain indicating decay may be visible on stump surfaces of recently-cut infected trees.

PORT-ORFORD-CEDAR ROOT DISEASE

Pathogen: *Phytophthora lateralis* Tucker and Milbrath

Hosts: Port-Orford-cedar; occasionally Pacific yew.

Distribution and Damage: *P. lateralis* is found in the Southwest Oregon Coastal Region, concentrated in areas of standing or flowing water and on poorly drained microsites. The pathogen causes mortality. Cedar bark beetles (*Phloeosinus* spp.) often attack *P. lateralis*-infected trees. Pacific yew has occasionally been found infected in areas of high inoculum where Port-Orford-cedar mortality has been severe.

Identification: The disease causes progressive discoloration of foliage from yellow to bright red, to red brown and then brown (Figs. 35a, b). The diagnostic symptom is a cinnamon-colored stain in the inner bark and cambium of roots and lower stems that abruptly adjoins healthy white cambium (Figs. 35c, d). Stain is best seen when foliage is wilted or yellow; it disappears when trees are dead and all the inner bark tissues become brown and dry.

Agents Producing Similar Symptoms and Signs: Mortality from cedar bark beetles and drought may be confused with Port-Orford-cedar root disease. Stained cambium on symptomatic trees can be used to differentiate those trees actually infected by *P. lateralis*.

Severity: Port-Orford-cedar root disease is very severe on suitable sites within the limited range of its host. *P. lateralis* is an introduced pathogen first reported on ornamentals near Seattle, Washington, in 1923 and not found within the native range of Port-Orford-cedar until 1952 when it was discovered at Coos Bay, Oregon. Since then, spread into mountainous regions has been slow but progressive. Extensive mortality occurs along streams and in drainage ditches on the downslope sides of roads. Where the disease has been present for one or more decades, shifts in diameter distribution have occurred towards higher proportions of trees in smaller diameter classes. The extensive killing of large Port-Orford-cedar in riparian zones by this disease may have severe ecological consequences.

References: 3, 34, 37, 71

- *Cinnamon-brown stain in chlorotic Port-Orford-cedar*


Figures 35a and b—Rapid death of Port-Orford-cedar of all ages is a typical indicator of infection by *P. lateralis.*


Figures 35c and d—Cinnamon-brown staining in the cambium is best seen when infected trees are wilted and chlorotic but before foliage is completely brown.

RHIZINA ROOT ROT

Pathogen: *Rhizina undulata* Fr.:Fr.

Hosts: Young conifer seedlings of several species including Douglas-fir, spruces, pines, hemlocks, and true firs.

Distribution and Damage: *R. undulata* is found throughout Oregon and Washington and is associated with recent burns. It causes mortality of groups of seedlings.

Identification: Foliage of affected seedlings becomes yellow; seedlings decline rapidly and die. Brown to black fleshy fruiting bodies (apothecia) resembling pieces of liver grow on the duff or mineral soil close to infected seedlings (Figs. 36a, b). When fresh, fruiting bodies have a whitish-yellow margin and a yellow-gray undersurface. Fruiting bodies are attached to host roots or other organic material in the soil via rootlike structures called rhizoids.

Agents Producing Similar Symptoms and Signs: Drought, animal damage, and other root diseases may be confused with Rhizina root rot. It can be separated from these based on occurrence of the characteristic fruiting bodies.

Severity: *R. undulata* causes very localized damage on burned sites for the first two years after fire. It has been reported as especially damaging to conifer seedlings in the northern Washington Cascades.

References: General

- *Diagnostic fruiting body.*

Figure 36a—Fruiting body of *R. undulata* associated with dead Douglas-fir seedling.

Figure 36b—Fruiting bodies of *R. undulata*.

TOMENTOSUS ROOT ROT

Pathogen: *Onnia tomentosa* (Fr.:Fr.) P. Karst. (previously known as *Inonotus tomentosus)*

Hosts: Engelmann spruce is the most common host in Washington and Oregon. Sitka spruce, Pacific silver fir, grand fir, white fir, lodgepole pine, ponderosa pine, and Douglas-fir are occasionally infected.

Distribution and Damage: *O. tomentosa* is found throughout Washington and Oregon. It causes a root and butt decay and occasionally tree mortality. Infected trees are readily windthrown. Bark beetles are associated with *O. tomentosa*-infected spruce.

Identification: Crown symptoms typical of all root diseases may be present but are not common (Fig. 37c). Many infected trees exhibit no crown symptoms. Windthrown trees may have root wads retaining large lateral roots with evidence of white pocket rot (Fig. 37f). Trees affected may be as young as 20 years old; however, the disease is most common in stands over 40 years old. Small (2.5 to 7.5 cm or 1 to 3 in diameter) yellow to reddish-brown fruiting bodies are the best diagnostic sign of the disease (Figs. 37a, b). Their upper surfaces are velvety to hairy, while the pore layers on the undersurfaces are white to light brown tube layers. Fruiting bodies with mycelia attached to tree roots emerge from the soil and have thick central stalks. Occasionally, bracketlike fruiting bodies may form on root collars and butts of infected trees. Fruiting bodies emerge in late summer and early fall if conditions are moist. Incipient decay is a reddish-brown to brown staining of solid wood (Figs. 37d, e). Advanced decay is a white pocket rot (Fig. 37f).

Agents Producing Similar Symptoms and Signs: Tomentosus root rot may be confused with Heterobasidion root disease and yellow root rot. It may be over-looked in areas of bark beetle infestation. The decay may be confused with that caused by *Porodaedalea pini*.

Severity: Tomentosus root rot does not cause extensive damage across most of the Pacific Northwest but may be locally important, particularly in the high Cascades and Blue Mountains. Spruce stands with infected trees suffer breakage and windthrow. Extensive infection may result in mortality of regeneration.

References: 34

- *Distinct fruiting bodies.*
- *Reddish-brown stained wood.*
- *White pocket rot.*

Figure 37a—Fruiting bodies of *O. tomentosa* are small, stalked, golden to reddish brown and velvety.

Figure 37b—The under surface of fruiting bodies (upper right) is a white to brown tube layer.

Figure 37c—Crown symptoms in a diseased Engelmann spruce.

Figure 37d—Early stage of *O. tomentosa* decay is a red-brown discoloration of the heartwood.

Figure 37e—Stain and decay in a cross-section of an infected Engelmann spruce.

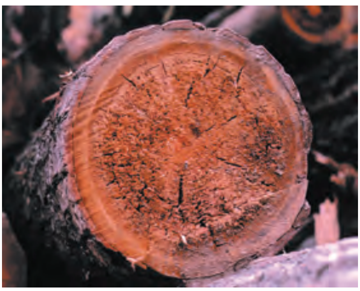


Figure 37f—*O. tomentosa* causes a white pocket rot that takes on a "honeycombed" appearance.

YELLOW ROOT ROT

Pathogen: *Perenniporia subacida* (Peck) Donk.

Hosts: The host list is large and includes: Douglas-fir, western hemlock, mountain hemlock, lodgepole pine, western larch, grand fir, and western redcedar.

Distribution and Damage: *P. subacida* can be found throughout Washington and Oregon. It causes mortality or butt rot in suppressed or already-weakened trees. Affected trees may be easily windthrown.

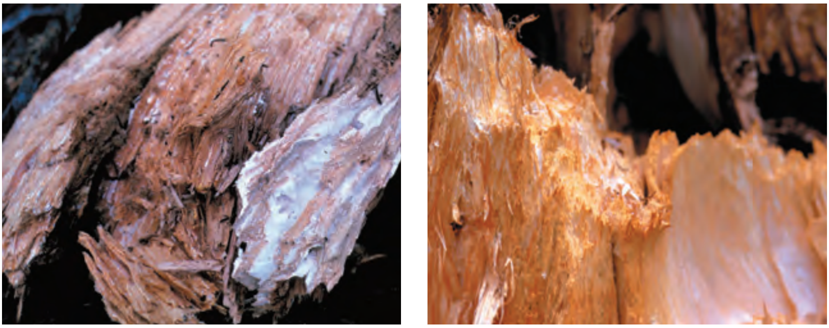
Identification: Fresh fruiting bodies are white, crustlike or leathery, and flattened against bark or wood (Fig. 38c). They turn cream colored to dirty yellow orange with age and may be up to 1 cm (1/2 in) thick and up to 0.6 to 1 m (2 to 3 ft) long. Fruiting bodies are found on the undersides of root crotches, logs, fallen trees, and exposed roots. Early decay is a light brown stain that resembles wetwood. As decay advances, irregularly shaped pockets of decayed springwood coalesce to form masses of stringy fibers with black flecks. Annual rings may separate readily in a laminated decay, and yellow-white mycelial mats often develop between laminae. In advanced stages, hollow trees or roots with pockets of a yellow-white spongy rot with mycelia resembling "marshmallows" are the only things remaining (Figs. 38a, b).

Agents Producing Similar Symptoms and Signs: Yellow root rot may be confused with Heterobasidion root disease, Armillaria root disease, saprophytic *Armillaria* spp., laminated root rot, Ganoderma trunk rot, and white mottled rot. The white-yellow spongy rot and the characteristic fruiting bodies can be used to separate yellow root rot.

Severity: *P. subacida* is most often considered a secondary agent. It is frequently found in older snags and cut stumps.

References: 34

- *Frequently found in decaying stumps and dead trees.*
- *Distinct white-yellow fruiting body.*
- *Yellow-white, "marshmallow" material within wood (not confined to cambial area).*



Figures 38a and b—Advanced decayed wood contains pockets of yellow-white spongy material, hence the nickname "marshmallow" rot.

Figure 38c—White to yellow fruiting bodies of *P. subacida* grow flattened against wood or bark.

Stem Decays

(HEART ROTS and SAP ROTS)

Stem decays are caused by hundreds of species of basidiomycetous fungi that invade and decompose the wood of trees. Many of these fungi decay only the nonliving heartwood portion of living trees while others decay heartwood and sapwood of dead trees, decay sapwood only, deteriorate wood in use, or decompose slash, roots, and organic matter in the soil. Decays change wood structure in such a fashion that excavations can be more easily made by cavity nesting birds and mammals (Fig. 39a). Decays also render timber unmerchantable, reduce wood quality, and predispose trees to windthrow and breakage (Fig. 39b).

As a rule, heartwood-rotting fungi, also known as heart rots, do not penetrate sound trees but require an opening into the heartwood through which they invade. Any opening into the heartwood or exposure of dead sapwood next to heartwood is a potential site for decay fungi to become established. Wounds caused by fire, weather, animals, or human activities are common points of entry for decay fungi. Natural openings in trees, such as branch stubs, open knots, and dead branches, also provide means of entrance. Some decay fungi enter the tree through injured roots or through basal fire scars. Others kill the root wood before entering the heartwood.

Several systems have been devised to classify decay fungi. The most useful classification concepts are based on 1) the type of decay, and 2) the characteristics of the fungal fruiting bodies also known as the sporophores or conks (Fig. 39c).

In the first classification scheme, two general types of decays are recognized: brown rots and white rots. Brown rots develop as a result of the selective utilization of carbohydrates (primarily cellulose) by the causal fungi, leaving behind the brownish lignin component of the wood. Brown rotted wood is usually dry and fragile; it tends to crumble readily or break apart into cubes. Most brown rots form solid columns of decay, while a few form pockets. Fungi that attack both the carbohydrate and lignin components of the wood produce white rots. They may form in pockets or be stringy or spongy.

The second classification system used to identify the decay fungi is based on characteristics of the fruiting bodies. These spore-producing bodies vary in form from fleshy mushrooms to woody brackets. Color, texture, and the nature of the spore-producing surface are examples of the characteristics used to identify the species. Some decay fungi produce annual sporophores; others are perennial. Some are able to fruit on trees after they are harvested.

Decay fungi often go unnoticed. Incipient decay may be very difficult to detect. While some incipient decays can be seen as distinct color changes in wood, others are much less obvious or virtually invisible. If conks are present, they are usually good indicators of decay; however, small but viable conks may escape casual inspection. Annual conks may not be apparent during certain times of the year. Woody conks are easily knocked off during harvest and transport.

References: 1, 5, 55

Figure 39a—Decay fungi change wood structure making excavation of trees by primary cavity nesters easier.

Figure 39b—Decay causes hazards by increasing the likelihood of tree windthrow and breakage.

Figure 39c—Decays are most often identified by their characteristic fungal fruiting structures.

BROWN CRUMBLY ROT

Pathogen: *Fomitopsis pinicola* (Sw.:Fr.) P. Karst. "red belt fungus"

Hosts: The host list is large and includes most western conifers, especially pines, true firs, Douglas-fir, western hemlock, western larch, spruce, incense-cedar, and western redcedar.

Distribution and Damage: *F. pinicola* is found throughout Oregon and Washington. The fungus causes a brown cubical rot and is one of the most common wood rot organisms in coniferous forests in western North America. It mainly decomposes dead and down timber, however, it may also cause heart rot in living trees, particularly in Alaska. *F. pinicola* causes decay in living true firs that is associated with large open bole swellings caused by dwarf mistletoe. The fungus is very important as a slash rotter. It also causes deterioration of recently killed standing trees, down trees, and stored logs.

Identification: Fruiting bodies are commonly associated with this decay. They are leathery to woody, perennial, bracket-shaped structures that, when young, appear as white, round, fungal masses. As they mature, the upper surfaces turn dark gray to black, the fresh lower pore surfaces remain white to creamy, and conspicuous reddish margins, the "red belts," develop between the two surfaces (Figs. 40a-c). Fruiting bodies are commonly seen on dead and fallen conifers. They range from 10 to 46 cm (4 to 16 in) in width.

The decay develops rapidly in the sapwood and then progresses to the heartwood. In its early stages, it may appear as a faint yellow-brown to brown stain. As it advances, the decayed wood becomes light reddish brown and forms a crumbly mass broken into rough, rather small cubes (Fig. 40d). Small patches of lighter colored wood may give a mottled appearance on the ends of logs.

Non-resinous mycelial felts form in the shrinkage cracks in decayed wood. On a relative scale, these felts are thicker than those associated with similar rots, but not as thick as those formed by *Fomitopsis officinalis*.

Agents Producing Similar Symptoms and Signs: Many other fungi cause brown rot. The fruiting body distinguishes this fungus.

Severity: *F. pinicola* occurs on dead trees, logs, stumps and dead portions of living trees. It is a very significant recycler of wood. It can cause economic losses when it decays dead trees scheduled for salvage or logs in storage.

References: 1, 55

- *Brown cubical decay.*
- *Bracket-shaped conks with reddish margin and white pore layer.*

Figure 40a—The often-distinct reddish-brown margin gives the fungus its common name, "red belt."

Figure 40b—A dark upper surface, reddish-brown margin, and creamy white pore layer distinguish this very commonly occurring conk.

Figure 40c—The underside of the conk has a creamy-white pore layer.

Figure 40d—The fungus decays heartwood and sapwood. Advanced decay is a brown crumbly rot.

BROWN CUBICAL ROT

Pathogen: *Laetiporus conifericola* Burdsall & Banik "sulfur fungus," "chicken of the woods"

Hosts: Douglas-fir, true firs, pines, hemlocks, spruces, larch, and western redcedar.

Distribution and Damage: *L. conifericola* causes a brown cubical rot in a variety of conifers in the Pacific Northwest, especially in true firs. It is very common in dead trees or dead portions of trees and is often seen on stumps and logs.

Identification: The conks are quite conspicuous. They appear in the late summer or fall on wounds at or near the base of living trees, on stumps, and on fallen logs. They are annual, clustered, shelflike conks that are soft, fleshy, and brilliant orange to red orange (Fig. 41a). When fresh the pore surface is bright sulfur yellow. Older fruiting bodies become hard, brittle, and chalky white.

The fungus decomposes cellulose in the heartwood and occasionally sapwood, causing a brown cubical rot. Hidden decay is usually present but detectable only microscopically. The earliest detectable stage is a light brown stain. In advanced decay the wood breaks down into medium-sized reddish-brown cubes (Fig. 41b). Cracks between cubes are often completely filled with nonresinous white mycelial felts. Decay is most common in the butts of trees.

Agents Producing Similar Symptoms and Signs: Many other fungi cause brown rots. Decay is similar to that caused by *Fomitopsis officinalis*. The fruiting body distinguishes *L. conifericola*.

Severity: *L. conifericola* is often seen but not usually considered a major heart rot or slash decayer of conifers.

References: 1, 55

- *Orange-yellow fruiting body.*
- *Brown cubical decay.*

Figure 41a—Its bright colors make *Laetiporus conifericola* one of the most spectacular decay fungi.

Figure 41b— *L. conifericola* causes a brown cubical rot.

BROWN TOP ROT

Pathogen: *Fomitopsis cajanderi* (P. Karst.) Kotl & Pouzar "rose-colored conk"

Hosts: Douglas-fir, grand fir, larch, lodgepole pine, ponderosa pine, white pines, hemlocks, and spruces.

Distribution and Damage: *F. cajanderi* occurs throughout the Pacific Northwest. Impacts are most noticeable in areas where storms have caused substantial amounts of top breakage (Fig. 42a). The fungus causes a brown cubical heartwood rot in living trees that is often limited to their very tops. It is frequently found in both standing and down dead trees. Decay develops rapidly. The decay may continue to develop in wood in service and is important in piled logs and pulpwood.

Identification: Fruiting bodies are perennial, woody, bracketlike to hoof shaped with pink to rose-colored undersurfaces and inner tissue (Figs. 42b, c). The upper surface of an individual conk is brown to black and usually cracked and roughened. Conks often appear stacked on one another in a shelflike arrangement.

Wood may be moderately affected before any discoloration or texture change becomes evident. A faint brownish or yellow-brown stain, sometimes marked by greenish-brown zone lines, may be seen in the early stages. As decay advances, yellowish to reddish-brown, soft, irregular cubes are formed. Thin mycelial felts that vary from white to faintly rose colored may develop in the cracks between the cubes.

Agents Producing Similar Symptoms and Signs: Many other fungi cause brown rot. The rose-colored pore layer on fruiting bodies distinguishes this fungus.

Severity: Brown top rot may cause locally severe impacts, especially in areas prone to windstorms, ice storms, or heavy wet snows.

References: 1, 55

- Rose-colored pore layers on fruiting bodies.
- Old broken or forked tops.

Figure 42a—Brown top rot is often associated with trees with old top breaks.

Figures 42b and c—Rose-colored fruiting bodies of *F. cajanderi* are formed on branches, stems, and log ends.

BROWN TRUNK ROT

Pathogen: *Fomitopsis officinalis* (Villars.:Fr.) Bondartsev & Singer
"quinine fungus"

Hosts: Douglas-fir, pines, western larch, spruces, and hemlocks; it is found occasionally on true firs.

Distribution and Damage: *F. officinalis* is found throughout Oregon and Washington. The fungus is most closely associated with old-growth conifers and is especially common in trees with old broken tops. Its incidence in second-growth forests is not well known but appears to be low.

Identification: Fruiting bodies are not common. When present they are hard, perennial, hoof shaped, and chalky white to grayish with ridged and cracked surfaces (Figs. 43a, b). Conks range in size from several centimeters (2 in) to more than 0.6 m (2 ft) long and may become long and cylindrical after several years. They develop at branch stubs or on wounds. Conk interiors are soft and white and have a bitter flavor if tasted, hence the common name "quinine fungus."

The decay is often difficult to detect in its early stages. Incipient decay color varies by host species. In Douglas-fir, discoloration is ordinarily absent, but is purplish in color when present. In ponderosa pine, incipient decay is commonly red brown or brown. On other hosts it is light yellow to red brown. In advanced stages, the wood breaks down into a crumbly mass of yellow-brown to reddish-brown cubical chunks (Figs. 43e, f).

Thick white to cream-colored mycelial felts are common in the shrinkage cracks between the cubes in advanced decay (Figs. 43c, d). Felts may be up to 5 mm (3/16 in) thick and can cover large areas in continuous sheets. Felts have a characteristic bitter taste and are associated with resinous pockets or resinous crusty areas.

The fungus is more frequently encountered in the upper parts of trees; it is found less commonly in the butt portion.

Agents Producing Similar Symptoms and Signs: Many other fungi cause brown rot. The decay caused by *F. officinalis* is most often confused with that of *Fomitopsis pinicola, Laetiporus conifericola,* or *Phaeolus schweinitzii.* The fruiting body distinguishes this fungus.

Severity: *F. officinalis* is an important decay organism in old-growth conifers. The presence of a single conk indicates extensive decay.

References: 1, 55

- White to gray chalky, hoof-shaped conks.
- Thick, bitter-tasting mycelial felts between wood cubes.
- Cubical decay.


Figures 43a and b—*F. officinalis* conks are white to gray in color, hoof shaped, and chalky with a ridged or cracked surface.


Figures 43c and d—Thick mycelial felts develop in the shrinkage cracks of the decayed wood.


Figures 43e and f—The decay caused by *F. officinalis* is yellow brown to reddish brown and cubical.

GANODERMA TRUNK ROTS

Pathogen: *Ganoderma tsugae* Murr. "lacquer fungus" or "varnish conk"
(= *Ganoderma oregonese* Murr.)
Ganoderma applanatum Murrill (Pers.) Pat. "artist's conk"

Hosts: *G. tsugae:* Primarily true firs, hemlocks, and spruces; occasionally occurs on Douglas-fir, pines.
G. applanatum: Douglas-fir, pines, spruces, true firs, western redcedar, and hemlocks.

Distribution and Damage: *G. tsugae* is found throughout the Pacific Northwest. It causes a white spongy rot, usually in dead trees but occasionally in wounded or broken live trees. The fungus is frequently found fruiting on stumps and down logs. *G. applanatum* is widely distributed throughout the region and occurs on both hardwoods and conifers. It causes a white spongy rot primarily of dead or down trees, but occasionally is associated with wounded live trees.

Identification: *G. tsugae:* Fruiting bodies are annual and leathery to woody, often with stalks that are laterally attached. The upper surface of each conk is thin, eggshell-like, reddish brown, and shiny as if lacquered or varnished (Figs. 44a, b). The conk undersurface is white to cream-colored with small, round pores. The pore surface does not darken when bruised. Fruiting bodies may grow to be quite large, reaching 0.3 m (1 ft) across. Incipient decay resembles water-soaked wood. Advanced decay is a white pocket rot that develops into a spongy white rot, often with distinct black flecks.

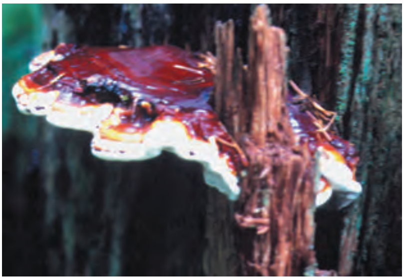
G. applanatum: Fruiting bodies are perennial, leathery to woody, and may or may not be stalked. The upper surface is smooth with pronounced grooves, dull and often dusty (not shiny), and gray brown to dark brown (Fig. 44c). The conk margin is usually white when fresh. The conk undersurface is white, creamy, or light brown when fresh and turns brown when bruised (hence the name "artist's conk") (Fig. 44d). Older conks have a dark, brittle pore layer. Fruiting bodies may grow quite large, up to 0.6 m (2 ft) across. Advanced decay is a white spongy rot. Black zone lines and black flecking are often evident in decayed wood.

Agents Producing Similar Symptoms and Signs: Decay caused by *G. tsugae* and *G. applanatum* may be confused with that caused by *Heterobasidion occidentale, H. irregulare,* and *Perenniporia subacida*. Fruiting bodies are quite characteristic and make separation possible.

Severity: Ganoderma trunk rots are most often associated with dead trees.

References: General

- *Shiny varnished upper surface of conk (*G. tsugae*).*
- *White pore layer that darkens after bruising (*G. applanatum*).*



Figures 44a and b—The shiny or varnished upper surface of the conk gives *G. tsugae* its common name.

Figure 44c—The upper surface of the "artist's conk" is light gray to light brown, smooth, and concentrically furrowed. The pore layer instantly bruises to dark chocolate brown when scratched or bruised.

Figure 44d—The pore layer of *G. applanatum* is creamy white when fresh.

MOTTLED ROT

Pathogen: *Pholiota adiposa* (Fr.:Fr.) P. Kumm. "yellow cap fungus"
Pholiota limonella (Peck) Sacc. "lemon cap fungus"

Hosts: True firs, hemlocks, pines, and spruces.

Distribution and Damage: *Pholiota* species are found on both conifers and hardwoods in the United States. In the West, significant decay occurs on true firs and hemlocks. In eastern and southern Oregon, *P. adiposa* and *P. limonella* are considered major heart rot organisms in old-growth true fir stands. *Pholiota* species are associated with wounds.

Identification: The fruiting body is a gilled mushroom (Fig. 45b). It is annual, fleshy, yellow on the upper surface, sticky when wet, and has a yellow stem and yellowish to brown gills. Mushrooms develop singly or in close groups from a common base (Figs. 45 a, b). They appear in fall, sometimes on living trees, but more commonly on snags, windthrown trees, or stumps, and last only a few weeks.

P. adiposa and *P. limonella* cause a white rot, destroying both cellulose and lignin. Incipient decay is light yellow in color and is usually confined to small pockets in the heartwood (Fig. 45c). As decay advances, discolored areas enlarge and darken to a honey color. Brown streaks appear, causing the mottled look the decay is named for. Wood breaks up into stringy strands in the last stages after separating at the annual rings. Stems may become completely hollow. Most decay is in the lower bole, but can extend 15 to 19 m (45 to 60 ft) above the ground in some cases. Decay is commonly associated with wounds, scars, frost cracks, and true fir and hemlock dwarf mistletoe cankers with open bark.

Agents Producing Similar Symptoms and Signs: *Pholiota* species may be confused with *Armillaria ostoyae* (or other *Armillaria species*) because of the golden fruiting bodies. *Pholiota*-caused advanced decay may be confused with the decays associated with Heterobasidion root disease or *Echinodontium tinctorium*.

Severity: Mottled rot may be severe in mature stands of susceptible hosts.

References: 1, 55

- *Yellow mushrooms with sticky, scaly caps.*

Figure 45a—Yellow mushrooms of *Pholiota adiposa* fruit on snags, down wood, and stumps in the fall.

Figure 45b—The mushrooms are bright yellow with sticky, scaly caps.

Figure 45c—Advanced decay is a white mottled rot.

PECKY ROT

Pathogen: *Oligoporus amarus* (Hedgc.) Gilb. & Ryvarden

Host: Incense-cedar.

Distribution and Damage: *O. amarus* is found throughout the range of its host. Pecky rot is the most important decay of incense-cedar in Oregon and is very common in older trees, especially those with fire scars or other large wounds. Conks indicate extensive decay. Pecky rot is not limited to the lower bole and may extend the entire length of the tree.

Identification: Annual conks form in late summer or fall. Conks are soft and moist, hoof shaped, bright yellow to buff colored when fresh, 10 to 20 cm (4 to 8 in) wide, with numerous angular pore coverings (Fig. 46a). Insects and rodents readily consume the conks; their use as a visible indicator is often short term.

Incipient decay is a yellowish-brown discoloration of the heartwood. Advanced decay consists of round-ended pockets 1 to 2.5 cm (1/2 to 1 in) long containing dark, crumbly rot with numerous shrinkage cracks (Figs. 46b, c). As decay intensifies, pockets become elongated, numerous, and sometimes coalesce (Fig. 46d). Depressions in the bark caused by woodpeckers searching for insects at former conk locations (“shot-hole cups”) are good indicators of infection.

Agents Producing Similar Symptoms and Signs: None known.

Severity: Pecky rot is very widespread in older incense-cedars, however, uninjured trees less than 150 years old are usually free of decay. Breakage is relatively uncommon even when decay is very advanced.

References: 1, 87

- *Moist yellow conks in the fall.*
- *Evidence of woodpecker activity.*

Figure 46a—Annual conks of *O. amarus* are produced in late summer to fall and are readily eaten by birds and small mammals.

Figure 46b—Pecky rot is evident on log ends.

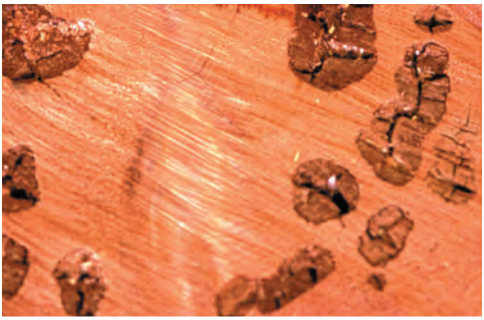


Figure 46c—Advanced decay consists of round-ended pockets containing dark crumbly rot.

Figure 46d—Decay pockets are elongated.

PENCIL ROT of WESTERN REDCEDAR

Pathogen: *Postia sericeomollis* (Romell) Jülich

Host: Western redcedar.

Distribution and Damage: *P. sericeomollis* occurs throughout the range of its host. It is the most common heartrot of western redcedar and causes a severe butt and lower bole decay.

Identification: Fruiting bodies are annual, thin, flat, white crusts with shallow round pores. They are infrequently observed, hence their use as an indicator of decay is limited. They may occasionally be seen on the ends of logs or on slash.

In the early stages of decay the wood is firm but discolored, appearing as yellow-brown pockets or columns. Advanced decay is a typical brown cubical pocket rot (Figs. 47a-c). The surface of the wood cubes may be covered with a thin white mycelium. In the lower bole, decay may be columnar or coalesce into a solid mass. Higher in the bole, decay usually occurs in long pockets.

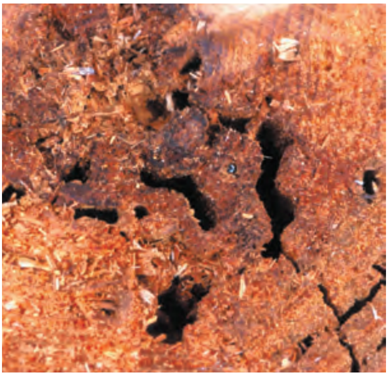
Infected trees may have a sunken or flattened area of decayed wood covered with bark called a “dry side” or “dry face” (Fig. 47d). Dry faces may extend as high as 14 m (45 ft) up the stem. The edge of the dry face may appear folded or callused.

Agents Producing Similar Symptoms and Signs: Pencil rot may be confused with brown cubical butt rot caused by *Phaeolus schweinitzii*, which does occasionally occur in western redcedar. *P. schweinitzii* is more often associated with a large central column of decay whereas *P. sericeomollis* more often occurs in pockets or rings. This distinction may be clearer higher on the stem.

Severity: Pencil rot causes a severe stem decay of western redcedar.

References: General

- *Brown cubical columnar decay.*
- *Flattened "dry face" on boles of western redcedar.*



Figures 47a and b—Advanced decay of *P. sericeomollis* in western redcedar.

Figure 47c—Decay occurs in irregular large patches up to several feet in length throughout the stem.

Figure 47d—*P. sericeomollis* decay may be hidden in trees but is often associated with a dry face or dry side.

RED RING ROT or WHITE SPECK

Pathogen: *Porodaedalea pini* (Brot.) Murrill (previously known as *Phellinus pini*) "ring-scale fungus"

Hosts: Douglas-fir, western larch, pines, hemlocks, spruces, true firs, western redcedar, and rarely incense-cedar.

Distribution and Damage: *P. pini* is found throughout Oregon and Washington. It causes a cellulose and lignin-destroying white pocket rot in the heartwood. The fungus occasionally enters living sapwood. Conks occur higher on trees in older stands; larger conks usually indicate more decay. The fungus is not a primary invader of dead wood and quickly dies out in cut lumber; decay does not continue in wood in service. *P. pini*'s impacts are most severe in the southern portions of the region, in older stands, in pure stands, on steep slopes, and on shallow soils.

Identification: Fruiting bodies occur on tree boles (Figs. 48a, b). They are perennial, hoof shaped to bracketlike, and produced on the stem at branch stubs and knots. They range in size from 5 to 25 cm (2 to 10 in) in width. The upper surface of each conk is rough, dark gray to brownish-black and concentrically furrowed (Figs. 48c, d). The interior and lower surface is cinnamon brown (Figs. 48c, d). Pores are irregular in shape (daedaloid), not round. Swollen knots filled with fungal tissue (punk knots) may be present on stems. Stems may be slightly flattened or "dished out" in areas associated with conks and punk knots.

Incipient decay of *P. pini* is usually reddish in color, but this varies with host species. It is usually red purple in Douglas-fir, light purplish gray in spruce, pink to reddish in pines, and colorless in cedar. Advanced decay occurs as few to many spindle-shaped white pockets with firm wood in between, hence one of the common names, "white speck" (Fig. 48e). Pockets may coalesce and in the latest stages may form distinct rings or crescents resulting in "red ring rot" (Fig. 48f). Zone lines are sometimes produced.

Agents Producing Similar Symptoms and Signs: Incipient decay caused by *P. pini* may be confused with incipient decay of *Echinodontium tinctorium*. In later stages, decay may be confused with other white pocket rots such as those caused by *Hericium abietis* or *Onnia tomentosa*. *P. pini* conks are diagnostic.

Severity: In western North America, *P. pini* is considered to be the most common and widespread heart rot organism.

References: 1, 55

- *Dark, rough fruiting bodies with cinnamon-brown pores.*
- *Rings or arcs of reddish stain or white pocket rot in log ends.*

Figures 48a and b—*P. pini* forms shelflike conks on many conifer species.

Figures 48c and d—The dark upper surface and cinnamon-brown pore surfaces distinguish the fruiting bodies of *P. pini.*

Figure 48e—Close-up of the decay showing white pockets separated by sound wood.

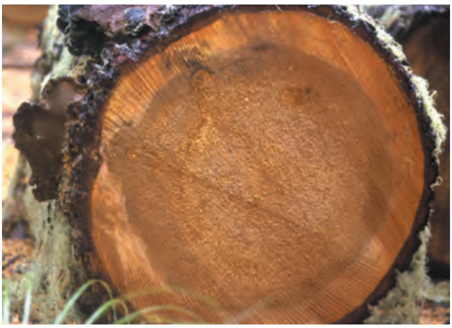


Figure 48f—Cross-section of decayed tree showing the reason for the common name of red ring rot.

RED RING ROT CANKER

Pathogens: *Porodaedalea cancriformans* (M.J. Larsen, Lombard & Aho) T. Wagner & M. Fisch. (previously known as *Phellinus cancriformans*) "butterfly conk"

Hosts: Grand fir, white fir, Shasta red fir, noble fir, Pacific silver fir, and subalpine fir.

Distribution and Damage: *P. cancriformans* occurs in southwest Oregon. Decay is similar to that described for *Porodaedalea pini* but occurs in a limited area of the tree bole, kills the surrounding cambium, and causes formation of a sunken canker.

Identification: Fruiting bodies of *P. cancriformans* are produced profusely over the surface of cankered or sunken portions of the host stem (Fig. 49a). They are not found on branch stubs or at branch whorls. Fruiting bodies are bracketlike with rough, dark, and furrowed upper surfaces and cinnamon-brown pore layers (Fig. 49b, c). They are usually found on the butt portion of the tree rather than high on stems. They resemble conks of *P. pini*, but are usually smaller, 1 cm (1/2 in) to more than 7 cm (3 in) wide (Fig. 49b). Swollen knots are not produced.

Incipient decay of *P. cancriformans* is light yellow to light brown. Advanced decay occurs as few to many spindle-shaped white pockets with firm wood in between; hence, it is also given the common name "white speck." Pockets may coalesce and in the latest stages may form distinct rings or crescents resulting in "red ring rot." Zone lines are sometimes produced.

Agents Producing Similar Symptoms and Signs: The fruiting bodies may be confused with those of *P. pini*, however, *P. cancriformans* conks are small and produced in clusters. Early stages of decay may be confused with incipient decay of *Echinodontium tinctorium*. In later stages, it may be confused with other white pocket rots such as *Hericium abietis* or *Onnia tomentosa*.

Severity: *P. cancriformans* can be locally severe in stands in southwestern Oregon, where it contributes to substantial amounts of stem breakage.

References: 1, 55

- *Cankered or sunken regions on true fir stems with clusters of fruiting bodies.*
- *Occurs in southwest Oregon on true firs.*

Figure 49a—Sunken canker caused by *P. cancriformans*.

Figure 49b—Fruiting bodies of *P. cancriformans* are small and numerous. Their upper surfaces are rough, dark, and furrowed.

Figure 49c—The under surfaces of *P. cancriformans* fruiting bodies are cinnamon brown. Conks resemble those of *P. pini* but are smaller and more delicate, hence the name "the butterfly conk."

RUST RED STRINGY ROT

Pathogen: *Echinodontium tinctorium* (Ellis & Everh.) Ellis & Everh.
"Indian paint fungus"

Hosts: True firs and hemlocks.

Distribution and Damage: *E. tinctorium* is found throughout Oregon and Washington. It is especially common in true fir or hemlock stands that have had selective harvest entries. The decay is often extensive and most common in the midtrunk region, but it may also extend into the butt or the upper portion of the stem.

Identification: The woody, perennial, hoof-shaped conks range from 5 cm to more than 20 cm (2 to 8 in) in width and are quite common on infected trees (Fig. 50a). Their upper surfaces are dull, black, and rough. Their undersurfaces are usually level but made up of hard, coarse teeth or spines; these toothed surfaces are gray when fresh but turn black when old (Fig. 50b). The conk interior is bright orange red (Fig. 50c). Conks develop on tree boles, usually on the undersides of branches or branch stubs. Punk knots may also be present.

The decay is described as a brown stringy rot; however, since the fungus decomposes lignin and, to a lesser extent, cellulose, technically it is a white rot organism. Hidden stages of decay result in weakening of the springwood, causing it to separate during drying and resulting in ringshake. In the first stages of noticeable decay, the wood becomes soft, with a light yellow to brown, or water-soaked stain. This discoloration gradually deepens to pale reddish brown. Fine rusty-red or black zone lines may appear at this stage. Advanced decay is a distinct brown, reddish-brown, or rusty-red color and is soft and stringy (Fig. 50d). Rotted wood appears to separate along the annual rings. In very late stages of decay, the heartwood is reduced to a fibrous, stringy mass; eventually stems may become hollow (Fig. 50e).

Agents Producing Similar Symptoms and Signs: Incipient decay may be similar to that caused by *Porodaedalea pini*. Later stages of decay may be confused with *Heterobasidion occidentale* when decay occurs close to ground level. *E. tinctorium* conks are diagnostic.

Severity: Indian paint fungus is considered to be the most significant heart rot organism of hemlocks and true firs. In some old-growth stands, losses of 25 to 50 percent or more of the gross volume have been recorded. Breakage in trees with advanced decay is common.

References: 1, 28, 55

Heart Rots

- *Dark hoof-shaped conks with spines; orange-red interior.*
- *Reddish, stringy decay in extensive hollows in trees.*
- *Occurs on true firs and hemlocks.*

Figure 50a—Indian paint fungus conks are distinctly rough, dark, and hoof shaped.

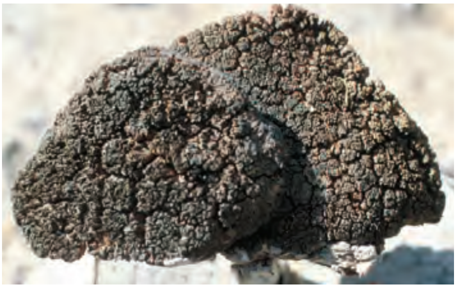


Figure 50b—The undersurface of the conk is dark and made up of hard, coarse teeth or spines.

Figure 50c—Conk context is bright reddish orange in color.

Figure 50d—Advanced decay is soft, stringy, and brownish to rusty red.

Figure 50e—Trees with advanced decay become hollow. Breakage is common.

SCHWEINITZII ROOT AND BUTT ROT

Pathogen: *Phaeolus schweinitzii* (Fr.:Fr.) Pat. "cow-pie fungus," "velvet top fungus"

Hosts: Most frequently found on Douglas-fir. Other common hosts include western larch, Engelmann spruce, Sitka spruce, lodgepole pine, ponderosa pine, Jeffrey pine, western white pine, and sugar pine. It is occasionally found on western redcedar, western hemlock, mountain hemlock, grand fir, white fir, Pacific silver fir, noble fir, Shasta red fir and subalpine fir.

Distribution and Damage: *P. schweinitzii* is found throughout Washington and Oregon. The fungus causes a severe root and butt decay of older trees. Wind breakage above the groundline is the most common result of decay. Douglas-fir beetles and *Armillaria* spp. often attack *P. schweinitzii*-infected Douglas-firs. *P. schweinitzii* may directly cause Douglas-fir mortality; however this occurs only rarely in Washington and Oregon.

Identification: Fruiting bodies are the most reliable sign of this disease. Large annual mushroomlike conks occur on the ground near or growing from the bases of infected trees. Conks may also occur on the lower 3 m (10 ft) of stems (Fig. 51c). Fruiting bodies growing on trees usually emerge from wounds, cracks, and fire scars. Conks appear in the late summer and fall. They are velvety in texture and reddish brown, greenish brown, or yellow brown, often with a yellow edge (Fig. 51a). As they age, they become dark brown and brittle, and resemble cow droppings (Fig. 51b). The conks are circular with depressed centers and taper to short, thick stalks. Those growing directly on stems may be bracket shaped. Fruiting bodies may develop on living trees, dead trees, logs, and stumps.

Early decay is light green to light brown, with firm wood. Advanced decay is a light brown cubical rot aging to dark brown cubical decay with resinous white mycelial sheets in the shrinkage cracks (Figs. 51e, f). Decay is confined to the heartwood and usually found in the roots and butts of the host. Infected trees may have pronounced butt swells or "jugbutts" (Fig. 51d).

Agents Producing Similar Symptoms and Signs: *P. schweinitzii*-caused decay may be confused with that caused by *Fomitopsis pinicola*, *Fomitopsis officinalis*, *Laetiporus conifericola*, or *Postia sericeomollis*. The fruiting body is diagnostic.

Severity: Schweinitzii root and butt rot occurs frequently in older stands. Decay is usually confined to the lower portions of infected trees; fruiting bodies emerging from the bole indicate higher levels of decay. Windthrow and breakage are commonly associated with this fungus.

References: 1, 34, 36

- *Distinct velvet top or "cow-pie" fruiting bodies on or near the ground.*
- *Swollen lower bole or "jugbutt."*

Figure 51a—Mushroomlike fruiting bodies of *P. schweinitzii* form in late summer and fall and are velvety when fresh.

Figure 51b—As fruiting bodies age, they become brittle and dark, resembling "cow pies."

Figure 51c—Fruiting bodies are most frequently found on the ground emerging from roots or at the bases of infected trees. They may also be found on lower boles as shown here.

Figure 51d—"Jugbutt" on older Douglas-fir due to Schweinitzii root and butt rot.

Figures 51e and f—Advanced decay of *P. schweinitzii* is a brown cubical rot.

YELLOW PITTED ROT

Pathogen: *Hericium abietis* (Weir ex Hubert) K.A. Harrison "coral fungus"

Hosts: True firs, hemlocks, and spruces.

Distribution and Damage: *H. abietis* occurs throughout the Pacific Northwest, but is particularly common on the Olympic Peninsula of western Washington and in the mountains of eastern Oregon and Washington. The decay is a white pocket or pitted heartwood rot that develops in living trees. The decay also commonly occurs in stumps, snags and fallen trees. Decay will continue to develop in stored logs.

Identification: Fruiting bodies are conspicuous, soft, creamy white, coral-like annual conks with many downwardly directed spines or teeth (Fig. 52a). Conks occur infrequently and are short-lived. They are most often found on old logs and fallen trees and occasionally at wounds on living trees.

A yellowish to brownish discoloration with scattered darker spots giving the wood a mottled appearance is typical in the earliest stages of decay. Elongated blunt-end pits, approximately 1 cm (1/2 in) long, form as decay advances (Fig. 52b). Pits may be filled with yellowish to white fibers, or they may be hollow. Pits are separated by firm wood. The decay may look like light honeycombing on log ends.

Agents Producing Similar Symptoms or Signs: Decay is somewhat similar to that caused by *Porodaedalea pini*. However, pits caused by *H. abietis* tend to be longer and more blunt and the decay appears more honeycombed than with *P. pini*. Fruiting bodies, when present, are diagnostic.

Severity: The presence of a *H. abietis* fruiting body indicates extensive decay in the stem, most frequently in the lower bole.

References: 1, 55

- *Soft, fleshy, toothed fruiting body.*
- *Large pits form in decayed wood.*

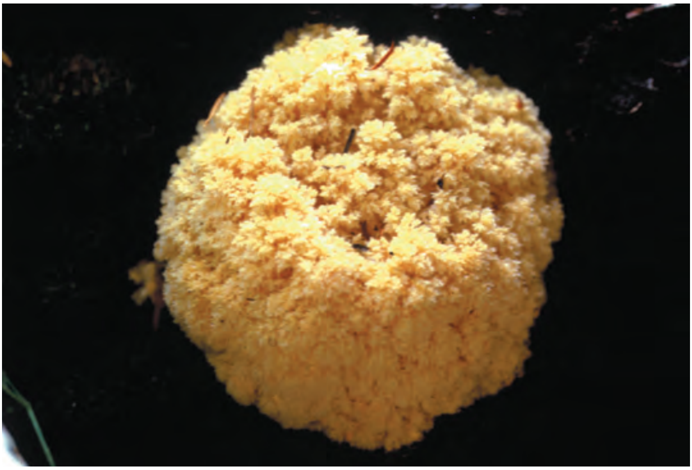


Figure 52a—Conks of *H. abietis* are creamy white, annual, and coral-like.

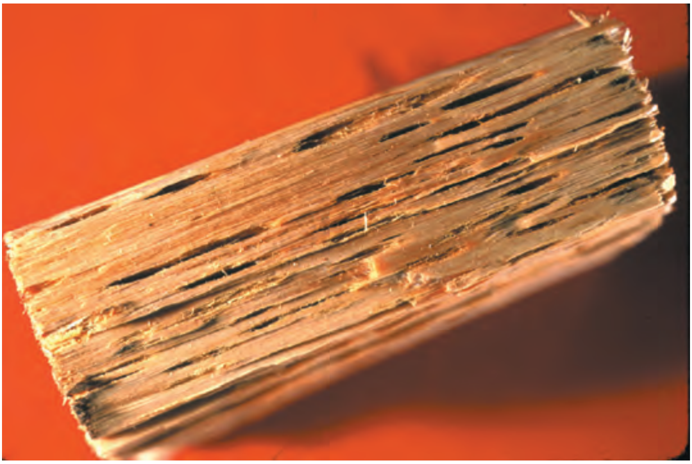


Figure 52b—Large pits form in decayed wood.

GRAY BROWN SAP ROT

Pathogen: *Cryptoporus volvatus* (Peck) Shear "the pouch fungus"

Hosts: All conifers. Frequently found on trees that have been infested by bark beetles or wood borers. Commonly associated with fire-killed or fire-injured trees.

Distribution and Damage: *C. volvatus* is widely distributed throughout Oregon and Washington. It causes a rapidly developing decay in the outer 1 to 2 cm (1/2 to 1 in) of sapwood on dead trees. Hundreds of conks may be found on single trees. Volume loss is usually low; it is based on the size of the sapwood cylinder. Presence of *C. volvatus* conks indicates insect activity on the bole (see p. 16); trees should be checked for bark beetles and wood borers.

Identification: Gray brown sap rot is most commonly identified by the leathery, annual conks up to 4 cm wide by 5 cm high by 4 cm deep (1-1/2 in by 2 in by 1-1/2 in) produced on the trunks of dead trees or on dead portions of living trees (Fig. 53a). Conks usually appear within the first year after a tree dies. Fresh conks are small, round, initially soft and fleshy, yellowish brown to golden brown (Fig. 53b). The pore surfaces are smooth and covered by a hard membrane (Fig. 53c). An opening develops near the base of the membrane as the conks age, exposing the inner brown pore layer. Conks bleach to dirty white in the second year after production (Fig. 53b). The pore surface is usually exposed and the conks have dried to a papery consistency in their third year.

The fungus causes a cream- to gray-colored discoloration in the outer sapwood (Fig. 53d). In the early stages of decay, gray areas develop in the small area of sapwood directly beneath individual conks. Large areas of sap rot are noticeable when many small areas coalesce.

Agents Producing Similar Symptoms and Signs: Conks may be confused with immature conks of other decay fungi, particularly *Fomitopsis pinicola*. Cutting open the fresh conk reveals the hidden pore layer (Fig. 53c).

Severity: *C. volvatus* plays an important role in beginning the wood recycling process. It can cause undesirable saprot on dead trees slated for salvage if they are not harvested rapidly. Two- and three-year-old conks indicate up to a 10 cm (4 in) diameter reduction to the scaling cylinder, often culling the top log(s).

References: 55

- *Pouchlike conks on dead trees.*
- *Pore layer covered by hard membrane.*
- *Associated with fire injury, bark beetles, and wood borer activity.*
- *Causes a sap rot.*

Figure 53a—Many *C. volvatus* conks may be found on an individual tree.

Figure 53b—Fresh conks are yellow brown and soft to doughy in texture. Conks bleach to dirty white the second year after their production.

Figure 53c—A hard membrane covers the pore layer of the pouch fungus (easily seen in this cross-section of a conk).

Figure 53d—The fungus causes a cream- to gray-colored discoloration of the outer sapwood.

PITTED SAP ROT

Pathogen: *Trichaptum abietinum* (Dicks.:Fr.) Ryvarden "the purple conk"

Hosts: All conifers.

Distribution and Damage: *T. abietinum* is common throughout Oregon and Washington. The fungus's primary role is as a deteriorating agent of dead wood. It occurs on slash and wood in service. It has also been reported to cause saprot and heartrot in living trees usually by colonizing wounded, scarred, and sun-scalded tissue. *T. abietinum* colonizes the sapwood rapidly, fruiting within 1 to 2 years.

Identification: Fruiting bodies rarely form on living trees but may be produced in large numbers on dead trees and down logs (Figs. 54a, b). Fruiting bodies are small (1 to 3 cm or 1/2 to 1 in across), annual, thin, and shelflike in shape. The upper surface is light gray and somewhat fuzzy, is zoned, and when older may be dark to black (Fig. 54a). The pore surface is violet to purple when fresh and turns light brown with age (Fig. 54c). Pores are angular. As a conk ages, pores become more elongated and separate into spines or ridges.

Incipient decay is light yellow to tan and soft. In advanced decay, small pits develop, becoming elongated in the direction of the grain. In cross-section, the decay has a honeycombed appearance.

Agents Producing Similar Symptoms and Signs: *T. abietinum* may be confused with other decay fungi. The pore surface of the fruiting body is a distinctive color when conks are fresh.

Severity: Extensive sapwood decay is indicated by the presence of fruiting bodies.

References: General

- *Abundant production of light gray fruiting bodies with violet to brown pore surfaces.*
- *Causes a sap rot.*

Figure 54a—The upper surface of *T. abietinum* fruiting bodies is soft, fuzzy, and light gray.

Figure 54b—Conks appear in clusters on down and standing dead trees.

Figure 54c—The pore surface of *T. abietinum* is violet colored when fresh.

Canker Diseases and Rusts

Hundreds of species of ascomycetous and basidiomycetous fungi, and their respective anamorphs, are responsible for cankers, diebacks, and galls on coniferous trees. Damage includes localized necrotic areas on branches or stems, rapid girdling and tip killing of twigs and branches, pronounced swellings of trunks or stems, top mortality, or whole tree mortality (Fig. 55a). Often dead branches or localized areas of sunken tissue are the only indicators of disease (Fig. 55c). Callus tissue may develop where fungi have only affected a small area. Tip and branch dieback occurs when canker fungi have girdled a stem or twig.

Canker-causing fungi can be buried deep in the wood, and fruiting structures are often cryptic or ephemeral (Fig. 55d). Many are excellent saprophytes that survive for long periods of time in dead wood and bark. Some canker fungi cause disease that occurs sporadically, for one year or one season only. Disease occurrence is frequently tied to periods of severe weather or particular climatic conditions that favor infection or disease development. Many canker organisms are weak parasites, taking advantage of trees under various stresses including those associated with off-site plantings, cold weather injury, or drought. Damage tends to be greater in single-species plantings. Other canker-causing fungi may remain active in trees for more than one year, killing branches and whole trees, or weakening and deforming their hosts. Usually the circumferential growth of the tree exceeds the growth of the canker and trees are not girdled; however, that is not always the case. Sometimes sunken, resinous, unhealed wounds occur on branches or stems, leaving them weakened and vulnerable to breakage (Fig. 55b). Wounds associated with cankers may also become entrance courts for decay fungi.

References: 29

Figure 55a—Tip killing of twigs and branches and top mortality that occurs relatively rapidly often indicates infection by canker fungi.

Figure 55b—Breakage is often associated with main stem cankers.

Figure 55c—Sunken wounds due to canker fungi may be found on branches and stems.

Figure 55d—Fruiting structures of canker fungi are often cryptic and ephemeral.

ATROPELLIS CANKER of PINES

Pathogens: *Atropellis piniphila* (Weir) M. L. Lohman & Cash
A. pinicola Zeller & Goodd.

Hosts: *A. piniphila*: Lodgepole pine, sugar pine, western white pine, ponderosa pine, and lodgepole pine.
A. pinicola: Lodgepole pine.

Distribution and Damage: Atropellis canker fungi are widely distributed in Washington and Oregon, but occurrence of significant amounts of tree damage is uncommon. Even on lodgepole pine, the most damaged host, usually only a few trees per stand are severely infected. Infection can result in reduction in wood quality, stem breakage, and occasionally, tree killing.

Identification: Elongated, flattened depressions, covered with tight, roughened bark occur on stems and branches (Fig. 56a). Substantial resin flow may be associated with cankers. Stems may be misshapened, branches surrounded by cankers may be killed, and occasionally small tree mortality occurs. Open-grown trees are less subject to infection than trees in overstocked stands.

Small black or dark brown irregular to cup-shaped fruiting bodies, 2 to 5 mm (1/16 to 3/16 in) in diameter, form on dead bark in the cankers (Figs. 56b, c). A dark bluish to blue-black stain occurs in the wood behind the cankers (Figs. 56d, e). The stain is wedge shaped in cross-section.

Agents Producing Similar Symptoms and Signs: The spindle-shaped swellings of Atropellis canker may be confused with swellings caused by white pine blister rust on five-needle pines and comandra rust or stalactiform rust on hard pines. The diagnostic dark blue to black staining in the wood caused by Atropellis canker fungi is not found associated with these agents. White pine blister rust, comandra rust, and stalactiform rust all produce distinct yellow-orange spore pustules; Atropellis canker fungi do not.

Severity: Atropellis canker is occasionally severe in lodgepole pine stands.

References: 29, 54

- *Small black fruiting bodies on spindle-shaped branch swellings.*
- *Blue-black stain under elongated canker.*

Figure 56a—Atropellis cankers cause elongated depressions covered with tight, roughened bark. Resin flow is often associated.

Figure 56b—Atropellis fruiting bodies are small, black brown, and irregular to cup shaped.

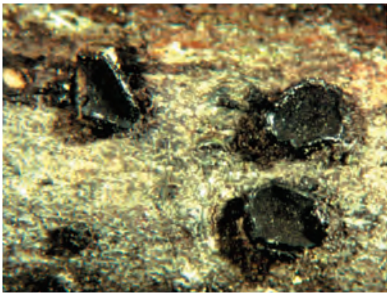


Figure 56c—Close-up of the cup-shaped fruiting body.

Figures 56d and e—Blue-black stain in the wood is diagnostic for Atropellis canker.

COMANDRA BLISTER RUST

Pathogen: *Cronartium comandrae* Peck

Hosts: Hard pines. Primary hosts are ponderosa pine and lodgepole pine. Jeffrey pine and knobcone pine are rarely attacked.

Alternate Hosts: *Comandra* spp.

Distribution and Damage: *C. comandrae* is widely distributed in Oregon and Washington, but significant impacts occur in relatively few locations. It appears to be most common east of the Cascade Mountains crest in southern Washington and central Oregon. Large infected trees have dead tops that continue to progressively die downward. Dead branches ("flags") are scattered throughout the crown. Mortality may occur, particularly in young trees.

Identification: The most obvious indicator of the disease is heavy resin impregnation associated with dead tops in larger ponderosa and lodgepole pines (Fig. 57a). On smaller trees, *C. comandrae* causes diamond-shaped trunk cankers that are usually two to three times longer than wide. Spindle-shaped swellings form on small stems and branches (Fig. 57b). Infections break open and produce cracked and pitted cankers or lesions with heavy resin flow. Inconspicuous reddish-orange drops or "ooze" appear in summer on infected branches or stems of young trees. Bright orange spore pustules (aecia) rupture through the bark in the spring of the following year (Fig. 57b). Aecia are seldom produced on trunk cankers on large trees. On comandra leaves, yellow spots with yellow spore pustules (uredia) and brownish hairlike structures appear throughout the summer.

Agents Producing Similar Symptoms and Signs: Topkill associated with bark beetles (particularly *Ips pini* and *I. paraconfusus*), animal damage, or dwarf mistletoe infections can be confused with comandra blister rust. The progressive nature of top death separates *C. comandrae*-caused topkill from topkill due to other agents. Otherwise, confusion with stalactiform rust is most likely. Comandra cankers are usually 2 to 3 times longer than wide whereas stalactiform rust cankers are very long and narrow, up to 10 times longer than wide. Microscopic examination of aeciospores is necessary to differentiate these two fungi. Nonsporulating cankers may be confused with cankers caused by *Atropellis* species; blue-black staining under the bark is diagnostic for Atropellis canker fungi.

Severity: Comandra blister rust can be locally severe on ponderosa pine.

References: 49, 94

- *Resin-impregnated topkill of large ponderosa pines.*
- *Yellow-orange spore pustules on cankers 2 to 3 times longer than wide.*
- *Two- and three-needle pines affected.*

Figure 57a—Topkill of ponderosa pine caused by comandra blister rust.

Figure 57b—Note the spindle-shaped swelling on this infected branch. In late spring and early summer, aecia may be found on the margins of cankers.

CYTOSPORA CANKER of TRUE FIRS

Pathogen: *Cytospora abietis* Sacc.

Hosts: True firs; has been reported on other conifer hosts.

Distribution and Damage: *C. abietis* is found throughout Washington and Oregon. Branch dieback is common; occasionally trees are killed. Young trees are most heavily impacted. The pathogen is a weak parasite, attacking those trees stressed by other agents including dwarf mistletoes, insects, or abiotic stresses such as drought and fire. Practically all stands that have true fir dwarf mistletoes are also affected by this fungus. Trees with many infections may be predisposed to bark beetle attack.

Identification: Numerous red-flagged branches are scattered in the crowns of true firs and are most conspicuous in spring and summer (Figs. 58a, b). Slightly sunken, gradually enlarging cankers occur on branches or stems. Small spore pustules (pycnidia) occur on dead bark. Large numbers of spores ooze from these structures during mild moist weather, forming yellow-orange tendrils (Fig. 58c).

Agents Producing Similar Symptoms and Signs: Cytospora canker may be confused with Grovesiella canker on young trees without dwarf mistletoe infection and with branch dieback caused by balsam woolly adelgid.

Severity: Cytospora canker occasionally reaches damaging proportions in years with conditions favorable for infection. It may be locally severe, especially in central and southern Oregon.

References: 73

- *Red-brown branch flags in true firs.*
- *Closely associated with true fir dwarf mistletoes.*

Figure 58a—Overview of numerous dead branches in heavily infected Shasta red fir.

Figure 58b—Branch flagging in crown caused by Cytopspora canker.

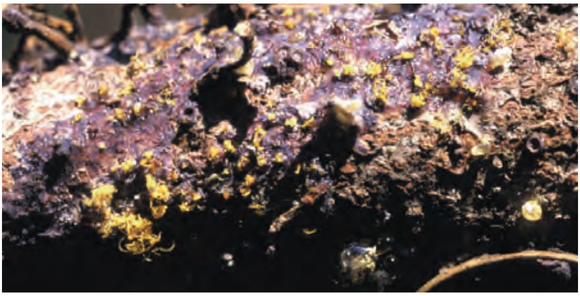


Figure 58c—Close-up of *C. abietis* yellow-orange spore tendrils.

DIPLODIA TIP BLIGHT

Pathogen: *Diplodia sapinea* (Fr.) Fuckel

Hosts: Primarily two- and three-needle pines, rarely other conifers.

Distribution and Damage: *D. sapinea* occurs throughout the western United States. The fungus is a weak parasite and usually infects only trees that are planted out of their natural environment or are weakened by drought or other agents. Topkill and occasional tree mortality occur.

Identification: Dying needles and twigs, as well as topkill and tree mortality are indicative of infection (Figs. 60a, b). Resin is often abundant on shoots at the bases of needles and buds (Figs. 60c, d). Fruiting bodies are tiny (less than 0.5 mm (1/64 in) in diameter), round, black, and embedded in the needles, in the bark of infected stems and on cone scales. Usually only a small portion of each fruiting body protrudes through the infected tissue, resembling a black pinpoint. Fruiting bodies usually are numerous.

Agents Producing Similar Symptoms and Signs: Tip and branch dieback on pines may also be caused by Atropellis canker, Lophodermella needle casts, western gall rust, western pine shoot borer, gouty pitch midge, pine bud mite, or injury caused by frost and drought. Shrunken resinous twigs and fruiting bodies help distinguish damage cause by this pathogen.

Severity: Damage caused by Diplodia tip blight often occurs in young plantations, particularly those planted with off-site stock or those situated on very dry sites. Significant damage, including some mortality, has occurred in mature ponderosa pine in the Willamette Valley and in interior valleys in southwestern Oregon.

References: 68

- *Drooping and dying needles and small twigs of pines.*
- *Sunken areas on young pine branches and stems.*

Figure 60a—Drooping needles and dead twigs caused by *D. sapinea* in larger ponderosa pine.

Figure 60b—Small ponderosa pine affected by Diplodia tip blight.

Figures 60c and d—Shrunken, resinous tissue typical of Diplodia tip blight.

DOUGLAS-FIR CANKERS

Pathogens: *Diaporthe lokoyae* Funk
(= *Phomopsis lokoyae*)
Dermea boycei (Dearn.) Rossman

Host: Douglas-fir. Grand fir is an occasional host for *D. boycei*.

Distribution and Damage: Douglas-fir cankers are common in western Washington and Oregon but also can be found in natural and planted stands elsewhere in the Pacific Northwest. These cankers occur periodically, typically 1 to 2 years after droughts, extreme temperature regimes, or other similar types of stand-level stresses. Single trees or small groups of young trees are affected. Topkill and branch dieback are common (Fig. 59a). Trees up to 8 cm (3 in) dbh may be killed.

Identification: The most obvious symptoms occur when foliage on individual branches or whole tops of trees fade to yellow or quickly turn red. Reddish discoloration on stems and branches is visible by late spring or early summer (Figs. 59b, c). Round to oval sunken cankers on affected limbs appear in the season of infection (Figs. 59b-d). Some resin flow may occur following infection. Bark sloughs off the following season (Fig. 59e). Small dead branchlets are frequently found in the center of cankers. Bark on dead growing tips has a blackish-brown scorched appearance.

Cankers caused by *D. boycei* have a characteristic reddish margin that disappears when affected trees die. Fruiting bodies may be found on the margins of cankers in spring and early summer. They are small black discs approximately 1 to 1.5 mm (about 3/64 to 1/16 in) in diameter.

D. lokoyae-caused cankers have no reddish margin. Small black fruiting bodies less than 0.5 mm (1/64 in) and embedded in the dead bark may be seen in the spring and summer.

Douglas-fir engraver beetles and Douglas-fir pole beetle are often associated with cankers. Wood boring insects may also be found in the wood killed by canker fungi.

Agents Producing Similar Symptoms and Signs: Frost and winter injury, drought damage, Douglas-fir engraver beetles, Douglas-fir pole beetle, and Douglas-fir twig weevil all cause similar symptoms on their own. On stressed sites, and during droughty periods, several agents may be working together to cause the symptoms.

Severity: Douglas-fir cankers are most severe in young plantations predisposed to infection by environmental conditions such as below normal precipitation or cold temperatures. Severe topkill may occur during these periods, causing breakage and deformity.

References: 29

- *Topkill and branch dieback of young Douglas-fir.*
- *Discolored, sunken areas on affected stems or branches.*

Figure 59a—Douglas-fir cankers frequently cause rapid topkill and branch dieback on affected trees. Younger trees are often affected during periods of stress.

Figure 59b and c—The dark sunken areas amidst living tissue on these Douglas-fir stems are cankers caused by *D. lokoyae.*

Figure 59d—Cutaway view of a canker showing the sharp demarcations between living and dead tissue.

Figure 59e—Older cankers exhibit sloughing bark.

GROVESIELLA CANKER

Pathogen: *Grovesiella abieticola* (Zeller and Goodd.) M. Morelet and Gremmen

Hosts: True firs.

Distribution and Damage: *G. abieticola* is found on true firs throughout the Pacific Northwest. It occurs sporadically. Infection results in annual cankers.

Twig dieback is the most common result of canker development; occasionally topkill or tree death occurs. Small trees are most often affected, however, lower branches of larger trees are also susceptible targets.

Identification: Topkill and dieback of small firs are the most obvious symptoms of infection (Figs. 61a, b). Slightly sunken dead tissue (canker) is seen on stems (Fig. 61c). Small, black, cup-shaped fruiting bodies, 0.5 to 1 mm (1/64 to about 3/64 in) in diameter, may be abundant on dead bark (Fig. 61d). The fungus primarily attacks 2-year-old or older stemwood or branches.

Agents Producing Similar Symptoms and Signs: Grovesiella canker may be confused with drought injury or Cytospora canker. The black fruiting bodies distinguish Grovesiella canker. Fir engravers infesting branches may cause similar symptoms on pole-sized trees.

Severity: Grovesiella canker can be locally severe in understory true firs, especially during protracted droughts.

References: General

- *Small twig dieback of true firs.*
- *Mortality of small, understory true firs following drought.*

Figure 61a—Mortality of understory white fir caused by Grovesiella canker.

Figure 61b—Twig dieback is the most common indicator of infection by *G. abieticola.*

Figure 61c—Sightly sunken dead tissue associated with Grovesiella canker.

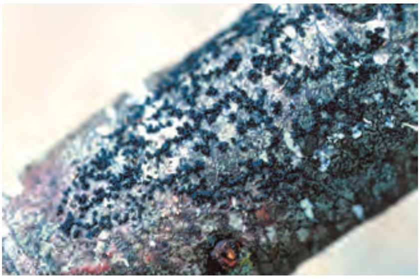


Figure 61d—Close-up of *G. abieticola* fruiting bodies.

STALACTIFORM RUST

Pathogen: *Cronartium coleosporioides* Arthur
(= *Cronartium stalactiforme*)

Hosts: Primarily lodgepole pine; less commonly ponderosa pine and Jeffrey pine.

Alternate Hosts: Members of the Scrophulariaceae Family, particularly *Castilleja* spp. (paintbrush).

Distribution and Damage: *C. coleosporioides* is found throughout Washington and Oregon. It causes stem malformation, breakage, pitch-soaked wood, and branch dieback. It may cause mortality of small trees when stems are completely girdled (Fig. 62c).

Identification: Young infections appear as spindle-shaped swellings on stems and branches. Clear "ooze" may be seen on the blisters of young cankers. Yellow spore pustules (aecia) form on the edge of active cankers in early summer (Fig. 62b). Older infections appear as diamond-shaped cankers that can be up to 9.1 m (30 ft) long (Fig. 62a). Cankers are pitch soaked and yellow (Fig. 62a). Bark sloughs off leaving ridges. Aecia are not easily seen on the margins of older cankers. Orange spore pustules (uredinia and telia) are produced on the leaves of the alternate hosts in the summer.

Agents Producing Similar Symptoms and Signs: Nonsporulating stalactiform rust cankers may be confused with Atropellis canker. Otherwise, confusion with comandra blister rust is most likely. Comandra blister rust cankers are usually 2 to 3 times longer than wide, whereas stalactiform rust cankers are very long and narrow, up to 10 times longer than wide.

Severity: Damage caused by stalactiform rust is greatest in southcentral Oregon on the central Oregon plateau.

References: 94

✦ *Lodgepole pine with cankers at least 10 times longer than wide.*

Figure 62a—Stalactiform rust cankers are pitch soaked and much longer than wide.

Figure 62b—Brightly colored spore pustules can be seen on the margins of active cankers in early summer.

Figure 62c—Small affected trees may die when their stems are completely girdled.

WESTERN GALL RUST

Pathogen: *Endocronartium harknessii* (J. P. Moore) Y. Hirats.
(= *Peridermium harknessii*)

Hosts: Very common on lodgepole pine and knobcone pine. May be locally important on ponderosa pine and Knobcone-Monterey hybrid pine.

Alternate Hosts: None

Distribution and Damage: *E. harknessii* is widespread throughout Washington and Oregon. It causes branch flagging (Fig. 63a), topkill (Fig. 63b), stem malformation, stem breakage, and mortality of young trees. Some brooming and proliferation of lateral branches may result from infection. Western gall rust is most commonly found in riparian areas or locations where moist air collects.

Identification: *E. harknessii* causes small to large, round to pear-shaped swellings on branches and stems (Figs. 63c-f). Inconspicuous white or colorless “ooze” may appear between the bark fissures in early spring. Bright yellow-orange spore pustules are produced in cracks in the galls in late spring and early summer (Fig. 63e). “Hip cankers” result when the main stem flattens and broadens as it grows around stem infections (Fig. 63f).

Agents Producing Similar Symptoms and Signs: The rounded galls are easily identified, especially when sporulating. Cankers of comandra rust or stalactiform rust are much longer and do not form galls.

Severity: Western gall rust can cause locally severe branch dieback. Damage is not usually significant on older trees if only branches are infected. Damage becomes more significant with main stem galls or with high numbers of branch infections on young trees. Trees with stem cankers are prone to breakage.

References: 66, 94

✦ *Round swellings or hip cankers on lodgepole pine, knobcone pine, or ponderosa pine.*

Figure 63a—Branch flagging on ponderosa pine caused by western gall rust.

Figure 63b—Topkill of small lodgepole pine caused by western gall rust.

Figure 63c—Western gall rust's most common indicators are round to pear-shaped swellings on pine branches and stems.

Figure 63d—Western gall rust's most common indicators are round to pear-shaped swellings on pine branches and stems.

Figure 63e—Bright yellow-orange aeciospores are visible on swellings when the fungus sporulates in late spring and early summer.

Figure 63f—"Hip-cankers" (partially grown over swellings on main stems) of western gall rust are prone to decay and breakage.

WHITE PINE BLISTER RUST

Pathogen: *Cronartium ribicola* J. C. Fisch.

Hosts: Western white pine, sugar pine, whitebark pine and limber pine.

Alternate Hosts: All *Ribes* spp.; *Pedicularis* spp. and *Castelleja* spp. at high elevations.

Distribution and Damage: *C. ribicola* is found throughout the range of five-needle pines in Oregon and Washington. It has had enormous impacts on five-needle pine populations. It causes branch flagging (Fig. 64a), topkill (Fig. 64b), and mortality of pines (Fig. 64c). Mountain pine beetles often attack infected older trees. Leaf spots and discoloration occur on *Ribes* spp.; defoliation may result from high infection levels.

Identification: Yellow and red needle spots appear on pine needles after infection. Spindle-shaped swellings subsequently form on branches (Fig. 64d). Sappy "ooze" appears on margins of cankers in spring. Bright yellow-orange pustules (aecia) with aeciospores are produced from raised blisters on the bark in spring and early summer (Figs. 64e, f). Bark tissue then dies. Cankers result in dead, roughened bark and have margins that appear greenish yellow to orange. Heavy pitch flow is often associated with cankers on the bole (Fig. 64c). Yellow to reddish pustules and tendrils of spores (uredinia and telia, respectively) appear on the undersides of *Ribes* spp. leaves in spring and summer (Fig. 64g).

Agents Producing Similar Symptoms and Signs: Atropellis cankers will not produce yellow-orange spores or spore pustules, but rather are distinguished by blue-black staining of the wood. Topkill caused by *Ips* species will appear similar from a distance but will not be associated with pitch streaming on the bark. Mountain pine beetles often attack trees with white pine blister rust.

Severity: White pine blister rust is the most significant disease of five-needle pines. *C. ribicola* is a non-native fungus; it was introduced to the west coast of North America in 1910 and rapidly spread throughout the range of five-needle pines, substantially decreasing host populations. It is a major killer of regenerating five-needle pines and makes reestablishment of wild populations of these species on high hazard sites difficult or impossible. White pine blister rust can significantly weaken large, older trees making them vulnerable to bark beetle attack. The disease has a significant role in altering stand structure and composition on sites where five-needle pines have major ecological roles.

References: 94

- *Five-needle pines affected.*
- *Yellow spores erupting from blisters.*
- *Diamond-shaped cankers on stems or spindle-shaped swellings.*
- *Pitch streaming from bole cankers.*
- *Branch flagging, topkill, mortality.*

Figure 64a—Scattered dead branches or "branch flags" in crowns of five-needle pines are symptoms of white pine blister rust.

Figure 64b—Bole cankers located in the upper portions of pines often girdle stems and cause topkill.

Figure 64c—Heavy pitch streaming is often associated with stem cankers. Small trees that are girdled at the base die from the effects of the disease.

Figure 64d—Spindle-shaped swellings form on branches after infection.

Figure 64e—Yellow-orange aeciospores erupt from bark blisters in late spring and early summer.

Figure 64f—Stem cankers often are distinctly diamond shaped.

Figure 64g—Infection on *Ribes* leaves causes leafspotting.

BALSAM WOOLLY ADELGID

Adelges piceae (Ratzeburg) (previously known as balsam woolly aphid)

Hosts: True firs, especially grand fir, Pacific silver fir, and subalpine fir.

Distribution and Damage: The balsam woolly adelgid is found throughout Oregon and Washington, most commonly in the western regions including the Cascade Mountains, and in the Blue Mountains. This insect sucks sap from the branches and boles of host trees while injecting toxic saliva, inducing changes in the sapwood that result in decreased water and nutrient transport. Chronic feeding progressively weakens trees, reduces cone production, and causes deformity and mortality. Infestations may occur on branches and terminal buds in the crown area only or on any thin-barked portion of the main stem. Trees with crown infestations take many years to die, while trees with severe stem infestations usually die within two or three years.

Identification: Knoblike "gouty" swellings at branch nodes and branch tips (Fig. 65a) and thin or misshapen crowns having shortened lateral branches, top curl, stunted terminal growth, scattered dead branches, abundant blackish *Bryoria* lichen growth, or general discoloration appearing blackish green to dark reddish brown can indicate presence of the balsam woolly adelgid (Figs. 65b, eII-V). Look on low branches, understory trees, fallen branches, and in the tops of windthrown trees for gouting and tiny white, cottony tufts on the bark (Fig. 65c). Beneath its white, woolly covering, the stationary, soft-bodied, aphidlike adult is about 1.5 mm (1/16 in) long, dark purple to black, and wingless. All individuals are females, and some may be covered with amber-colored eggs. Under magnification, the purplish-brown crawler stage may be observed moving about on the bark surface. The best times to see the adelgids are early summer and late fall, when adult population levels peak. The insects are difficult to find in the winter months and during some years.

Agents Producing Similar Symptoms and Signs: Abnormal crowns may occur in trees subjected to repeated heavy defoliation or growing on sites exposed to severe weather. Other unknown agents can cause well-defined branch swellings that are not restricted to branch nodes and terminal buds. Bark beetles, Cytospora canker, and hail also cause branchlet and branch mortality. Balsam woolly adelgid is distinguished by the white "wool"-covered adults and by the characteristic branch gouting and top abnormalities it causes. A similar-appearing species, the hemlock woolly adelgid, occurs on the branches of western hemlock (Fig. 119d).

Severity: The balsam woolly adelgid is a widely established non-native insect that causes subtle but significant long-term ecological effects. Chronic crown infestations may predispose trees to bark beetle attack and root disease intensification, and can severely limit natural regeneration or kill trees outright. Grand firs growing in the western lowland valleys, and subalpine firs and Pacific silver firs growing at the lower extremes of their elevational ranges are particularly susceptible. Infestations also tend to be more severe on trees growing at the edges of avalanche chutes, mountain meadows and lakes, and on lava flows (Fig. 65d).

References: 70

- *Stationary, white “woolly” tufts on tree branches and boles.*
- *Abnormally swollen branch nodes and terminal buds.*
- *Misshapen crowns.*
- *Thin, reddish-brown or blackish-green crowns.*

Figure 65a—"Gouting" of branch nodes and terminal buds caused by balsam woolly adelgid feeding.

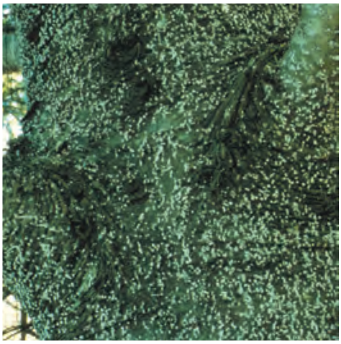


Figure 65c—Balsam woolly adelgid adults occur on tree boles and branches and look like tiny white cottony tufts.

Figure 65b—Symptoms of balsam woolly adelgid infestation include crown abnormalities such as top curl (left), and thin foliage, reduced terminal and upper crown lateral growth, and a dark, black-green appearance (right).

Figure 65d—Foliage discoloration and mortality of subalpine fir caused by the balsam woolly adelgid is often more severe along forest edges such as this avalanche chute.

Figure 65e—Healthy crown silhouette (I), and adelgid-infested crown silhouettes (II, III, IV, V).

CARPENTER ANTS

Camponotus spp.

Hosts: Dead wood (stumps, logs, snags, and wood structures) of all tree species.

Distribution and Damage: Carpenter ants are found throughout Oregon and Washington. These large ants are general feeders on animal and plant material and do not eat wood; however, they construct nests in it to rear their young. They may colonize dead interior portions of living trees, snags, down logs, stumps, or wood in service. Their excavations in the bases of fire-scarred and butt-rotted trees and snags weaken stems and predispose them to breakage. Carpenter ants sometimes damage young conifers by gnawing around the root collars.

Identification: External evidence of a carpenter ant colony in dead wood often consists of copious amounts of sawdustlike borings lying in piles on the ground beneath entrance holes (Fig. 66a). If a colony is present and active, you often will see large, dark-colored ants moving in and out of the entrance holes. Colonized or previously colonized stump or log interiors have honey-combed appearances (Figs. 66b, c). Tunnels extend in all directions, contain no debris, and have smooth walls. Carpenter ants are between 6 and 16 mm (1/4 and 5/8 in) long, and entirely black, brown, or red and black in color (Fig. 66d). They have elbowed antennae and a constricted “waist.” The winged forms often observed swarming in the spring are larger, between 19 and 25 mm (3/4 and 1 in) long. Their hind wings are smaller than their front wings, and the wings have few veins.

Agents Producing Similar Symptoms and Signs: Wood borers and dampwood termites may cause superficially similar signs and symptoms. However, dampwood termite galleries tend to follow annual rings and the gallery surfaces have a velvety appearance, while carpenter ant galleries are smooth walled and randomly oriented. Unlike wood borers, which construct individual tunnels filled with boring debris, carpenter ants honeycomb the wood interior with debris-free, interconnected galleries and produce large external piles of sawdustlike borings. Winged carpenter ants may be distinguished from winged termites by their elbowed antennae, constricted waist, and wing characteristics.

Severity: Carpenter ant damage to forest trees is usually minor and very localized. Excavations in the bases of snags and living portions of dead trees shorten the standing times of affected trees. Carpenter ants play important beneficial roles in forest ecosystems by helping to decompose woody debris, preying on defoliating insects such as western spruce budworm, and serving as important food sources for many wildlife species, including the pileated woodpecker. They can be important pests when they establish colonies in wooden buildings.

References: 5, 39, 40

- *Piles of sawdust at the base of dead wood.*
- *Dead wood honeycombed with smooth-walled galleries.*
- *Medium to large ants that are black, brown, or black and red.*

Figure 66a—Large piles of sawdust at the base of trees, snags, logs, or stumps are usually caused by carpenter ants.

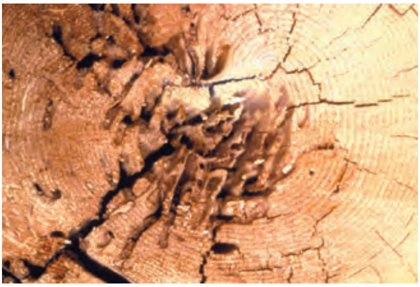


Figure 66b—Honeycomblike carpenter ant galleries.

Figure 66c—Carpenter ant nest in a down log.

Figure 66d—Closeup of a carpenter ant.

HORNTAILS (WOOD WASPS)

Several species, Family Siricidae

Hosts: Numerous conifers and hardwoods.

Distribution and Damage: Horntails are found throughout Oregon and Washington. The larvae mine through sapwood and heartwood in dead and dying trees, degrading logs used for lumber. Adults produce large exit holes in finished interior surfaces as they emerge in buildings constructed of lumber milled from infested, often windthrown or fire-salvaged, trees.

Identification: Larval galleries are circular tunnels about 5 mm (3/16 in) in diameter and are packed with fine boring dust and frass. The galleries extend into the sapwood and heartwood. Larvae are creamy white, round bodied, 25 to 38 mm (1 to 1-1/2 in) long, and have a short, dark spine on the ends of their abdomens (Fig. 67a) that is used to propel their bodies forward as they tunnel through wood. Larval development lasts 2 to 5 years. Emerging adults leave perfectly round, clean-cut exit holes. The robust, wasplike adults have long, cylindrical bodies without a noticeable constriction behind the wings (Fig. 67b). They are 2.5 cm (1 in) long or larger, and are often a dark metallic blue or black color with bold red, ivory, and yellow markings. Each adult has a short horn-like projection at the end of its abdomen. Females are larger than males and have long straight ovipositors that look like giant stingers. Flying adults make a noisy buzzing sound. They are especially attracted to trees freshly killed by fire.

Agents Producing Similar Symptoms and Signs: Roundheaded and flatheaded wood borers produce similar damage in sapwood and heartwood. The horntail larva is distinguished by its cylindrical body and the presence of a spine on its posterior end.

Severity: Horntails are nonaggressive, colonizing only dead and dying trees. The damage they cause usually is noticed only when lumber from fires and windthrown trees is marketed in large amounts. Damage typically is more cosmetic than structural, as the total number of adults emerging in a building constructed with infested lumber is normally quite small. Once emerged, horntails will not reinfest milled lumber. In the forest setting, they play an important role in cycling woody material back to soil.

References: 89

- *White larva with a single, short, dark spine on the posterior end of the abdomen.*


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Figure 67a—Horntail larva. Note spine on the tip of the abdomen.

Figure 67b—Adult female horntail.

PITCH MOTHS

SEQUOIA PITCH MOTH *Synanthedon sequoiae* (Hy. Edwards)
DOUGLAS-FIR PITCH MOTH *Synanthedon novaroensis* (Hy. Edwards)

Hosts: **Sequoia pitch moth:** Two- and three-needle pines, including ponderosa pine, lodgepole pine, and ornamental pines; also sugar pine and Douglas-fir.

Douglas-fir pitch moth: Douglas-fir, Sitka spruce, Engelmann spruce, ponderosa pine, western white pine, lodgepole pine, and wounded western larch.

Distribution and Damage: Pitch moths are found throughout Oregon and Washington. Attacks usually occur below 18 m (60 ft) on tree boles at limb junctions and around injuries. Egg-laying females are highly attracted to the odor of resin. Larval feeding in the cambium results in formation of pitch blisters, pitch seams, and on small trees, points of weakness that may contribute to stem breakage. Attacks are more frequent on trees pruned or girdled during spring, and near pruning cuts made inside the branch collar.

Identification: Look for large masses of cream-colored to yellow, pink, reddish, or gray pitch mixed with frass located on the bole of the tree at limb junctions or around injuries (Figs. 68a-c). Pitch masses can exceed the size of a fist on pines and tend to be smaller on other hosts. Fresh pitch masses may be pliable and globular, or may tend to flow or drip down the tree bole below the attack. Pitch masses can remain on the tree for many years, becoming flat, hard, and dirty gray as they age. Old attack sites are commonly reinfested, resulting in pitch masses comprised of soft fresh pitch mixed with crusty old pitch. Removal of a fresh pitch mass often exposes a single whitish caterpillar with a brown head (Fig. 68b) feeding on the cambium in a 2.5 to 15 cm (1 to 6 in) pit or tunnel. Mature larvae become as large as 3.8 cm (1-1/2 in) long. Development from egg to adult generally takes two to three years, with most of the life cycle spent as a larva feeding in the cambium. During their second year, larvae move to the outer pitch mass and pupate within amber-brown pupal cases that protrude through the pitch mass surface (Fig. 68d). Adults are daylight active during summer but rarely seen. They have transparent wings with black borders and resemble yellowjacket wasps in size and coloration, having striking yellow and black (sequoia pitch moth) or orange and black (Douglas-fir pitch moth) coloration (Fig. 68e).

Agents Producing Similar Symptoms and Signs: Red turpentine beetles, pitch nodule moths, and several species of *Dioryctria* moths not covered in this guide, including *D. cambiicola*, and *D. contortella*, produce pitch masses that could be confused with those caused by *Synanthedon* spp. *Synanthedon* pitch masses usually can be distinguished from those caused by red turpentine beetles and pitch nodule moths by their large size and association on the bole with limb junctions and injuries. Identification based on emerged adult morphology or taxonomic keys for larvae may be required to reliably distinguish *Synanthedon* spp. from *Dioryctria* spp. *Synanthedon* pitch masses are easily distinguished from other agents when they have protruding amber-brown pupal cases or are comprised of both old crusty pitch and soft fresh pitch.

Severity: The localized feeding of pitch moth larvae generally does not kill trees, but it lowers the quality of veneer and lumber produced. Very young, heavily attacked trees may experience reductions in growth rates or increased stem breakage. Young, fast growing trees 10 to 50 years old are most seriously affected. Pitch moth infestations are often more severe at off-site plantings, conifer seed orchards, and in urban settings.

References: 4, 19, 59

- *Large masses of cream, yellow, pink, or grayish pitch on the bole near limb junctions or injuries.*
- *Whitish caterpillar under a pitch mass.*
- *Dark brown pupa or pupal case protruding from a pitch mass.*

Figure 68a—Pitch masses created by *Synanthedon* pitch moths on pines usually are quite large.

Figure 68b—Sequoia pitch moth larva on ponderosa pine, exposed after pitch mass removal.

Figure 68c—Pitch moth pitch masses tend to be located at limb junctions or around injuries.

Figure 68d—Pitch moth pupal case protruding from pitch mass.

Figure 68e—Sequoia pitch moth (top) and Douglas-fir pitch moth (bottom). Note lack of abdominal constriction behind wings.

PITCH NODULE MOTHS

Retinia spp.

Hosts: Lodgepole pine, Sitka spruce, Engelmann spruce, grand fir, subalpine fir, and ornamental pines.

Distribution and Damage: Pitch nodule moths are found throughout Oregon and Washington. Larvae bore into the new and old growth of stems, twigs, and branches. Their feeding girdles and kills branch tips and terminal shoots and weakens main stems, predisposing young trees to wind and snow breakage.

Identification: A small, rounded, dirty lump of pitch and frass that is hollowed out beneath is formed at the point of attack (Fig. 69). Attacks usually occur at branchlet nodes, the crotch of branch junctions, and branch whorls but may also occur between nodes. Pitch nodules tend to be located on the upper sides of branches or junctions. Each pitch mass is about 13 to 25 mm (1/2 to 1 in) long and conceals a single feeding larva. Larvae are small, about 1.5 cm (5/8 in) and body color varies from creamy white to orange brown. Head capsules are reddish brown. Pupation occurs inside the pitch nodule. Adult moths are small, with 2.5 cm (1 in) wingspans and mottled tan, brown, or gray coloration. They fly in spring and summer. Most *Retinia* species have a one year life cycle.

Agents Producing Similar Symptoms and Signs: Pitch nodule moths may be confused with *Synanthedon* pitch moths and *Dioryctria* spp. The small size, domelike character, and location of their pitch nodules help distinguish pitch nodule moths from other agents.

Severity: Pitch nodule moths are minor pests of young trees. Attacks occur more commonly in plantations than in dense, naturally regenerated stands. Trees are seldom girdled and killed by larval activity, but may be weakened so that wind or snow breaks their tops.

References: 19

- *Small pitch nodule occurring at tree branchlet node, branch junction, or branch whorl.*

Figure 69—Small pitch mass of a pitch nodule moth on a young lodgepole pine. Attacks usually occur at branch junctions and branchlet nodes.

ROOT-FEEDING BEETLES

BARK BEETLES	*Hylastes* spp., *Hylurgops* spp., (see also *Pseudohylesinus granulatus*, p. 48)
WEEVILS	*Hylobius* spp., *Otiorhynchus* spp. (root weevils), *Panscopus* spp., *Pissodes* spp., *Steremnius* spp.
"WHITE GRUBS"	*Polyphylla decimlineata* (Say) (tenlined June beetle), *Polyphylla crinita* Le Conte

Hosts: Various conifers. White grubs and root weevils also feed on a wide variety of non-coniferous plant species.

Distribution and Damage: Many species of root-feeding beetles occur throughout Oregon and Washington. White grubs, root-feeding weevils, and *Hylastes* bark beetles sometimes damage or kill seedlings and saplings by feeding on their roots or girdling their main stems at or below the root collar. Several bark beetle and weevil species transmit the fungal pathogen that causes black stain root disease, carrying spores on their bodies from infected trees to new hosts. They feed on trees of all ages and are attracted to areas with freshly injured trees.

Identification: **White grubs:** Seedling roots are chewed or stripped, and large white grubs may be present in surrounding soil during spring and summer (Fig. 70a). Discoloration and wilting of seedling foliage is most evident during summer and fall. Grubs are 20 mm to 50 mm (3/4 to 2 in) long, "C-shaped," and somewhat hairy, with brown heads and three pairs of well-developed legs. The posterior end is slightly enlarged and appears darker due to soil particles showing through the body wall. Adults are big, robust beetles with large clublike antennae. They are about 25 to 35 mm (1 to 1-3/8 in) long, and longitudinally-striped cream and brown.

Root-feeding weevils: Seedling or saplings may be girdled at the root collar by adult weevils, which create irregular, open feeding galleries that extend through the bark to the sapwood and sometimes score the sapwood surface (Fig. 70b), or by the mining of weevil larvae under the bark. Alternatively, the bark of roots may be stripped and fine roots consumed by soil-inhabiting root weevil larvae (Fig. 70c). Weevil larvae are legless and cream-colored with brown heads (Fig. 70d). Some species pupate on the root inside distinctive "chip cocoons" made of long shredded wood fibers (e.g., Fig. 83c). Adults have elongated snouts, are 4 to 11 mm (5/32 to 7/16 in) in length, and colored brown, gray, or black, sometimes with lighter colored patches.

Root-feeding bark beetles: Egg and larval galleries containing frass are evident beneath the bark of roots or root collars. Larvae are legless and cream-colored with brown heads. Adult beetles are about 3 to 6 mm (1/8 to 1/4 in) long and reddish brown to black with rounded posteriors. *Hylastes* adult maturation feeding sometimes girdles small seedlings (Fig. 70e).

Agents Producing Similar Symptoms and Signs: Damage to seedlings and saplings may resemble that from other causes affecting the root system, such as drought or root diseases.

Severity: These insects generally are not important forest pests but occasionally can be serious in greenhouses, nurseries or high-value plantations. Some species facilitate infection and spread of root disease pathogens. Damage is often strongly associated with drought, recent site disturbance or conversion from sod, or sandy or gravelly soils. *Otiorhynchus* weevils are non-native.

References: 81

Figure 70a—"White grubs" and their feeding damage on Douglas-fir seedling roots.

Figure 70c—Soil-inhabiting root weevil larvae feed below ground, stripping off the root bark. Healthy seedling (left), root weevil-damaged roots (right).

Figure 70d—Root collar weevil (*Pissodes schwarzi*) larva in root collar of lodgepole pine.

- *Seedling or sapling crown discolored or wilted.*
- *Roots or root collar chewed, or girdled by galleries.*
- *Frass or chip cocoons at or below root collar.*
- *White grubs or larvae in soil near roots.*

Figure 70b—Adult root weevil (*Steremnius* sp.) feeding gallery. Note sapwood scoring near wound center.

Figure 70e—Root-feeding bark beetle (adult *Hylastes* sp.) damage on ponderosa pine seedling.

The following may also damage stems or roots:

Branch and Terminal

DWARF MISTLETOES

Arceuthobium spp.

Hosts: Eleven taxa of dwarf mistletoes affect native conifers in Washington and Oregon (Table 6). Major hosts include Douglas-fir, western larch, ponderosa pine, lodgepole pine, true firs, western hemlock, and mountain hemlock.

Distribution and Damage: Dwarf mistletoes are found throughout Washington and Oregon. Distribution of dwarf mistletoes usually coincides with the ranges of their host trees. The exceptions are 1) Douglas-fir dwarf mistletoe, which is not found north of the Calapooya Divide on the west slopes of the Cascades or in the Coast Range; and 2) true fir dwarf mistletoe, which does not occur in Washington north of Klickitat County.

Dwarf mistletoes are flowering plants. They are obligate parasites that depend almost entirely on food produced by their hosts. Growth loss, distortion, topkill, mortality and predisposition to attack by bark beetles result from dwarf mistletoe infections. Brooms, the abnormal proliferation of branches or twigs on a single branch, often form on infected trees. Stem infections may cause bole swellings and cankers that are colonized by stem decay fungi.

Identification: Dwarf mistletoe plants form shoots on branches or stems of host trees. Shoots are yellow, purple, brown, or olive green with small scalelike leaves and are 1 to 15 cm (1/2 to 6 in) in length, depending upon the dwarf mistletoe species involved (Figs. 71a-c). Distinct male or female flowers develop (Fig. 71a, b, d). Female plants produce tiny round to ellipsoidal fruit (Fig. 71b). When shoots are shed, small basal cups often remain embedded in the bark (Figs. 71e, f). Dwarf mistletoe species can be distinguished by differences in shoot length, color, and branching pattern. Brooms (Figs. 71i-o), cankers (Fig. 71p, q), and swellings (Figs. 71g, h, r) on stems and branches are also indicators of dwarf mistletoe infections. Branch dieback on true firs may indicate infection by dwarf mistletoe (Figs. 71p, q, r). However, for positive identification, plants or basal cups should be associated with these deformities whenever possible.

Agents Producing Similar Symptoms and Signs: Spruce broom rust (on spruces) and true fir broom rust (on true firs) will produce very compact brooms with chlorotic, reduced needles; yellow-orange aecia may be seen on needles in the summer. Elytroderma needle cast (on ponderosa pine), produces brooms that are generally tightly formed, sweeping upward from the ground. Needles are red in the spring, and black elongate fruiting bodies form on needles in the fall. Blue broom (on sugar pine), stimulation brooms produced after a stand has been thinned, or other brooming resulting from stimulation of adventitious buds resemble dwarf mistletoe infections but have no plants or fruiting structures associated with them. Dwarf mistletoe stem infections may be confused with stem cankers caused by fungi, sunscald, or mechanical injury.

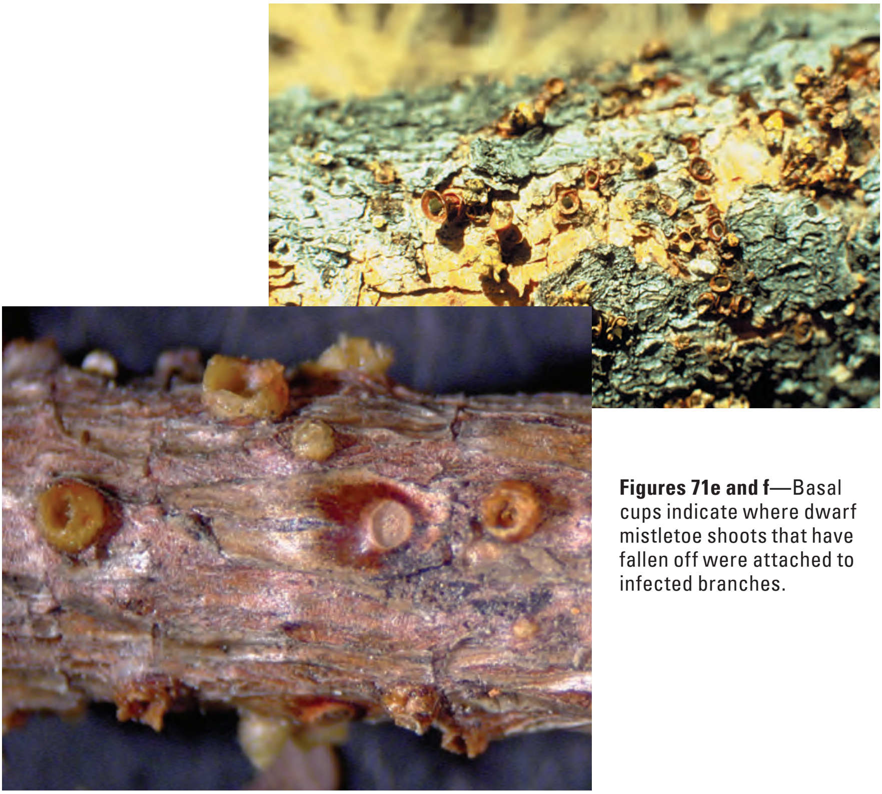
Severity: Effects of dwarf mistletoes on Douglas-fir, western larch, and ponderosa pine are very severe on a regionwide basis. For these affected species, growth loss is high at moderate severity levels (DMR 3 and 4, see p. 160) and mortality often occurs at high severity levels (DMR 5 and 6). For all other dwarf mistletoes, impacts increase with increasing infection level in the tree and generally result in increasing growth loss. Effects can be highly detrimental in young trees. Impacts are greatest in single-species host stands, and in stands with infected overstories above susceptible understories.

References: 2, 27, 35, 43, 45, 46, 52

Figures 71a and b—Shoots produced by Douglas-fir dwarf mistletoe are small; they are usually no longer than the tree's needles.

Figure 71c—Shoots of lodgepole pine dwarf mistletoe may be quite long.

Figure 71d—Male (right) and female (left) dwarf mistletoe plants on western hemlock. (Note different appearance of different-sex plants).



Figures 71e and f—Basal cups indicate where dwarf mistletoe shoots that have fallen off were attached to infected branches.

- *Brooms made of host foliage.*
- *Dwarf mistletoe plants. Look on the forest floor.*
- *Check understory trees of the same species if there are questions about brooms or cankers in overstory trees.*
- *Basal cups on broomed branches.*

Figures 71g and h—Branch swelling is often associated with western dwarf mistletoe infection.

Figures 71i and j—Brooms induced by Douglas-fir dwarf mistletoe often have branches that are elongated and drooping.

Figure 71k—Brooms and plants of western dwarf mistletoe.

Figure 71l—Lodgepole pine dwarf mistletoe brooms.

Figure 71m—Ponderosa pine mortality caused by western dwarf mistletoe.

Figure 71n—Dwarf mistletoe in western larch. Snow-loading and subsequent breakage of brooms often results in extensive loss of foliage.

Figure 71o—Dwarf mistletoe brooms in western hemlock often are relatively small.

Figures 71p and q—Dwarf mistletoe and Cytospora canker in white fir results in branch flagging.

Figure 71r—Stem infections of dwarf mistletoe may cause obvious swellings. Decay and stem breakage are often associated with stem infections.

Description of Hawksworth Dwarf Mistletoe Severity Rating (DMR) system

Assessing the severity of dwarf mistletoe infection (Fig. 72) within individual trees is accomplished by:

Step 1) Dividing the live crown of the tree into thirds.

Step 2) Rating each crown third separately according to the following scale:

- 0 No visible infections.
- 1 1/2 or fewer of the total number of branches in the third are infected.
- 2 More than 1/2 of the total number of branches in the third are infected.

Step 3) Adding the ratings for each third to obtain a rating for the entire tree.

A tree with an infection on the bole but none on the branches is given a total tree rating of 1. Otherwise, bole infections are not considered in the rating system.

**Douglas-fir dwarf mistletoe should be rated in a slightly different manner:* Because the plants are difficult to see (they are often the same length as the needles), severity should be assessed by determining the proportion of crown (rather than the number of infected branches) in each crown third that is in brooms. The numerical system described above is then applied.

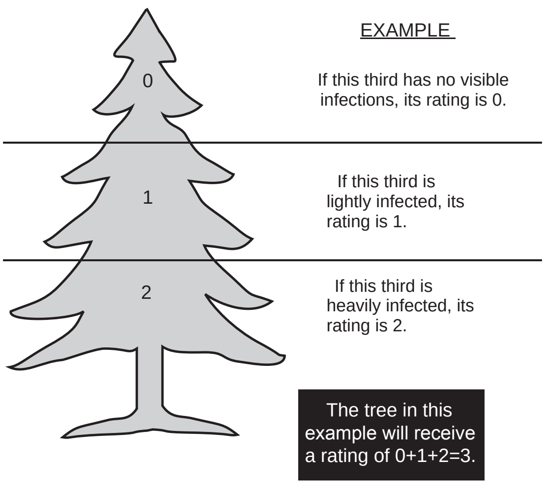


Figure 72 —The 6-Class Hawksworth Dwarf Mistletoe Rating System.

Table 6—Dwarf mistletoes found in Oregon and Washington.

Arceuthobium spp.	Principal Host[1]	Secondary Host[2]	Occasional or rare host[3]
A. abietinum f. sp. *concoloris*	white fir grand fir	Pacific silver fir Brewer spruce	subalpine fir, lodgepole pine, sugar pine, western white pine
A. abietinum f. sp. *magnificae*	Shasta red fir		
A. americanum	lodgepole pine		ponderosa pine, whitebark pine, Engelmann spruce, Douglas-fir, subalpine fir
A. campylopodum	ponderosa pine Jeffrey pine		lodgepole pine
A. cyanocarpum	whitebark pine limber pine	western white pine mountain hemlock	
A. douglasii	Douglas-fir		Pacific silver fir, grand fir, white fir, subalpine fir, Engelmann spruce
A. laricis	western larch mountain hemlock	lodgepole pine	Engelmann spruce, whitebark pine, ponderosa pine, white fir, western white pine, grand fir, Pacific silver fir, subalpine fir
A. monticola	western white pine	sugar pine	Brewer spruce, Jeffrey pine
A. siskiyouense	knobcone pine		lodgepole pine, Jeffrey pine, ponderosa pine
A. tsugense subsp. *mertensianae*	mountain hemlock Pacific silver fir noble fir subalpine fir	whitebark pine	western white pine, Brewer spruce, lodgepole pine, grand fir, western hemlock
A. tsugense subsp. *tsugense*	western hemlock Pacific silver fir noble fir subalpine fir		grand fir, lodgepole pine, western larch, Sitka spruce

[1] Infection factor of at least 90%, to nearly 100%; [2] Infection factor 50-90%; [3] Infection factor greater than 0, up to 50%

CYPRESS-JUNIPER MISTLETOE
"DENSE MISTLETOE"

Phoradendron densum Torr. Ex Trel.

Hosts: Cypress and juniper species.

Distribution and Damage: *P. densum* occurs in the southern Oregon Cascade Mountains. Infection can be conspicuous with many mistletoe plants occurring on individual host trees.

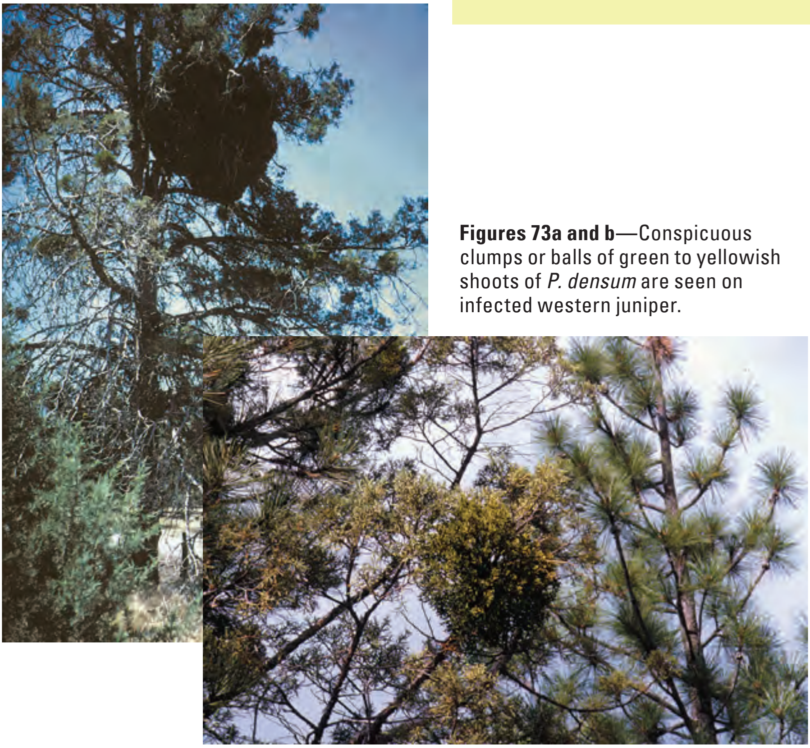
Identification: Clusters of greenish foliage occur on branches throughout the host crown (Figs. 73a, b). These clusters or small brooms are formed from the true mistletoe plant shoots and are not made up of host tree twigs and branches, as with dwarf mistletoes. Shoots bear narrow leaves that are usually 2 to 5 mm (1/16 to 3/16 in) wide and 12 to 20 mm (1/2 to 3/4 in) long (Fig. 73c).

Agents Producing Similar Symptoms and Signs: Juniper mistletoe will appear similar from a distance. However, a close examination of plants will show that juniper mistletoe is leafless.

Severity: Cypress-juniper mistletoe appears to have negligible affects on its hosts. *Phoradendron* species are true mistletoes. These flowering plants depend on their hosts for water and also obtain some nutrients from their hosts; however, they are capable of producing food via photosynthesis. Thus their impacts on individul trees are usually much less than impacts due to dwarf mistletoes.

References: 44

- *On juniper.*
- *Clumps of leafy plants.*



Figures 73a and b—Conspicuous clumps or balls of green to yellowish shoots of *P. densum* are seen on infected western juniper.

Figure 73c—Cypress-juniper mistletoe has conspicuous leaves.

JUNIPER MISTLETOE

Phoradendron juniperinum A. Gray

Hosts: Western juniper.

Distribution and Damage: *P. juniperinum* occurs along the eastern slope of the Cascade Mountains in central Oregon. Infection can be conspicuous with many plants occurring on individual host trees.

Identification: Conspicuous clumps or balls of green to yellowish shoots usually occur in the tops of trees (Fig. 74a). These clusters or small brooms are formed from the true mistletoe plant shoots and are not made up of host tree twigs and branches, as with dwarf mistletoes. Leaves have been reduced to inconspicuous scales less than 3 mm (about 1/8 in) long (Fig. 74b). Berries are light pink (Fig. 74c). This is the only leafless mistletoe occurring on juniper.

Agents Producing Similar Symptoms and Signs: Cypress-juniper mistletoe has conspicuous leaves.

Severity: Juniper mistletoe has negligible effects on its host. Phoradendron species are true mistletoes. These flowering plants depend on their hosts for water and also obtain some nutrients from their hosts; however, they are capable of producing food via photosynthesis. Thus their impacts on individual trees are usually much less than impacts due to dwarf mistletoes.

References: 44

- *On juniper.*
- *Clumps of leafy plants.*

Figure 74a—*P. juniperinum* plants on western juniper.

Figure 74b—Leaves of *P. juniperinum* have been reduced to inconspicuous scales less than 3 mm (about 1/8 in) long.

Figure 74c—Berries are light pink.

INCENSE-CEDAR MISTLETOE

Phoradendron libocedri (Engelm.) Howell

Hosts: Incense-cedar.

Distribution and Damage: *P. libocedri* occurs in southern Oregon. Many plants may occur on individual host trees, however incense-cedar mistletoe is rarely responsible for host mortality on its own. On older hosts, incense-cedar mistletoe occasionally builds up to high populations and may weaken trees, leaving them vulnerable to other agents. *P. libocedri* occasionally infects stems and causes swellings.

Identification: Incense-cedar mistletoe is the only true mistletoe of incense-cedar (Fig. 75a). It forms round, usually pendant green clumps of shoots (Fig. 75b). These clusters or small brooms are formed from the true mistletoe plant shoots and are not made up of host tree twigs and branches, as with dwarf mistletoes. Leaves are reduced to inconspicuous scales about 3 mm (1/8 in) long (Fig. 75c). Berries are light pink.

Agents Producing Similar Symptoms and Signs: Dwarf mistletoes (*Arceuthobium* spp.) do not occur on incense-cedar. Incense-cedar mistletoe infections are most commonly confused with incense-cedar rust brooms. Incense-cedar rust brooms are formed of densely compact host branches, whereas incense-cedar mistletoe is indicated by rounded clusters composed of the true mistletoe shoots themselves.

Severity: Incense-cedar mistletoe usually causes little damage. *Phoradendron* species are true mistletoes. These flowering plants depend on their hosts for water and also obtain some nutrients from their hosts; however, they are capable of producing food via photosynthesis. Thus their impacts on individual trees are usually much less than impacts due to dwarf mistletoes.

References: 44

- *On incense-cedar.*
- *Clumps of leafless shoots that are not host branches.*

Figure 75a—True mistletoe plants on incense-cedar.

Figure 75b—Incense-cedar mistletoe forms round, usually pendant green clumps of shoots.

Figure 75c—Leaves of *P. libocedri* are reduced to inconspicuous scales about 3mm (1/8 in) long. Berries are light pink.

INCENSE-CEDAR RUST

Pathogen: *Gymnosporangium libocedri* (Henn.) F. Kern

Hosts: Incense-cedar.

Alternate Hosts: Rosaceous shrubs, predominantly *Amelanchier* spp. and *Crataegus* spp. Also occasionally apple, pear, quince, and mountain ash.

Distribution and Damage: *G. libocedri* is found throughout the range of incense-cedar in Oregon. It causes spindle-shaped branch and trunk swellings on incense-cedar, may cause small brooms, and can contribute to death of small sprays of foliage. Heavy infection may result in crown deformation. *G. libocedri* causes spotting of leaves, fruits, and tender shoots of alternate hosts.

Identification: In early spring, foliage on branches of infected incense-cedar appears slightly discolored. Small brown tufts can be found on the underside of foliage. These mature to become conspicuous red-orange, gelatinous spore pustules (telia) later in spring (Figs. 76c, d). The telial masses dry to an orange-brown crust in summer (Fig. 76e). Erect brooms composed of host foliage are eventually formed at many infection sites (Figs. 76a, b).

Agents Producing Similar Symptoms and Signs: Dwarf mistletoes (*Arceuthobium* spp.) do not occur on incense-cedar. Brooming caused by incense-cedar mistletoe can be confused with incense-cedar rust brooms. Rust brooms are composed of tightly clumped host foliage. “Brooms” associated with incense-cedar mistletoe are clusters of mistletoe plant shoots.

Severity: Incense-cedar rust is commonly seen during moist springs. It generally has minor effects on its hosts. Growth loss may occur in small trees that are very heavily infected.

References: 94

- *Clumps or brooms consisting of host foliage.*
- *Orange-red gelatinous masses on foliage during spring.*

Figure 76a and b—Tight compact brooms of host foliage are formed in response to *G. libocedri* infection.

Figure 76c—Orange-red gelatinous telial masses are visible on infected incense-cedar foliage during spring.

Figure 76d—Close-up of orange-red gelatinous telial masses on incense-cedar foliage in spring after rain.

Figure 76e—Telial masses dry to an orange crust in summer.

FIR BROOM RUST

Pathogen: *Melampsorella caryophyllacearum* J. Schröt.

Hosts: All true firs.

Alternate Hosts: *Cerastium* spp. (chickweed) and *Stellaria* spp.

Distribution and Damage: *M. caryophyllacearum* is found throughout Washington and Oregon, causing brooms on true firs. Severe infection may result in stem malformation, decay, growth loss, and occasional mortality. The fungus causes a leaf or shoot blight of chickweed.

Identification: Conspicuous, dense, usually upright brooms, composed of host branches and twigs on true firs (Figs. 77a, b). Needles within brooms are usually yellow and are shorter and thicker than healthy needles (Fig. 77c). Yellow spore pustules (aecia) appear in great numbers on needles of the brooms in summer (Fig. 77d). Broom foliage often dies in the fall. Orange spore pustules (uredinia and telia) occur on chlorotic alternate host leaves in spring and summer.

Agents Producing Similar Symptoms and Signs: Dwarf mistletoe brooms may appear similar to broom rust infections from a distance. True fir dwarf mistletoe brooms are not usually dense, tightly formed, and upright. Foliage associated with dwarf mistletoe brooms is not chlorotic; no yellow spore pustules occur.

Severity: Fir broom rust is not usually considered damaging at the stand level. It can have severe impacts on individual trees that are heavily infected. The disease may be of local importance.

References: 67, 94

- *Dense, chlorotic brooms on true firs.*
- *Yellow-white spores on needles of brooms in spring.*
- *Needle shed from brooms in the fall.*
- *No dwarf mistletoe plants associated.*

Figures 77a and b—Tight, chlorotic branches with shortened needles make up the diagnostic brooms caused by *M. caryophyllacearum.*

Figure 77c—Needles infected by *M. caryophyllacearum* become thickened, short, and yellow.

Figure 77d—Close-up of yellow aecia on infected true fir needles.

SPRUCE BROOM RUST

Pathogen: *Chrysomyxa arctostaphyli* Dietel

Hosts: Engelmann and Sitka spruces.

Alternate Hosts: *Arctostaphyllos uva-ursi* (bearberry or kinnikinnick).

Distribution and Damage: *C. arctostaphyli* is found throughout Washington and Oregon causing brooms on spruce. Heavy infection may result in spike tops, dead branches, stem deformity, growth loss, and occasionally, mortality. Brooms may provide entrance courts for decay fungi. *C. arctostaphyli* causes a purple-brown leafspot on kinnikinnick.

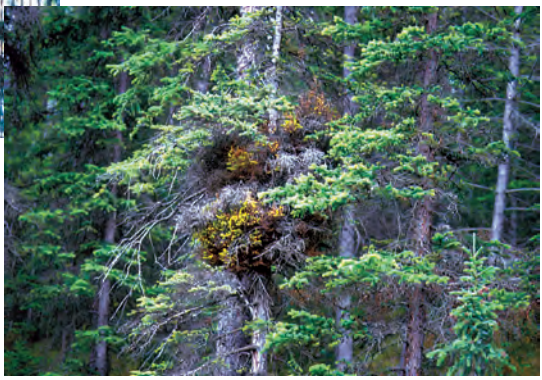
Identification: Conspicuous, dense brooms composed of host branches and twigs with chlorotic, short, thick needles are found on host branches (Figs. 78a-c). Brooms appear chlorotic. Whitish-yellow spore pustules (aecia) occur in great numbers on the foliage of brooms in the summer (Fig. 78d). Needles die and are shed in the fall. Orange-brown spore pustules (telia) occur on the undersides of kinnikinnick leaves in late spring.

Agents Producing Similar Symptoms and Signs: Dwarf mistletoe brooms may appear similar to broom rust infections from a distance. However, spruces are only occasional or rare hosts of dwarf mistletoes in Oregon and Washington. Dwarf mistletoe plants or evidence of plants are usually present on dwarf mistletoe-infected trees. Also, foliage associated with dwarf mistletoe brooms is not chlorotic; yellow-white spore pustules do not occur.

Severity: Spruce broom rust is not usually considered damaging at the stand level. Individual trees may be severely impacted when heavily infected. It may be of local importance.

References: 94

- *Dense, chlorotic brooms on spruce.*
- *Yellow-white spores on needles of brooms in spring.*
- *Needles shed from brooms in the fall.*
- *No dwarf mistletoe plants associated.*



Figures 78a and b—Tight, chlorotic branches with shortened needles make up the diagnostic brooms caused by *C. arctostaphyli.*

Figure 78c—Needles infected with spruce broom rust become stunted and yellow.

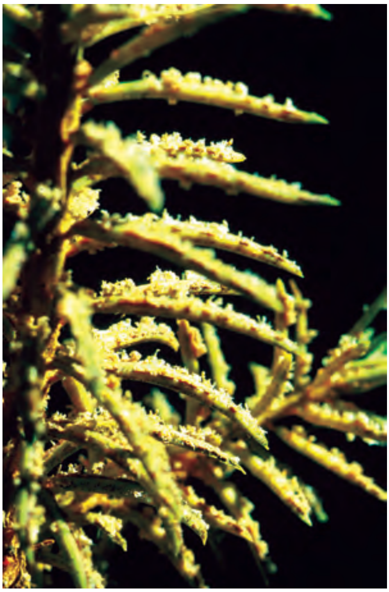


Figure 78d—Close-up of yellow aecia on infected spruce needles.

BLUE BROOM

Pathogen: None known

Host: Sugar pine

Distribution and Damage: Blue broom occurs sporadically in the southern Oregon Cascade and Siskiyou Mountains. There is no known cause for blue broom.

Identification: Conspicuous clumps or balls of foliage scattered in the crown but more prevalent in the tops of trees (Fig. 79a). Broomed branches often fall to the ground (Figs. 79b, c).

Agents Producing Similar Symptoms and Signs: Many people who see blue brooms assume that they are caused by dwarf mistletoe. However, sugar pine is not a common host of dwarf mistletoe in Oregon. Blue brooms lack mistletoe plants. The very dense, tight clusters of foliage are not typical of brooms caused by dwarf mistletoes.

Severity: Though often quite noticeable, blue broom appears to have negligible effects on its host.

References: General

OTHER BROOMING

Tight clusters of branches and dense foliage that are not associated with insects, mites, or pathogens sometimes occur in trees. These are often referred to as "physiological brooms" or "genetic brooms." These brooms are relatively uncommon, and when present, usually occur singly in a given tree. No plants, fruiting structures, feeding patterns, or other biotic indicators are associated with these types of brooms. Brooming apparently results from mutation in vegetative cells.

Tight clumps of branches known as adventitious shoots may form on stems or limbs of conifers in response to injury or other stresses (Figs. 79d, e). Adventitious shoots grow from buds that are released or formed along the bole or limbs of trees. These buds respond when apical buds die or lose their normal dominance. Severe loss of branches due to wind, hail, mechanical pruning, substantial changes in light when stands are thinned widely, or dieback resulting from defoliation or disease may trigger the growth of adventitious shoots. "Brooms" formed by adventitious shoots are usually small and clustered tightly around a bud or group of buds. No plants or fruiting bodies are found associated with adventitious shoots.

- *Dense cluster of foliage on sugar pine.*
- *No dwarf mistletoe plants associated with brooming.*

Figure 79a—Blue brooms are composed of dense clumps of sugar pine foliage.

Figure 79b—Close-up of blue broom.

Figure 79c—Old, dead blue brooms often may be found on the ground at the base of the tree.

Figure 79d—Broomlike epicormic branches formed in response to recurring, high winds. Similar branching patterns may occur on trees recovering from severe defoliation by insects such as the western spruce budworm or Douglas-fir tussock moth.

Figure 79e—Broomlike branching patterns resulting from stimulation of adventitious shoots after pruning and/or thinning.

Branch and Terminal Insects

Many insects, including various species of beetles, moths, adelgids, and flies, colonize the shoots, twigs, or branches of coniferous trees (Figs. 80a-c). Although most are seldom noticed and innocuous, having neutral to mildly beneficial effects (such as aiding natural branch pruning), some fairly harmless branch and terminal insects are associated with eye-catching symptoms, and a few can cause damage that significantly affects tree growth, form, and long-term survival.

Although infestations can be locally severe, most branch and terminal insect activity is of little significance in natural forest settings. However, these insects can be significant pests in agricultural settings such as Christmas tree plantations, conifer seed orchards, and nurseries, and they often are a source of concern for homeowners.

Younger trees in the sapling, pole, or small tree size classes tend to be more seriously affected by branch and terminal insects than older, larger trees, and insects that injure the terminal leaders of young trees generally cause the greatest detrimental impacts. It is rare for even the most damaging branch and terminal insects to directly cause tree mortality; rather, they may stunt growth to the point that host trees take a long time to reach mature size, and in mixed stands, are prevented from successfully competing with the growth of other, non-host tree species. In some cases, they may cause tree deformation to the extent that the economic value of the wood is much reduced. In addition, some branch and terminal insects may lower cone production when they kill cone-bearing branches. Generally speaking, the most important branch and terminal insect pest in the Pacific Northwest is the white pine weevil on Sitka spruce, because of its severe impact upon Sitka spruce regeneration (Figs. 80b, 83a-d).

References: General

Figure 80a—European pine shoot moth, *Ryaciona buoliana,* distorts and kills the buds and shoots of pines. It commonly damages ornamental pines but rarely is a problem in natural forest settings.

Figure 80b—The current and previous year's terminal growth of this young Sitka spruce have been killed by the white pine weevil.

Figure 80c—Some species of adelgids cause the formation of conelike galls on spruce branches.

LODGEPOLE TERMINAL WEEVIL

Pissodes terminalis Hopping

Hosts: Lodgepole pine is most affected; also occurs on other pines.

Distribution and Damage: Lodgepole terminal weevil is found throughout Oregon and Washington. Larvae kill current-year growth of the terminal leaders of young pines. Terminal leader death results in reduced height growth and produces main-stem deformity or a bushy, multiple-topped tree. The weevils most commonly occur in open-grown, even-aged stands of young trees which are 0.3 to 9 m (1 to 30 ft) tall.

Identification: Adults make feeding punctures and egg niches in the bark of terminal shoots in the spring. Resin droplets are associated with these wounds. Adults are about 6 mm (1/4 in) long, have long, slender beaks, and are reddish brown with patches of gray or brown scales. In early summer, newly hatched larvae first mine beneath the bark and then later mine the pith. Tunnels are loosely filled with tiny curled shavings. Mature larvae are about 8 mm (5/16 in) long, cream-colored, wrinkled, and legless. Infested terminals begin to discolor and may droop in midsummer (Fig. 81a), then die and turn reddish brown by late summer or fall of the same year that they become infested (Fig. 81b). Pupal "chip cocoons" composed of shredded wood fiber are evident under the bark of the terminal leader by August (e.g., Fig. 83c). Large holes made by emerging adults may be visible on the dead leader in late summer and fall.

Agents Producing Similar Symptoms and Signs: Western pine shoot borer and other terminal feeders produce similar damage. Canker diseases also cause terminal leader death. The lodgepole terminal weevil may be distinguished on the basis of adult appearance, legless larvae, chip cocoons, and damage characteristics.

Severity: Although damage caused by the lodgepole pine terminal weevil may be locally severe, in general it is a minor forest pest.

References: 23

- *Discolored, drooping, or dead terminal leader.*
- *Mining under bark and in pith of affected leader.*
- *Legless larvae or chip cocoons under bark of affected leader.*

Figure 81a—Discolored, drooping terminals indicate infestation by the lodgepole terminal weevil.

Figure 81b—Lodgepole pine terminals killed by the lodgepole terminal weevil.

WESTERN PINE SHOOT BORER

Eucosma sonomana Kearfott

Hosts: Ponderosa pine is the principal host; also found on lodgepole pine, Jeffrey pine, and knobcone pine.

Distribution and Damage: The western pine shoot borer is found throughout Oregon and Washington. Larval mining in the pith of new terminal and lateral shoots stunts or kills them, depending on their diameter. When infested, the large terminal shoots of ponderosa pine, Jeffrey pine, and knobcone pine usually become stunted, while the smaller-diameter terminal shoots of lodgepole pine and the lateral shoots of any host usually die. Occasionally, terminal buds are killed. Repeated attacks reduce tree height, and may cause forking and excessive branching. Significant growth loss occurs primarily in young, open-grown stands of even-aged ponderosa pine that are 1.3 to 6.5 m (4 to 20 ft) tall.

Identification: On ponderosa, Jeffrey, and knobcone pine, compare the length and appearance of live terminal shoots and their adjacent lateral branches found in the uppermost whorl. Unlike their healthy counterparts, infested terminal shoots often are shorter than adjacent laterals. Infested terminals appear stunted and develop a “shaving brush” appearance, with a compact arrangement of shortened needles at their tops (Fig. 82a). Look also for scattered dead lateral shoots. On lodgepole pine, dead or dying terminals and laterals may indicate western pine shoot borer activity. When split in two lengthwise, infested shoots will show a dark brown color in their piths where larval feeding occurred (Fig. 82b). Uninfested terminals have uniformly light-colored piths. Cream-colored larvae may be present in shoots dissected in early to midsummer. A single larva occupies each infested shoot. External evidence of infestation, such as frass, webbing, or debris, is absent while the larva feeds in the shoot. Circular, often pitch-filled exit holes made when the larvae leave to pupate in the soil become visible on the outside of the shoot in midsummer.

Agents Producing Similar Symptoms and Signs: Canker diseases and other shoot borers such as lodgepole terminal weevil also cause dead shoots in pine. The western pine shoot borer may be distinguished by its tunnels, which are long, packed with dark frass, and centered in the pith. No other agent produces the shortened, compacted, shaving-brush appearance of terminal leaders.

Severity: Western pine shoot borer is generally considered a problem only on trees managed for wood or fiber production. It does not kill trees, but can cause significant growth loss by reducing the rate of tree height growth.

References: 23, 72

- *Stunted, green terminal leaders with “shaving brush” appearance.*
- *Mined pith packed with dark frass.*

Figure 82a—Ponderosa pine terminal and lateral shoot damage by western pine shoot borer. Note stunted, “shaving brush” appearance of terminal leader, and dead small-diameter lateral shoot at lower right.

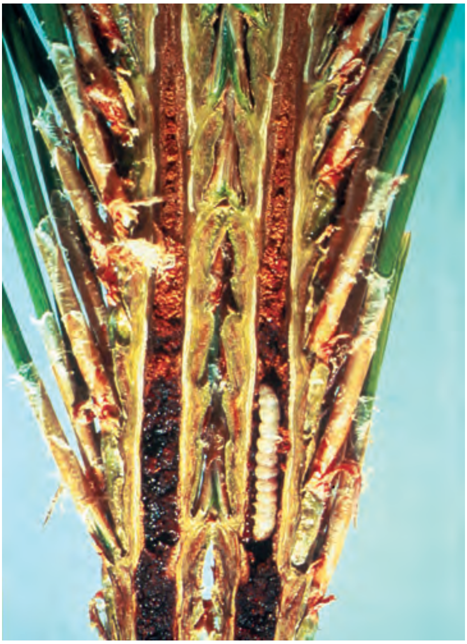


Figure 82b—Dissected ponderosa pine terminal with western pine shoot borer larva feeding in the pith. Note diagnostic dark brown color of the packed frass behind the larva.

WHITE PINE WEEVIL on SPRUCE

Pissodes strobi (Peck), once considered to be three distinct species: Sitka-spruce weevil, *Pissodes sitchensis* (Hopkins), Engelmann spruce weevil, *Pissodes engelmanni* (Hopkins), and white pine weevil, *Pissodes strobi* (Peck)

Hosts: Sitka spruce and Engelmann spruce, ornamental spruces.

Distribution and Damage: White pine weevil is found throughout the range of Sitka spruce and Engelmann spruce in Oregon and Washington. Larvae kill or severely injure current- and previous-year terminal growth of young spruce as they mine downward through the inner bark and girdle the terminal stem, causing reduced height growth, forked tops, and crooked stems. Repeated occurrences may result in other tree species outcompeting spruce for dominance in affected stands. Weevils begin attacking trees when they are 1 m (3 ft) tall, and rarely attack trees taller than 18 m (60 ft). Open-grown, even-aged stands of young spruce trees that are 1.4 to 9.1 m (4-1/2 to 30 ft) tall are highly susceptible to frequent attacks.

Identification: In spring, copious resin flow from small punctures near the top of the previous year's leader indicates new attacks by egg-laying female weevils, which can be recognized by their long, slender, curved beaks and roughened, reddish-brown wing covers with patches of lighter brown or gray scales (Fig. 83d). By midsummer, the new shoot growing from the top of the infested leader begins to droop in a characteristic manner reminiscent of a shepherd's crook (Fig. 83a). The needles of the 1-year-old portion turn yellowish, and larval mining is evident under the bark. Larvae are legless, wrinkled yellowish white grubs with light brown heads and are about 5 mm (13/64 in) long. They are present beneath the bark of the 1-year-old portion of the terminal leader from early to midsummer. The drooping leader turns reddish brown and brittle by late summer or fall (Fig. 83b). Pupal "chip cocoons" composed of shredded wood fiber are evident under the bark of the dead terminal leader by August (Fig 83c). In the fall, new adults make exit holes in the bark of infested leaders as they emerge from pupation. Killed leaders frequently break off during the winter. Previous attacks are indicated by deformed or discolored terminals, bushy, stunted trees, crooked stems, stems with forks or multiple leaders, and remnant stubs of killed leaders at branch whorls along the main stem. Larval mines, chip cocoons, and exit holes may be visible for many years on these remnant stubs.

Agents Producing Similar Symptoms and Signs and Signs: None.

Severity: White pine weevils can seriously impact the growth of young spruce plantations. Egg-laying females show a preference for the longest leaders, and thus attack the fastest growing trees. In some stands, nearly 50 percent of the trees are infested each year. Generally damage is less severe within 2 miles of the coast; however, in western Washington damage is less severe inside the variable width of the coastal fog belt. White pine weevil has made it nearly impossible to successfully regenerate Sitka spruce stands in many areas, and is the most injurious insect attacking spruce reproduction in Oregon and Washington.

References: 86, 93

- *Discolored, drooping, "shepherd's crook" terminal leader.*
- *Mining or chip cocoons under previous-year bark.*

Figure 83a—White pine weevil larvae feed under the bark of spruce terminals, causing them to wilt in midsummer and then die.

Figure 83b—Spruce terminal leaders killed by the white pine weevil resemble a shepherd's crook.

Figure 83c—"Chip cocoons" constructed by terminal weevils under the bark of a spruce terminal.

Figure 83d—White pine weevil adult.

COOLEY SPRUCE GALL ADELGID on SPRUCE

Adelges cooleyi (Gillette)

Hosts: Engelmann spruce, Sitka spruce, Brewer spruce, and ornamental spruces (Alternate and secondary host: Douglas-fir).

Distribution and Damage: Cooley spruce gall adelgid is found throughout Oregon and Washington. It has a complex life cycle that includes several forms, alternate hosts, and may extend over two years. One form of this insect alternates successive generations between spruce and Douglas-fir. Other forms cycle successive generations on one host (spruce or Douglas-fir) without alternating to the other host. Cooley spruce gall adelgids feed by sucking plant fluids through their straw-like mouthparts. On spruce, their feeding causes formation of cone-shaped galls on the branch tips of spruce trees. On Douglas-fir, they feed on new foliage and young growth without forming galls (see p. 274).

Identification: Immature Cooley spruce gall adelgids feed at needle bases on expanding branchlet shoots, stimulating formation of elongate, conelike galls that are about 13 to 75 mm (1/2 to 3 in) long (Fig. 84a). Galls start to form by June or July. As the galls form, they enclose the stationary feeding nymphs and provide protective habitat. Developing galls are terminal and usually involve an entire branchlet shoot (one season's growth). They are covered with needles, somewhat flexible, and dark green to light purple from early spring to late summer while they contain the adelgid nymphs. As the galls mature, openings develop through which the nymphs exit. The newly emerged nymphs molt to winged adults that can migrate to Douglas-fir. After the insects leave, the galls harden and turn brown, developing an appearance that is reminiscent of a pineapple (Fig. 84b). The galls may persist on the host tree for several years.

Agents Producing Similar Symptoms and Signs: Several *Pineus* adelgid species induce similar conelike galls and have similar impacts on spruces, including *Pineus similis* (ragged spruce aphid), and *P. pinifoliae*. These species are most prevalent in coastal areas, being relatively uncommon on inland sites, and are considerably more common in western Washington than in other vicinities. Galling adelgid species on spruce cannot be reliably identified using gall morphology alone due to overlapping variations in gall structure among species. However, galls caused by *Pineus* species tend to be "looser," or more flexible, than those produced by the Cooley spruce gall adelgid. When viewed in cross-section, adjacent chambers in *Pineus* galls interconnect, while chambers in *Adelges* galls remain separated by gall tissues.

Severity: Young trees tend to be more affected than older trees. Galls are often noticeable but are of little importance under natural forest conditions.

References: 11, 20

- *Green or brown conelike galls on spruce branches.*

Figure 84a—Cooley spruce gall adelgid feeding causes spruce to develop conelike galls.

Figure 84b—Galls turn brown and harden in autumn after the adelgids leave.

DOUGLAS-FIR TWIG WEEVIL

Cylindrocopturus furnissi Buchanan

Hosts: Douglas-fir; occasionally noble fir and other true firs.

Distribution and Damage: Douglas-fir twig weevil is found throughout Oregon and Washington. Larval feeding kills small branches and terminal leaders on young trees less than 4.5 to 6 m (15-20 ft) tall (Figs. 85a, b). Height growth is slowed, and trees may be deformed. Trees smaller than 1.5 m (5 ft) are sometimes killed.

Identification: Look for scattered dead twigs, bark irregularities (calluses, abnormal cracking, reddish-brown necrotic areas, swellings), and tiny exit holes on the bark surface left by emerging adults. Severely affected smaller trees appear generally unthrifty, having yellow-green foliage or terminal dieback (Fig. 85b). Branch infestations tend to be heaviest on 2-year-old growth. Split open affected twigs or stems to look for feeding galleries and frass under the bark, mined piths, L-shaped pupation chambers, and tiny white larvae or pupae. Examine or beat branches to dislodge adults. Infested noble fir twigs often have resin exudate on their bark surfaces.

Adult weevils are about 3 mm (1/8 in) in length, have long, slender, curved beaks, and dark bronze bodies and legs with light-colored mottling (Fig. 85c). Adults are present year-round, but most abundant mid-June through fall. They feed on tender twigs before depositing eggs in small bark punctures on 1- to 3-year-old twigs. Eggs are laid in the fall and, to a much lesser extent, spring. The legless, white to cream-colored larvae grow to about 4 mm (5/32 in) long (Fig. 85d). Larvae may be found beneath the bark from fall to mid-summer. Maturing larvae may mine the pith before pupating in L-shaped pupation chambers in the pith and xylem of the killed twig. Most pupation occurs during May and June.

Agents Producing Similar Symptoms and Signs: Similar damage is caused by other twig miners, including *Pityophthorus orarious, Argyresthia pseudotsuga*, and *Dioryctria* spp. Damage to Douglas-fir saplings by Douglas-fir engraver beetles and Douglas-fir pole beetle may superficially resemble that caused by this weevil. Necrotic bark patches, branch dieback, and seedling mortality also can be caused by severe winter cold and Douglas-fir cankers. Damage caused by Douglas-fir twig weevil may be distinguished by larval characteristics and the presence of mining under the bark and in the pith of killed twigs that are not wilted.

Severity: Damage is most common on young, open-grown Douglas-fir trees growing in the drier portions of the range of Douglas-fir or on droughty soils. Damage is associated with trees growing under stress conditions and is most pronounced in drought years (Fig. 85e). In the Willamette Valley, *C. furnissi* frequently infests noble fir Christmas trees growing on heavy, waterlogged soils. Effects are of minor importance in natural stands, but may sometimes be important in forest plantations, conifer seed orchards, urban settings, and Christmas tree plantations.

References: 31

- *Dead twigs on young, open-grown Douglas-fir trees.*
- *Bark irregularities, mined pith, frass and feeding galleries under twig bark, exit holes.*

Figure 85a—The Douglas-fir twig weevil kills small branches on open-grown Douglas-fir reproduction.

Figure 85b—Terminal mortality and chlorosis caused by severe infestation of Douglas-fir twig weevil.

Figure 85c—Douglas-fir twig weevil adult.

Figure 85d—Douglas-fir twig weevil larvae mine beneath the bark and in the pith of host tree twigs and young stems.

Figure 85e—Larger trees occasionally are damaged by the Douglas-fir twig weevil during droughty periods.

GOUTY PITCH MIDGE

Cecidomyia piniinopis Osten Saken

Hosts: Ponderosa pine; occasionally lodgepole pine.

Distribution and Damage: Gouty pitch midge is found throughout Oregon and Washington. Larvae feed in the vascular tissue of current-year shoots, causing them either to twist and become stunted or to die. Young, open-grown trees 1.2 to 5 m (4 to 16 ft) tall are most commonly infested, especially in plantations. Severe attacks retard tree growth and repeated severe attacks may kill small trees.

Identification: Look for dead needles, dead or dying shoot tips, and distorted, twisted terminal growth (Fig. 86a). In early stages of damage, needles on infested new shoots droop, turn yellow and then reddish-brown; needles die in tufts. Heavily infested twigs show up as yellow to reddish-brown “flags” scattered over a portion of or the entire crown (Fig. 86b); these begin to appear in summer but are more conspicuous in late winter or early spring the year following attack. Infested shoots have slight swellings on the bark surface under which small, bright orange to red maggots feed in resin-filled pockets, or pits (Fig. 86c). The maggots are present from summer until the following spring. Copious exudations of resin may also occur on the infested shoot.

Agents Producing Similar Symptoms and Signs: Pine needle sheath miner, some twig beetles, mites, and scale insects, drought, high temperatures, western gall rust, and Diplodia tip blight may cause tip flagging that superficially resembles the work of the gouty pitch midge. However, only the gouty pitch midge causes the slight swellings that occur on the surface of infested shoots.

Severity: Gouty pitch midge is not considered to be a serious forest pest. Few trees are actually killed by this insect.

References: 22, 23

- *Dead, dying, or distorted branch tips.*
- *Bright orange to red maggots feeding in small, resin-filled pits under bark swellings.*

Figure 86a—Distorted branch terminal growth caused by the gouty pitch midge.

Figure 86b—The gouty pitch midge is often responsible for dead and dying shoot tips on ponderosa pine.

Figure 86c—Gouty pitch midge maggots are bright orange to red, and feed in tiny pits found under bark swellings on infested branch shoots.

The following may also cause damage to branches or terminals:

APHIDS AND ADELGIDS . . . . Page 272
ATROPELLIS CANKER OF PINES . . . . Page 122
BALSAM WOOLLY ADELGID . . . . Page 140
COMANDRA BLISTER RUST . . . . Page 124
DIPLODIA TIP BLIGHT . . . . Page 128
DOUGLAS-FIR CANKERS . . . . Page 130
DROUGHT/WATER STRESS . . . . Page 292
ELYTRODERMA NEEDLE CAST . . . . Page 210
ERIOPHYID MITES . . . . Page 278
GROVESIELLA CANKER . . . . Page 132
HAIL. . . . . Page 296
BUD MOTHS. . . . . Page 236
MECHANICAL INJURIES . . . . Page 298
PITCH NODULE MOTH. . . . . Page 148
STALACTIFORM RUST . . . . Page 134
SUNSCALD/HEAT INJURY . . . . Page 300
WESTERN BLACKHEADED BUDWORM . . . . Page 266
WESTERN GALL RUST. . . . . Page 136
WESTERN SPRUCE BUDWORM . . . . Page 270
WHITE PINE BLISTER RUST. . . . . Page 138
WINTER INJURY . . . . Page 302

Foliage

Table 7—Comparison of agents affecting Douglas-fir foliage.

Disease	Symptoms	Location of Fruiting Body	Fruiting Body Description	Fruiting Season	Needles Shed
Rhabdocline needle cast	Yellow spotting followed by red-purple-brown banding	Undersides of needles, either side of midrib	Purplish-pink to orange-brown	Spring	12 to 15 months following infection
Swiss needle cast	General chlorosis or reddening and browning of needles	Undersides, emerging from stomata in lines on either side of midrib	Round, black, tiny; “sooty” appearance to undersides of needles	All year, most visible in spring	1 to 4 years following infection
Insect	**Symptoms**	**Feeding Habits**	**Appearance**	**Season Present**	**Needles Shed**
Cooley spruce gall adelgid	Yellow-spotted, kinked needles	Adelgids stationary on upper surface of new foliage	White tufts of wax cover adult adelgid; tiny black crawlers in spring	Spring to fall	Variable
Douglas-fir bud mite (an eriophyid mite)	Abnormally swollen and dead buds	Mites feed inside developing buds	Minute, translucent mite with four legs and elongate body	Spring and early summer	N/A
Douglas-fir bud moth	Hollow buds, missing and partially chewed current-year needles, webbing and frass	Larvae feed completely concealed in opening buds	Whitish-brown to brownish-yellow body with tan head, fewer than 6 pairs of prolegs, sluggish behavior	May through July	N/A
Douglas-fir needle midges	Yellow to purple swollen galls on current-year needles	Larvae found inside needle galls	Tiny, cream to orange, legless maggots	Spring to late summer	Late summer
Douglas-fir tussock moth	Messily chewed needles; “top-down” defoliation of crown	Larvae move freely on the foliage as they feed	Larvae hairy and grayish with black tufts projecting for-ward (head) and backward (rear)	May through June	N/A

Table 7—Comparison of agents affecting Douglas-fir foliage (cont.).

Insect	Symptoms	Feeding Habits	Appearance	Season Present	Needles Shed
Grasshoppers	Random, indiscriminate chewing	Grasshoppers feed freely and move rapidly from place to place	Elongate, leathery body with enlarged hind legs that are used for jumping	Spring through fall	N/A
Loopers	Messily chewed needles; loose webbing associated with some species	Larvae move about freely on the foliage	Green to brown larvae with various patterns; larvae crawl with a looping motion	Late June through September	N/A
Sawflies	Needles messily chewed; persisting needle stubs; old foliage preferred	Larvae feed in groups, resting on the foliage with their heads all pointed outward	Dark yellow to green larvae with black heads and six or more pairs of prolegs	Spring and summer	N/A
Silver-spotted tiger moth	Spottily distributed, defoliated branches with loose, debris-filled webbing	Larvae live in colonies that feed in or near a loose webbed structure until nearly mature	Hairy brown caterpillars that attain mature size by mid-spring	February through June	N/A
Spruce spider mite	Yellow to bronze needles covered with fine webbing that contains tiny debris	Mites feed on needles surrounded by silken webbing	Tiny, dark green to black, spiderlike mites with eight legs	Most noticeable in late summer and early fall	Variable
Western blackheaded budworm	Chewed, discolored foliage; new preferred, but will also eat older foliage	Larvae feed in debris-filled, webbed shelters	Green caterpillars with black or green heads	May through July	N/A
Western spruce budworm	Chewed, discolored needles and webbing; new foliage preferred	Larvae feed in debris-filled webbed shelters	Tan caterpillars with white dots and black or tan heads	May through early July	N/A

Table 8—Comparison of agents affecting hemlock foliage.

Disease	Symptoms	Location of Fruiting Body	Fruiting Body Description	Fruiting Season	Needles Shed
Brown felt blight	Dark brown to black feltlike masses of fungal material cover needles and branches	Within and on dark fungal masses	Small dark, globose structures are hidden within felt	Summer and fall in year following infection	N/A Needles die within felt
Hemlock needle rust	Scattering of chlorotic or missing current year foliage	Undersides of needles	Yellow to orange pustules develop in rows	Late spring through summer	Late spring through summer
Insect	**Symptoms**	**Feeding Habits**	**Appearance**	**Season Present**	**Needles Shed**
Hemlock loopers	Messily chewed needles; loose webbing associated with some species	Larvae move about freely on the foliage	Larvae green to brown with various markings; crawl with a looping motion	Late June through September	N/A
Hemlock sawfly	Needles messily chewed; persisting needle stubs; prefers old foliage	Larvae feed in groups that rest on the foliage with their heads all pointed outward	Dark yellow to green larvae with black heads and 6 or more pairs of prolegs	Late spring and early summer	N/A
Hemlock woolly adelgid	Thin crowns, premature needle drop, branch dieback; symptoms usually associated with seed orchards, roadside, forest/urban interfaces, and urban situations	Adult adelgids are stationary on twigs	White "woolly" tufts on twigs at the needle bases	Most noticeable in late spring and early summer	Late summer and fall
Silver-spotted tiger moth	Spottily distributed, defoliated branches, with loose, debris-filled webbing	Larvae live in colonies that feed in or near a loose webbed structure until nearly mature	Hairy brown caterpillars that attain mature size by mid-spring	February through June	N/A
Spruce spider mite	Yellow to bronze needles covered with fine webbing that contains tiny debris	Mites feed on needles surrounded by silken webbing	Tiny, dark green to black, spiderlike mites with eight legs	Most noticeable in late summer and early fall	Variable
Western black-headed budworm	Chewed, discolored foliage; prefers new, but will also eat older foliage	Larvae feed in debris-filled, webbed shelters	Green caterpillars with black or green heads	May through July	N/A

Table 9—Comparison of agents affecting larch foliage.

Disease	Symptoms	Location of Fruiting Body	Fruiting Body Description	Fruiting Season	Needles Shed
Larch needle blight	Entire needles drooping red or gray; lower third of tree crown	Undersides of needles	Black, oval, elongate hysterothecia	Late summer to early spring	1 to 3 years following infection
Larch needle cast	Distinct yellow and red spots or bands on needles; lower third of tree crown	Undersides of needles, associated with stomata	Colorless, usually cannot detect without use of special stains	Spring, summer	2 to 4 weeks following infection
Insect	**Symptoms**	**Feeding Habits**	**Appearance**	**Season Present**	**Needles Shed**
Larch budworm	Missing and partially chewed needles with webbing, new shoots gouged out on one side	Larvae feed inside “tubes” of webbed needles and webbed tunnels constructed along the branch axis	Yellowish-brown to black larvae with black heads	Late spring through summer	N/A
Larch casebearer	Yellow to red, hollowed-out and shriveled, partially chewed needles	Larvae move freely about the foliage	Tiny larvae with straw-colored “cases” of hollowed-out needles on their abdomens	Larvae present late summer through spring; pupae present in late spring	N/A
Larch sawfly	Reddened, partially chewed needles	Larvae move about freely and feed in groups, resting on the foliage with their heads all pointed outward	Larvae gray-green above, pale green below, with shiny black heads and 6 or more pairs of prolegs	Summer	N/A
Western spruce budworm	Chewed, discolored needles and webbing; new foliage preferred	Larvae feed in debris-filled, webbed shelters	Tan caterpillars with white dots and black or tan heads	May though early July	N/A

Table 10—Comparison of agents affecting pine foliage.

Disease	Symptoms	Location of Fruiting Body	Fruiting Body Description	Fruiting Season	Needles Shed
Brown felt blight	Dark brown to black felt-like masses of fungal material cover needles and branches	Within and on dark fungal masses	Small dark, globose structures are hidden within felt	Summer and fall	N/A Needles die within felt
Dothistroma needle blight	Yellow-brown to red-brown bands on needles; gradually dying out to the tip (base of needle often remains green)	Outside surfaces of needles	Small black dots within dark band of needles break through the needle surface	Spring through summer	12 to 24 months following infection
Elytroderma needle blight	Ponderosa pine needles gradually turn red-brown; most visible in the spring following infection	Outside surfaces of needles	Narrow dark lines of varying length, up to 10 mm (3/8) in) long, often with a visible slit	Late summer, early fall	10 to 12 months after infection
Lophodermella needle cast–"Bynum's blight"	Reddish discoloration in summer and fall; starting as wide bands on ponderosa pine foliage	Outside surfaces of needles	Dark elongated fruiting bodies	Late spring	12 to 13 months following infection
Lophodermella needle cast–Lodgepole pine	Wide red-brown bands on lodgepole pine needles in summer and fall; entire needle tan the following spring	Outside surfaces of needles under epidermis	Not readily visible; shallow oval tan-colored depressions	Late spring	12 to 13 months after infection
Lophodermella needle cast–Other pine species	Reddish discoloration in summer and fall; starting as wide bands on sugar pine foliage and other pine foliage	Outside surfaces of needles	Dark elliptical fruiting bodies	Late spring	12 to 13 months following infection
Lophodermium needle cast	Reddish discoloration in summer and fall; starting as wide bands on pine foliage	Outside surfaces of needles	Dark elliptical fruiting bodies; may be separated by shiny dark lines	Late spring	12 to 13 months after infection

Table 10—Comparison of agents affecting pine foliage (cont.).

Insect	Symptoms	Feeding Habits	Appearance	Season Present	Needles Shed
Black pineleaf scale	Sparse tree crowns, yellowish to reddish needles, stunted needles	Adult scales are stationary on needle surface	Small black oval scales	All year	Variable
Defoliating weevils	New foliage with punctures, or partially-chewed, sawtoothlike needles that break off and turn brown	Adults move freely about the foliage	Beetles with elongated, downward curving snouts; black or metallic colored	Summer	N/A
Eriophyid mites	Twisting, stunting, discoloration, and premature drop of current-year needles	Mites feed inside the needle sheaths of current-year foliage	Minute, translucent mite with four legs and elongate body	Spring and summer	Summer through winter
Grasshoppers	Random, indiscriminate chewing	Grasshoppers feed freely and move rapidly from place to place	Elongate, leathery body with enlarged hind legs that are used for jumping	Spring through fall	N/A
Loopers	Missing and partially chewed needles	Larvae move freely about the foliage	Larvae crawl with a looping motion	Summer	N/A
Pine needle scale	Yellow-brown needles	Adult scales are stationary on needle surface	Small white elongated-oval scales	All year	N/A
Pandora moth	Missing and partially chewed needles, old foliage preferred	Larvae move freely about the foliage and feed in groups when young, then individually	Mature larvae large; brown and yellow banded bodies with black branched spines	Fall and spring of alternate years	N/A

Table 10—Comparison of agents affecting pine foliage (cont.).

Insect	Symptoms	Feeding Habits	Appearance	Season Present	Needles Shed
Pine butterfly	Missing and partially chewed needles, old foliage preferred	Larvae move freely about the foliage and feed in groups when young, then individually	Mature larvae green, with two longitudinal white stripes and green heads	Summer	N/A
Pine needle miners	Needles with yellowish or reddish portions and having one or two tiny holes; sparse or stunted foliage	Larvae live and feed individually inside needles	Small, yellow to red larvae with black heads	Summer	N/A
Pine needle sheath-miner	Drooping, discolored needles; dead needles easily pulled from sheath leaving sheath attached to twig; webbing and small hole in sheath	Feed inside needles when young, move to needle sheaths and feed in silken webs when older	Small tan larvae with two dull orange, longitudinal stripes	Inside needles mid- to late summer through winter; in needle fascicle sheath during spring and early summer	Summer
Pine sawfly	Needles messily chewed; persisting needle stubs; old foliage preferred	Larvae move about freely and feed in groups, resting on the foliage with their heads all pointed outward	Mature larvae green with pale lateral stripes and shiny brown heads; 6 or more pairs of prolegs	Summer	N/A
Silver-spotted tiger moth	Spottily distributed, defoliated branches with loose debris-filled webbing	Larvae live in colonies that feed in or near a loose webbed structure until nearly mature	Hairy brown caterpillars that attain mature size by mid-spring	February through June	N/A

Table 10—Comparison of agents affecting pine foliage (cont.).

Insect	Symptoms	Feeding Habits	Appearance	Season Present	Needles Shed
Webspinning sawflies	Softball-sized nest of webbing filled with frass and debris	Larvae live in colonies that feed inside a protective nest	Larvae have hornlike projections on their heads and posteriors; 6 or more pairs of prolegs	Summer	N/A
Western pine budworm	Missing and partially chewed current-year foliage	Larvae feed in debris-filled, webbed shelters	Tan caterpillars with white dots and black or tan heads	Late spring, early summer	N/A

Table 11—Comparison of agents affecting true fir foliage.

Disease	Symptoms	Location of Fruiting Body	Fruiting Body Description	Fruiting Season	Needles Shed
Brown felt blight	Dark brown to black feltlike masses of fungal material cover needles and branches	Within and on dark fungal masses	Small dark, globose structures are hidden within felt	Summer and fall in year following infection	N/A Needles die within felt
Fir needle casts	Chlorosis of one year's component of needles usually in lower portion of crown	Undersides of needles; along the midrib	Elongate black structures	Summer	12 to 24 months following infection
Fir needle rusts	Chlorosis of current or one-year-old needles usually in lower portion of crown	Undersides of needles	Yellow to orange pus-tules develop in rows	Summer	Within 12 to 24 months following infection
Snow blight	Death and discoloration of patches of foliage; light brown foliage becomes bleached	Undersides of needles; in rows on either side of needle midrib	Black or brown oval to round fruiting bodies	Summer through fall	Needles slowly decay away 1 to 2 years after infection
Insect	**Symptoms**	**Feeding Habits**	**Appearance**	**Season Present**	**Needles Shed**
Balsam twig aphid	Twisting and matting of new needles and twigs, wax or honeydew may be present	Aphids stationary on new foliage and twigs	Greenish yellow or powdery blue-gray aphids	Most abundant in June and July	Sometimes, timing variable
Douglas-fir tussock moth	Messily chewed needles; "top-down" defoliation of crown	Larvae move freely on the foliage, feed individually	Larvae hairy and grayish with black tufts projecting forward (head) and backward (posterior end)	May through June	N/A

Table 11—Comparison of agents affecting true fir foliage. (cont.).

Insect	Symptoms	Feeding Habits	Appearance	Season Present	Needles Shed
Loopers	Missing and partially chewed needles	Larvae move freely on the foliage, feed individually	Larvae crawl with a looping motion	Summer	N/A
Sawflies, free-feeding	Old needles messily chewed; needle stubs; affected foliage may be a reddish color	Larvae move freely on the foliage, feed in groups with heads all pointing outward towards foliage tips	Larvae with yellow to green bodies, shiny black heads, rear-tapering abdomens, and greater than 6 pairs of abdominal prolegs	Probably May through June	N/A
Sawflies, webspinning solitary	New needles consumed, leaving little stubs	Larvae feed singly inside tubular white silken shelters spun alongside new growth branchlets	Larvae with wrinkled, rear-tapering abdomens; “horns” on heads and posteriors	Late spring and summer	N/A
Silver-spotted tiger moth	Spottily distributed, defoliated branches with loose, debris-filled webbing	Larvae live in colonies that feed on or near a loose webbed struc-ture until nearly mature	Hairy brown caterpillars that attain mature size by mid-spring	February through June	N/A
Spruce spider mite	Yellow to bronze needles covered with fine webbing that contains tiny debris	Mites feed on needles surrounded by silken webbing	Tiny, spiderlike, four-legged mites	Most noticeable in late summer and early fall	Variable
Western black-headed budworm	Chewed, discolored foliage; new preferred, but will also eat older foliage	Larvae feed in debris-filled, webbed shelters	Smooth, green caterpillars with black or green heads	May through June	N/A
Western spruce budworm	Chewed, discolored needles and webbing; new foliage preferred	Larvae feed in debris-filled, webbed shelters	Smooth, tan caterpillars with white dots and black or tan heads	May through early July	N/A

Foliar Pathogens

Conifers vary in the number of years that they normally retain live foliage. Most conifers depend on having a 2- to 11-year complement of needles for maximum growth and development. Loss of a large proportion of these needles results in growth reduction, and can, in severe cases, lead to mortality (Fig. 87a). Reduced needle retention for one year may have only a minor impact on tree health; loss of needles for several years in a row may be fatal.

There are a number of biological agents that cause needle death or abscission (Tables 7-11). Abiotic factors such as air pollution, herbicides, salt injury, over fertilization, high temperatures, drought, and winter injury may kill whole needles or needle parts as well.

Fungi are also responsible for needle damage and mortality. Most disease-causing needle fungi have life cycles that are timed to coincide with the development of host needles and may take several years to complete.

In a generalized foliar pathogen life cycle, fruiting bodies on 1-year-old needles release spores during moist conditions in spring. These spores infect newly emerged current-year needles and the fungus grows within that needle tissue through summer, fall, and winter. By the following late winter or spring, fruiting bodies are visible on infected needles. Infected needles with fruiting bodies may be green and healthy-appearing, but more often are slightly chlorotic or yellow, or orange red to brown. Needle shed occurs in the summer following infection. Variations on this life cycle are most often associated with sporulation from fruiting bodies on older needles and length of time after infection until needle shed.

Many foliar fungi have very restricted seasons of sporulation, spread, and infection. Successful infection usually depends upon a strict set of environmental conditions and a specific stage of host development. Because of this, heavy infection usually takes place during occasional years when conditions are optimal (Fig. 87b). Trees, for the most part, can survive those occasional years with only minor growth reductions. However, trees located where the environment constantly favors a foliar pathogen may experience repeated years of needle loss and much more serious impacts (Fig. 87c). Off-site trees may also be more prone to infection and damage from foliar fungi (Fig. 87d).

Identifying the fungi that cause needle loss can be difficult if the observer's timing is less than optimal. Fruiting bodies may not be visible for much of the year. Visible symptoms may consist only of retention of certain years' needles and loss of others.

References: 30

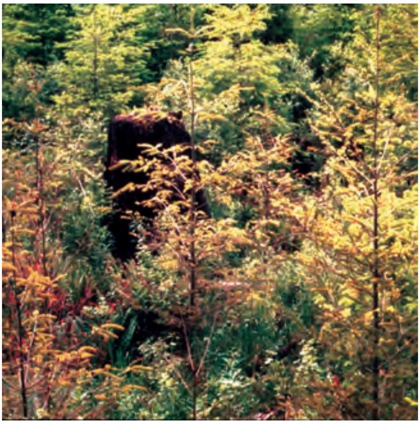


Figure 87a—Repeated infections by foliar pathogens may lead to substantial growth loss and even mortality.

Figure 87b—Heavy infection by needle pathogens usually takes place during occasional years when conditions are optimal (mild and wet in spring and summer).

Figure 87c—Moist areas with poor air drainage are places where needle pathogens thrive.

Figure 87d—Off-site trees are frequently infected by foliar pathogens.

BROWN FELT BLIGHT

Pathogens: *Herpotrichia coulteri* (Peck) S.K. Bose "snowmold"
Herpotrichia juniperi (Duby) Petr. "snowmold"

Hosts: *H. coulteri*: Pines.
H. juniperi: True firs, junipers, spruces, pines, hemlocks, cypress.

Distribution and Damage: Felt blight fungi are found throughout the high elevation forests of Oregon and Washington. Branch death and growth loss may occur when foliage covered by snow is infected and killed. Severe infections on small suppressed trees or seedlings may lead to mortality.

Identification: Foliage and branches are covered with a dense, "cobwebby" growth of brown to black mycelium (Figs. 88a-d). Small black globose fruiting bodies are scattered over the mycelium. *H. coulteri* and *H. juniperi* are macroscopically identical.

Agents Producing Similar Symptoms and Signs: The dark mats of *H. coulteri* and *H. juniperi* mycelia are fairly distinct, however brown felt blight may be confused with gray mold of seedlings caused by *Botrytis cinerea*.

Severity: Effects of brown felt blight usually are not severe.

References: 30

- *Brown felt on needles that have been buried under snow.*

Figure 88a and b—Snow mold on a mountain hemlock sapling (left) and seedling (right).

Figure 88c—Brown felt of *H. coulteri* on a pine branch.

Figure 88d—Close-up of brown felt blight on a true fir branch.

CEDAR LEAF BLIGHT

Pathogen: *Didymascella thujina* (E. J. Durand) Maire
(= *Keithia thujina*)

Host: Western redcedar.

Distribution and Damage: *D. thujina* is distributed throughout the range of western redcedar in Oregon and Washington. Photosynthetic area is reduced due to death of portions of leaf scales. Damage is greatest when seedlings and young saplings are heavily infected.

Identification: Bleached or reddish-brown areas are seen on 1-year-old foliage in the spring (Fig. 89a). Discoloration is often conspicuous, especially on lower branches. Fruiting bodies become visible in June and gradually darken from brown to black spots. When sporulation is complete, fruiting bodies may fall from foliage, leaving small, circular pits (Fig. 89b). Twigs with heavily infected foliage are often shed in the fall.

Agents Producing Similar Symptoms or Signs: Cedar leaf blight may be confused with normal foliar color changes in autumn. Leaf blight occurs scattered in the crown on newer foliage whereas fall leaf color change is a uniform loss of older foliage.

Severity: Cedar leaf blight can cause significant impacts in small trees in dense stands where humidity levels are high. Small trees may suffer growth loss and occasional mortality.

References: 30

- *Tan to reddish-brown blotches on foliage.*
- *Dark fruiting bodies on individual scales.*
- *Holes or pits where fruiting bodies resided.*

Figure 89a—Reddish-brown blotches on leaves caused by cedar leaf blight.

Figure 89b—In summer, fruiting bodies fall out of infected foliage scales, leaving dark cavities.

Foliar Pathogens

DOTHISTROMA NEEDLE BLIGHT or RED BAND NEEDLE BLIGHT

Pathogen: *Dothistroma septosporum* (Dorog.) M. Morelet

Hosts: Most common on ponderosa pine, western white pine, knobcone pine, or Knobcone-Monterey hybrid pine; also reported on lodgepole pine and Jeffrey pine.

Distribution and Damage: *D. septosporum* is found throughout Oregon and Washington. One-year-old needles are killed and shed one to two years following infection or remain attached, drooping, on the twigs. Growth loss may occur after repeated years of severe infections. Trees are seldom killed directly by Dothistroma needle blight. Impacts are most serious on young or small trees.

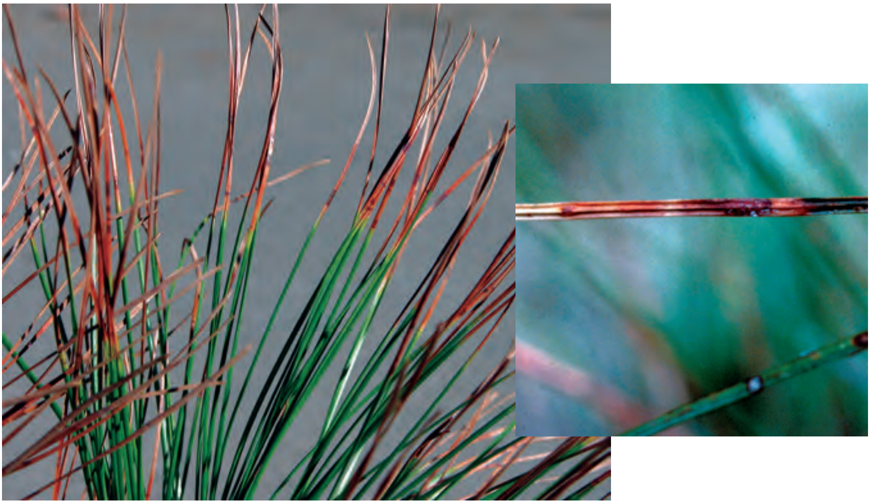
Identification: Needles of all ages may be infected. On most pine species, yellow to tan needle spots develop on newly infected needles that become translucent, water-soaked chlorotic bands; this typically occurs from September through November. The bands turn brown to reddish brown during the spring and summer (Figs. 90a, b). Entire needles or portions of needles distal to the infection die and become tan, reddish brown or brown in fall or spring following infection (Fig. 90a). It is common for the bases of infected needles to remain green. Small black round fruiting bodies appear in the red bands during the spring and summer. On infected western white pine needles, red transverse banding is indistinct or absent. Damage may occur throughout the entire tree or may be limited to the lower portion of the crown (Fig. 90c). Trees infected for several years often exhibit a “bottle brush” or “lion’s tail” appearance, with only a few needles remaining at the ends of branches (Fig. 90d).

Agents Producing Similar Symptoms and Signs: Agents causing overall decline of pines, such as root diseases, will superficially appear similar to pine needle diseases. Pine needle scales, winter desiccation, pine needle sheath miner, and air pollutants can be confused with needle blights. Dothistroma needle blight, Lophodermella/Lophodermium needle casts and Elytroderma needle blight may appear similar; fruiting body characteristics can be used to separate these diseases; brooming and necrotic flecking in the phloem occur with Elytroderma needle blight.

Severity: Dothistroma needle blight may be locally severe, especially in coastal areas and in moist microsites east of the Cascade Mountains.

References: 69

- *Red banding of needles with dark round fruiting structures.*
- *Severe needle loss.*



Figures 90a and b—Red banding on needles caused by *D. septosporum.*

Figure 90c—Foliage low in the crown is most often affected by *D. septosporum.*

Figure 90d—Needle loss on infected trees may result in "lion tails."

ELYTRODERMA NEEDLE BLIGHT

Pathogen: *Elytroderma deformans* (Weir) Darker

Hosts: Ponderosa pine, Jeffrey pine; less commonly found on lodgepole pine.

Distribution and Damage: *E. deformans* is found throughout Oregon and Washington east of the Cascade Mountains as well as in southwestern Oregon. Infection results in needle loss and death of branch cambium. When infection is severe, growth loss occurs and entire treetops may be deformed. Severely infected trees may be weakened, predisposing them to attack by bark beetles, or killed outright.

Identification: Branch “flagging” (production of reddened, dead 1-year-old needle clumps with green current-season needles at the tips) is conspicuous in spring (Fig. 91a). Clear tendrils of inconspicuous pycnidiospores appear on reddened needles in spring. Black elongated fruiting bodies (hysterothecia), varying in length up to 10 mm (3/8 in) long and often with a visible slit, form on dead needles in summer (Figs. 91b, c). Small to large compact brooms with upward turning branches and many dead needles occur when infections become perennial (Figs. 91d-f). Slicing into the inner bark of curled infected branches reveals numerous small patches of dead tissue (Fig. 91g).

Agents Producing Similar Symptoms and Signs: Dwarf mistletoe on ponderosa pine causes similar brooming, however, dwarf mistletoe plants or basal cups should be visible. Dwarf mistletoe brooms tend to be flattened or drooping while the brooms caused by Elytroderma needle blight are more often compact, upturning, and contain many dead needles. Dothistroma needle blight or Lophodermella/Lophodermium needle casts cause needle reddening and dieback but do not cause brooming or necrotic flecking of branch phloem; they can also be separated by the characteristics of their fruiting bodies.

Severity: Elytroderma needle blight is most damaging along creeks and lakeshores or in drainages with moist environmental conditions. Impacts are greatest on young trees. However, moderate to severe infection in all sizes of trees reduces growth and vigor and may predispose hosts to other agents.

References: 7

- *Tight brooms with red needles in the spring.*
- *Necrotic flecks in the phloem of infected branches.*
- *Long dark fruiting bodies on dead needles in late summer and fall.*

Figure 91a—Branch "flagging" caused by *E. deformans* is conspicuous in the spring.

Figure 91b and c—The fruiting bodies of *E. deformans* are elongated and black. They are found on dead needles in late summer and fall.

Figure 91d, e, and f—Brooms caused by Elytroderma needle blight are usually compact and their branches tend to turn upward.

Figure 91g—Diagnostic necrotic flecks in the phloem of an infected branch.

FIR NEEDLE CAST and SNOW BLIGHT of FIR

Pathogens: *Lirula abietis-concolor* (Mayor ex Dearn.) Darker
Gremmenia abietis (Dearn.) Crous

Hosts: Pacific silver fir, white fir, grand fir, noble fir, and subalpine fir.

Distribution and Damage: Fir needle cast and snow blight are found throughout Oregon and Washington. Infected needles are shed within 1 to 4 years following infection. Severe and repeated infections may cause growth loss. Economic damage may occur in Christmas tree plantings. Damage is usually greatest on small trees.

Identification: Infections are heaviest in the lower portion of the crown (Figs. 92a, b). One year's complement of needles is usually infected at a given time. Repeated infections may leave trees with thin crowns and dead lower branches.

Lirula abietis-concolor produces elongate black fruiting bodies that appear as lines on the midribs of the undersides of needles (Fig. 92c). Occasionally, one can see shorter brown or black lines on the upper midribs. New foliage is infected. Sporulation occurs on 1- to 4-year old needles. Needles are shed after sporulation is complete.

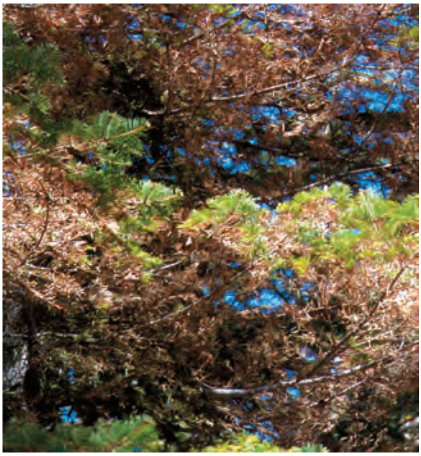
Gremmenia abietis infects needles under snow. Different ages of foliage may be infected. A thin mat of white mycelium grows among snow covered branches. After snow melt, needles turn brown or gray and the white mycelium disappears. Black or brown, oval to round fruiting bodies are formed on either side of the midribs on undersides of needles. After a year or so, fruiting bodies fall out of the dead needles leaving small holes.

Agents Producing Similar Symptoms and Signs: Fir needle rusts cause similar damage. The lack of colorful aecia in summer will separate fir needle cast and snow blight from these fungi. Winter desiccation may appear similar to needle cast or snow blight; however, damage caused by winter injury is often greater in the upper portions of trees.

Severity: Fir needle cast and snow blight may be locally severe.

References: 30

- *Fruiting structures on needles.*
- *Needle browning in lower crown.*
- *Needle loss.*



Figures 92a and b—Older needles on lower crowns are often affected by fir needle cast fungi.

Figure 92c—*L. abietis-concolor* fruiting bodies on undersides of white fir needles.

FIR and HEMLOCK NEEDLE RUSTS

Pathogens: *Pucciniastrum goeppertianum* (Kühn) Kleb.
P. epilobii (Pers.) G. H. Otth
P. vaccinii (G. Winter.) Jørst

Hosts: *P. goeppertianum*: Pacific silver fir, subalpine fir, white fir, grand fir, Shasta red fir.

Alternate Hosts: *Vaccinium* spp. (huckleberries, blueberries, etc).

Hosts: *P. epilobii*: Pacific silver fir, subalpine fir, grand fir, white fir, and Shasta red fir.

Alternate Hosts: *Epilobium* spp. (fireweed).

Hosts: *P. vaccinii*: Western hemlock and mountain hemlock.

Alternate Hosts: *Vaccinium* spp.

Distribution and Damage: Fir and hemlock needle rusts are found throughout Oregon and Washington, however damage is usually negligible. Needles are killed within one or two years following infection. Severe and repeated infections may reduce growth, especially on small trees. Economic damage to Christmas trees may result from severe infections. *P. goeppertianum* has been reported to cause damage in blueberry plantings.

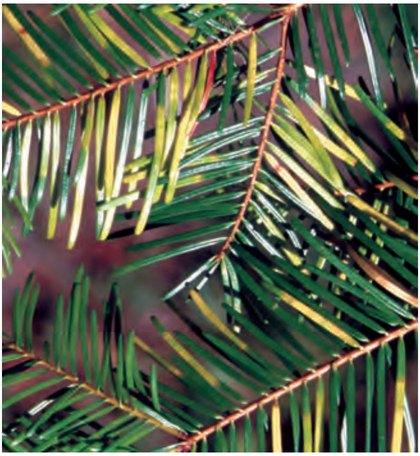
Identification: On conifers, infected needles turn yellow and may drop (Figs. 93a, b, e). White to yellowish protruding pustules of spores mature on the undersides of previous year's needles or on the current year's needles in late summer in the case of *P. goeppertianum*, or on the current year's needles in early summer with *P. epilobii* and *P. vaccinii* (Figs. 93c, d, f). Infections are greatest in the lower portion of host tree crowns. One year's complement of needles is usually infected at a given time. Repeated infections may leave trees with thin crowns and dead lower branches. *P. goeppertianum* causes the production of conspicuous brooming on *Vaccinium* hosts. *P. epilobii* causes leaf blotches on fireweed leaves. *P. vaccinii* causes yellowing and premature abscission of leaves of *Vaccinium* species.

Agents Producing Similar Symptoms and Signs: Fir needle casts cause similar damage. Fruiting bodies should be used to separate these fungi. Winter desiccation may appear somewhat similar; however, such damage is usually greatest in the upper portions of tree crowns.

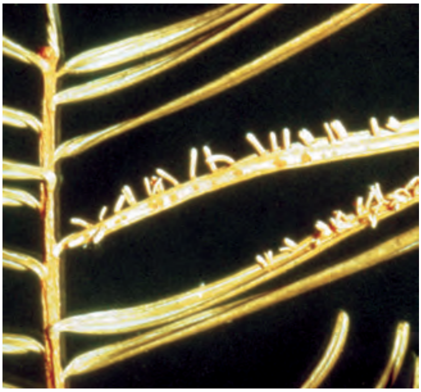
Severity: Fir and hemlock needle rusts may be locally severe. They cause their greatest impacts following especially wet years in damp microsites.

References: 30

- *Scattering of yellow needles in lower host crowns.*
- *Yellow-white spore pustules on true fir or hemlock needles.*



Figures 93a and b—Current year's needles are infected and turn yellow.



Figures 93c and d—White to yellowish protruding pustules of spores mature on the undersides of infected needles.

Figure 93e—Yellowing of hemlock needles caused by hemlock needle rust.

Figure 93f—Aecial pustules of *P. vaccinii* form in rows on undersides of hemlock needles.

LARCH NEEDLE BLIGHT

Pathogen: *Hypodermella laricis* Tebeuf

Hosts: Western larch, subalpine larch.

Distribution and Damage: *H. laricis* is found throughout the ranges of its hosts in Oregon and Washington. Infected needles are killed. Repeated infection may cause growth loss and, rarely, mortality. Spur shoots and occasionally succulent new shoots can be killed.

Identification: Young needles are infected in the early spring. Within a few weeks, the infected needles turn reddish brown over their entire length as if scorched by fire (Fig. 94a). Typically, all needles on a spur are affected. Infected needles are retained for one year or more (Fig. 94b). Small black oval fruiting bodies (hysterothecia) form on dead needles in late fall and early the following spring (Fig. 94c). Fruiting bodies often merge to form narrow lines. Severe infections are usually related to moist conditions at the time of budbreak. Infections are often heaviest low in the crown and vary greatly from tree to tree.

Agents Producing Similar Symptoms and Signs: Larch needle cast and larch needle blight require similar conditions for infection and frequently occur together on the same tree (Fig. 94d). With larch needle blight, needles remain attached to spurs, while with larch needle cast, infected needles are shed. Larch needle blight is often confused with frost damage; however, frost damage tends to be heaviest in the upper crowns of trees. Larch casebearer, larch budmoth, and larch sawfly cause defoliation of larch that superficially appears similar to needle blight.

Severity: Larch needle blight may be locally severe, especially after repeated years of cool, moist springs and summers. Its impacts are usually greatest on small trees and trees growing in understories.

References: 30

- *"Fall color" in May or June.*
- *Dead larch foliage remains on trees.*
- *Black elliptical fruiting bodies on needles.*

Figure 94a—Western larch with larch needle blight.

Figure 94b—Blighted needles remain on branches.

Figure 94c—Close-up of infected western larch needle spur with fruiting bodies of *H. laricis.*

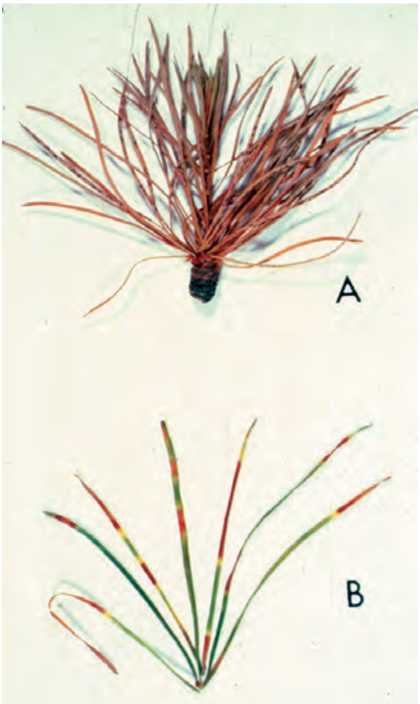


Figure 94d—Comparison of larch with *H. laricis* (A) versus *Rhabdocline laricis* (B).

Foliar Pathogens

LARCH NEEDLE CAST

Pathogen: *Rhabdocline laricis* (Vuill.) J.K. Stone (previously known as *Meria laricis*)

Hosts: Western larch, subalpine larch, rarely Douglas-fir.

Distribution and Damage: *R. laricis* is encountered throughout the ranges of its hosts in Oregon and Washington. It is also found in tree nurseries and ornamental plantings well outside of the native ranges of the hosts. Infected needles are killed and shed. Growth loss may occur after repeated years of severe infections. Severe infection may result in death of suppressed and intermediate hosts in the forest. Damage is often very great on 2-year-old and older seedlings in nurseries.

Identification: Infection is usually heaviest in the lower portion of the crown (Figs. 95a-c). Not all needles on each individual spur are affected. Yellowish, discolored spots or bands appear at the tips or in the middle of needles, expanding from the tip downward, and becoming reddish brown (Fig. 95d, e). Small clusters of colorless spores are found in and emerging from stomatal openings on the undersides of needles. These spore clusters are difficult to see without staining and magnification. Within a month of infection, needles fall to the ground. *R. laricis* infects needles in early spring and may continue to reinfect throughout the summer if moist conditions continue. The fungus overwinters in needles on the ground.

Agents Producing Similar Symptoms and Signs: Larch needle blight and larch needle cast frequently occur together due to the similarity of conditions required for infection (Fig. 94d). With larch needle blight, needles remain attached to spurs; however, with larch needle cast, infected needles are shed. The damage caused by larch needle cast may be confused with frost damage, but frost damage is often most evident in the upper portions of tree crowns. Superficially, larch casebearer, larch budmoth, and larch sawfly feeding resembles larch needle cast.

Severity: Effects of larch needle cast may be locally severe, especially after repeated years of cool, moist springs and summers. It has been very severe in some nursery situations.

References: 30

- *"Fall color" in May and June.*
- *Red banding or discoloration on needles.*
- *Foliage is lost from the tree.*
- *Interior and lower crown most heavily affected.*

Figure 95a—Larch needle cast is most visible in lower portions of tree crowns.

Figure 95b—Larch needle cast in lower crown.

Figure 95c—Western larch with larch needle cast.

Figure 95d and e—Close-up of infected needles showing discoloration.

Foliar Pathogens

LOPHODERMELLA / LOPHODERMIUM NEEDLE CASTS of PINES

Pathogens: *Lophodermella morbida* Staley & Bynum
(causes "Bynum's Blight")
Lophodermella concolor (Dearn.) Darker
Lophodermella spp.
Lophodermella arcuata (Darker) Darker
Lophodermium nitens Darker
Lophodermium spp.

Hosts: *L. morbida*: Ponderosa pine, knobcone pine.
L. concolor: Lodgepole pine.
L. arcuata: Five-needle pines.
L. nitens: Five-needle pines.
Lophodermella spp., *Lophodermium* spp.: Pine species.

Distribution and Damage: Lophodermella and Lophodermium needle cast fungi are found throughout Oregon and Washington. One-year-old needles are killed and shed. Growth loss may occur after repeated years of severe infections. Trees are seldom killed directly by Lophodermella and Lophodermium needle casts, but *L. morbida* in particular can cause very severe growth impacts and predisposition to other agents. Needle casts are most serious on young or small trees. Economic damage to Christmas trees may result from severe infections.

Identification: Infected needles turn reddish brown to brown in spring of the year following infection (Figs. 96a-f). Trees appear scorched. Infections are usually most severe in the lower portions of the crowns. If trees are repeatedly infected, branches begin to look like "bottle brushes" or "lion tails." Short, dark, elliptical fruiting bodies (hysterothecia) are produced on the needles (Figs. 95b, g) (EXCEPT with *L. concolor*, where fruiting bodies are inconspicuous oval depressions that are the same color as the needle). Needle casts are fairly host specific and the host identity can be used as a general indicator of needle cast species.

Agents Producing Similar Symptoms and Signs: Agents causing overall decline of pines, such as root diseases, will superficially appear similar to pine needle casts. Pine needle scales, winter desiccation, pine needle sheathminer, and air pollutants can be confused with needle casts. Dothistroma needle blight and Elytroderma needle blight may appear similar.

Severity: *L. morbida* has been locally severe on ponderosa pine in southwestern Oregon, especially on off-site plantings. Other Lophodermella and Lophodermium needle casts may be locally severe where favorable cool, moist environmental conditions persist.

References: 30

- ✦ *Scorched appearance of foliage in the spring.*
- ✦ *Bottle-brush or "lion's tail" appearance of the tree.*
- ✦ *Presence of fruiting bodies.*

Figure 96a—*Lophodermella morbida* on ponderosa pine.

Figure 96b—Fruiting bodies of *L. morbida.*

Figure 96c—Lodgepole pine affected by *L. concolor.*

Figure 96d—*L. concolor* infection of previous year's needles.

Figure 96e—Sugar pine showing spring symptoms of pine needle cast.

Figure 96f—*Lophodermium arcuata* on sugar pine.

Figure 96g—*Lophodermium* on lodgepole pine.

RHABDOCLINE NEEDLE CAST of DOUGLAS-FIR

Pathogens: *Rhabdocline* spp.

Host: Douglas-fir.

Distribution and Damage: Rhabdocline needle cast fungi are found throughout Oregon and Washington. Infected needles are killed and shed. Growth loss may occur on severely infected trees. There are several recognized pathogenic species of *Rhabdocline* found on Douglas-fir.

Identification: Foliage of affected trees may appear thin and sparse (Figs. 97a, b). Newly developing infected needles do not show symptoms. Yellow, red, and purplish blotching and transverse banding appear on infected needles in the fall and spring following infection (Fig. 97c). Purplish-pink fruiting bodies break through the undersides of 1-year-old or sometimes older needles, exposing orange-brown spores (Figs. 97d, e). Needles are shed shortly after spore release.

Agents Producing Similar Symptoms and Signs: Swiss needle cast, Douglas-fir needle midge, and Cooley spruce gall adelgid cause damage to Douglas-fir foliage. Root disease symptoms such as thinning, chlorotic foliage and tree decline, may superficially appear similar to needle casts. The diagnostic fruiting bodies can be used to separate Rhabdocline needle cast from other agents that cause similar impacts.

Severity: Rhabdocline needle cast may be locally severe where cool, moist conditions persist in the spring. Effects are most noticeable on off-site plantings.

References: 30

- *Yellow, red, and purplish blotching and transverse banding on needles.*
- *Reddish-purple fruiting bodies that erupt from the needle.*

Figure 97a—Needle loss due to Rhabdocline needle cast can be significant.

Figure 97b—Comparison of healthy versus infected foliage.

Figure 97c—Yellow, red, and purplish blotching and transverse banding appear on infected needles in the fall and spring following infection.

Figure 97d—Rhabdocline needle cast fruiting bodies are reddish purple. They break through the undersides of infected needles and split open to release spores.

Figure 97e—Close-up of fruiting bodies of *Rhabdocline* spp.

SWISS NEEDLE CAST

Pathogen: *Nothophaeocryptopus gaeumannii* (T. Rohde) Videira, C. Nakash., U. Braun & Crous (previously known as *Phaeocryptopus gaeumannii*)

Hosts: Douglas-fir.

Distribution and Damage: *N. gaeumannii* is found throughout Oregon and Washington. It is particularly damaging in stands within 30 miles of the coast in northwest Oregon. Infected needles are killed and shed. Growth loss occurs on severely infected trees. Economic damage to Douglas-fir growing in plantations and young stands and to Christmas trees may occur.

Identification: Yellowing and browning of infected previous year's needles is most obvious in spring and early summer; most needle loss occurs throughout the summer (Fig. 98a, b). Severely infected trees may have only current-season's needles in the fall. Tiny black fruiting bodies (pseudothecia) of the fungus appear in the stomatal openings on the undersides of the current-year's needles as early as October and increase in numbers and size throughout the winter and spring until the needles are shed (Figs. 98c, d). Large numbers of fruiting bodies cause the undersides of the infected needles to appear "sooty." Because there is a great deal of variation in the length of time infected needles are held on trees, infected needles with visible fruiting bodies may be seen at any time of year.

Agents Producing Similar Symptoms and Signs: Rhabdocline needle cast, Douglas-fir needle midge, and Cooley spruce gall adelgid cause damage to Douglas-fir foliage. Root disease or nutrient deficiency symptoms such as thinning, chlorotic foliage and tree decline, may superficially appear similar to needle casts. Swiss needle cast can be separated from agents that cause similar damage based on the fruiting bodies of the causal fungus.

Severity: Swiss needle cast is of local concern where conditions are cool and moist in spring. It is very damaging on the northwest Oregon coast where conditions are especially favorable for the pathogen and where extensive plantations of Douglas-fir have been established.

References: 30, 62

- *Thin crowns and chlorotic needles on Douglas-fir.*
- *Sooty or peppery appearance to undersides of needles.*
- *Small, round, black fruiting bodies emerging from stomata on needles.*

Figure 98a—Chlorotic foliage of Douglas-fir with Swiss needle cast. Symptoms are most visible in spring before bud break.

Figure 98b—Needle loss due to Swiss needle cast.

Figure 98c and d—Small, round, black fruiting bodies emerge from stomata on undersides of Douglas-fir needles.

LATE SUMMER and FALL FOLIAGE LOSS

Pathogens: Not applicable

Hosts: All conifers.

Distribution and Damage: Conifers vary in the number of years that they normally retain live foliage. Most conifers depend on having a two- to 11-year complement of needles for maximum growth and development. All conifers lose their oldest needle complements over time. Loss of older foliage is not considered damaging. Late summer and fall foliage loss may be very subtle and scattered in the inner crown. In species such as western redcedar and incense-cedar, foliage loss is often very noticeable because the color change is dramatic and the pattern of change is very uniform. Long spells of hot, dry weather in late summer may hasten and enhance the visibility of foliage loss.

Identification: Foliage turns yellow to red-brown in late summer and early fall (Figs. 99a-d). Foliage produced in the most recent years is not affected; color change and foliage drop occurs on older foliage in the inner crown.

Agents Producing Similar Symptoms and Signs: Many agents cause needle color change and loss, including fungi, insects, drought, winter injury, and chemicals. Timing of color changes, presence of fruiting bodies, evidence of feeding, and age of foliage affected are key to idenfying other agents.

References: None

- *Discoloration of foliage in late summer and fall.*
- *Oldest foliage lost.*
- *Foliage loss can be relatively uniform in pattern.*
- *No evidence of fruiting bodies or insect feeding.*

Figure 99a—Fall lodgepole pine foliage. Natural loss of older, interior, and lower crown foliage in late summer and fall is often confused with foliage loss caused by needle cast fungi.

Figure 99b—Fall sugar pine foliage.

Figure 99c—Fall Douglas-fir foliage.

Figure 99d—Fall cedar foliage. Most symptoms associated with foliar pathogens occur in spring to early summer.

Defoliating Insects

For the purposes of this field guide, the term "defoliating insects" is loosely applied to include both insects and mites that feed on conifer foliage. Although the feeding effects of most defoliating insects are negligible, some are capable of causing significant damage to individual trees and stands.

Most of the important defoliating insects of conifers are the immature, or larval, stages of moths, butterflies, and sawflies. In addition, some fly larvae, sucking insects, grasshoppers, adult beetles, and mites also cause noticeable defoliation. Defoliating insects that are considered major forest pests typically undergo sporadic or periodic outbreaks over widespread areas. Other defoliators mentioned in this text may become occasionally severe in local areas.

Tree and Defoliator Interactions

Defoliating insects feed on conifers in two ways; by chewing or by sucking. Many species of moths, butterflies, beetles, flies, grasshoppers, and sawflies are chewing defoliators. Chewing defoliators consume portions of needles or entire needles (Fig. 100a). Most chewers remove foliage by ingesting or severing the needles, though some of the gall-forming midges that live inside needles defoliate by causing premature needle drop. Most chewing defoliators have 1-year life cycles and four life stages: egg, larva, pupa, and adult. Many live and feed on the outside of the foliage, while some live and feed inside the needles for all or a portion of their lives. Sucking defoliators, such as aphids, adelgids, scale insects, and mites, feed by inserting needle-like mouthparts into foliage tissue and sucking out the plant juices (Fig. 100b). They defoliate by causing needle deterioration and premature drop. Typical effects of sucking defoliators include foliage stippling, necrosis, and needle distortion such as twisting or stunting. They commonly have three life stages: egg, nymph, and adult, although some have very complex and unusual life cycles. Most of the defoliators that cause abnormal bud growth and gall formation are either sucking insects or mites.

Many defoliating insects have a feeding preference for either new (current-year), or old (previous years') foliage. This preference determines the pattern of defoliation on a tree.

A significant amount of defoliation will result in reduction or cessation of tree growth. Defoliation may also cause topkill, epicormic branching, tree mortality (especially of smaller or understory trees), and a predisposition to mortality caused by other agents, such as bark beetles or *Armillaria ostoyae*. Generally, high levels of defoliation must occur for several consecutive years before tree death results.

Figure 100a—Feeding effects of a sawfly on Douglas-fir. Partially chewed and missing foliage is a sign of chewing defoliator activity.

Figure 100b—Heavy infestation of pine needle scale on lodgepole pine. Severe infestations of sucking defoliators may cause needle yellowing and premature shedding.

Defoliator Identification

Defoliator activity causes a range of damage patterns within a stand and on a tree. Sometimes the signs and symptoms are obvious enough to be easily attributed to defoliators, while at other times they are so subtle as to be easily confused with other damage agents such as frost or scattered root disease. Correct identification may be especially challenging during periods following a defoliator outbreak, when damage is still apparent but trees are beginning to recover and the defoliator itself is no longer present. Examining affected areas when the defoliator is actively feeding is the surest way to correctly identify the causal agent. When the defoliator is absent, or is present in more cryptic stages such as eggs or pupae, searching for diagnostic signs and symptoms and carefully observing damage patterns will facilitate accurate identification.

Knowing the defoliator history of an area is often helpful. Consult previous annual aerial survey maps of insect activity in Oregon and Washington, available online at *https://www.fs.usda.gov/main/r6/forest-grasslandhealth,* under *Aerial Detection Surveys (ADS),* or by contacting USDA Forest Service Forest Health Protection, P.O. Box 3623, Portland, Oregon 97208, for records of previous defoliation that was detectable from the air.

Patterns of Damage

Within a stand

In many instances, defoliating insects and their effects are distributed among most of the host trees throughout an area (Fig. 100c). Often, host trees of all sizes and ages are infested, but sometimes one canopy layer is more severely affected than others, e.g., the understory usually is more heavily affected by the western spruce budworm (Fig. 100d). Although many defoliators routinely affect widespread areas, others tend to occur more commonly in small, localized infestations, or are often associated with particular situations, such as plantations, or forestlands adjacent to agricultural lands where pesticides are routinely applied.

Within a tree

Some defoliating insects prefer new foliage but can feed on old foliage in later life stages. These insects defoliate the outer foliage first, and then move inward; they also remove more foliage from the top of the tree than from lower portions (Fig. 100e). Defoliators that prefer old foliage can give trees a bushy-tipped appearance (Fig. 100f). In general, several consecutive years of light to medium defoliation often tend to make crowns look sparse, and similar in appearance to trees that are exhibiting symptoms of root disease.

Figure 100c—Major forest defoliators, such as the western spruce budworm, often affect foliage on most of the host trees throughout a relatively large geographical area.

Figure 100d—Understory mortality due to feeding by western spruce budworm.

Figure 100e—Light defoliation by Douglas-fir tussock moth. Feeding preference for new foliage results in heavier effects on the upper crown and outer branch tips.

Figure 100f—The bushy-tipped appearance of this ponderosa pine is the result of preferential feeding on the older foliage by pandora moth.

Signs of Occurrence

On the tree

1) Chewed, missing, discolored foliage.
2) Needle twisting, distortion, stunting, stippling.
3) Holes in needle surface leading to the interior, needle-mining.
4) Webbing containing chewed needles or frass among foliage.
5) Accumulations of frass on the ground beneath tree crowns.
6) Abnormally swollen buds, leaf galls.
7) Pupal cases, cast larval skins and head capsules, new or old cocoons and egg masses.

Distinguishing Defoliator Species

Host preferences

Although some defoliating insects are general feeders and may occur on many coniferous species, most have a relatively small set of preferred host species. Observation of which tree species are and are not affected can aid identification (Fig. 100g).

Characteristic effects

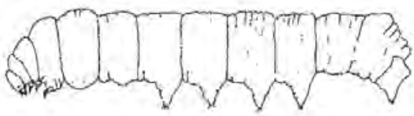
Most defoliators produce a unique signature that is defined by signs of occurrence, damage patterns, and host tree preferences (Tables 7-11). Usually one can ascertain fairly quickly whether defoliation has been caused by a chewing insect, a sucking insect or mite, or a disease by closely examining the affected foliage. By considering additional information, such as host tree species and patterns of damage, one can often correctly identify the damaging agent, even when the agent is not visibly present.

Insect/mite body characteristics

The best method of identifying defoliating insects is to examine the defoliator itself. Larval characteristics usually are best for differentiating chewing insect defoliators, because they are generally consistent and distinguishing. In addition, larvae are easier to find than other life stages. Identifying features include presence or absence of hairs or spines, color, coloration pattern, and the number of prolegs on the abdomen (Fig. 100h). Sucking insects are usually identified using adult characteristics such as shape, color, and size. Mites are so tiny that they are difficult to see with the unaided eye (Fig. 100i). Mites therefore are usually distinguished from other types of defoliators based upon the type of damage they cause, as well as their minute size.

References: General

Figure 100g—Nonhost pines remain unaffected during a Douglas-fir tussock moth outbreak.



Caterpillars

Sawflies

Loopers

Figure 100h—Number and presence of prolegs in the body midsection are used to distinguish caterpillars, sawflies, and loopers. Caterpillars (top) have no more than four proleg pairs in their midsection, sawflies (middle) have six or more, and loopers (bottom) have none.

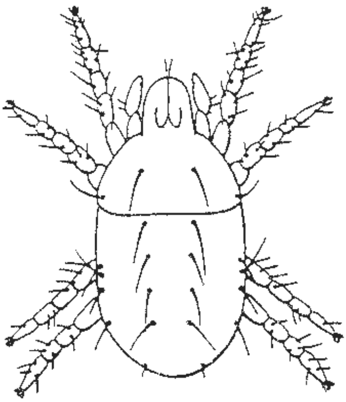


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Figure 100i—Most mature mites have four pairs of true legs (insects have three pairs) and are difficult to see without magnification.

Figure 101a Defoliating Insects Key

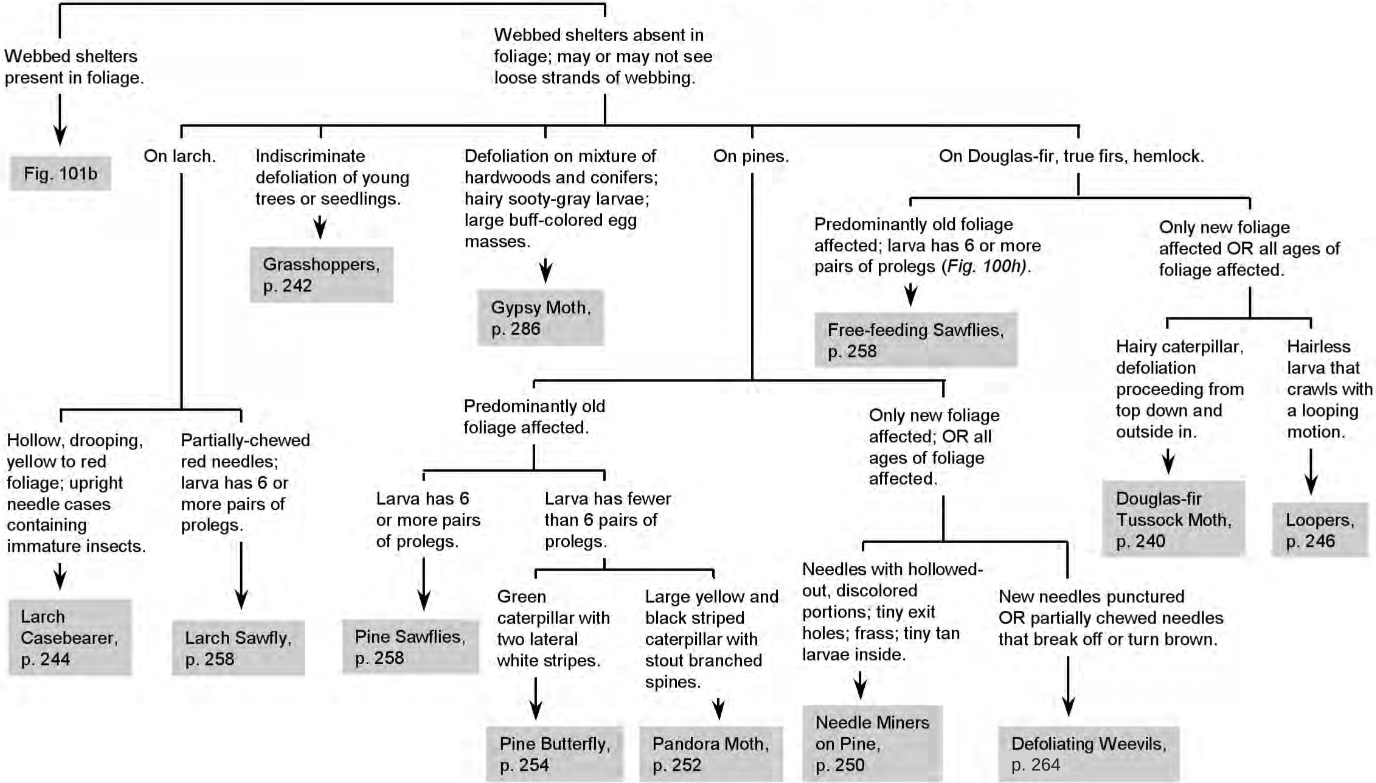
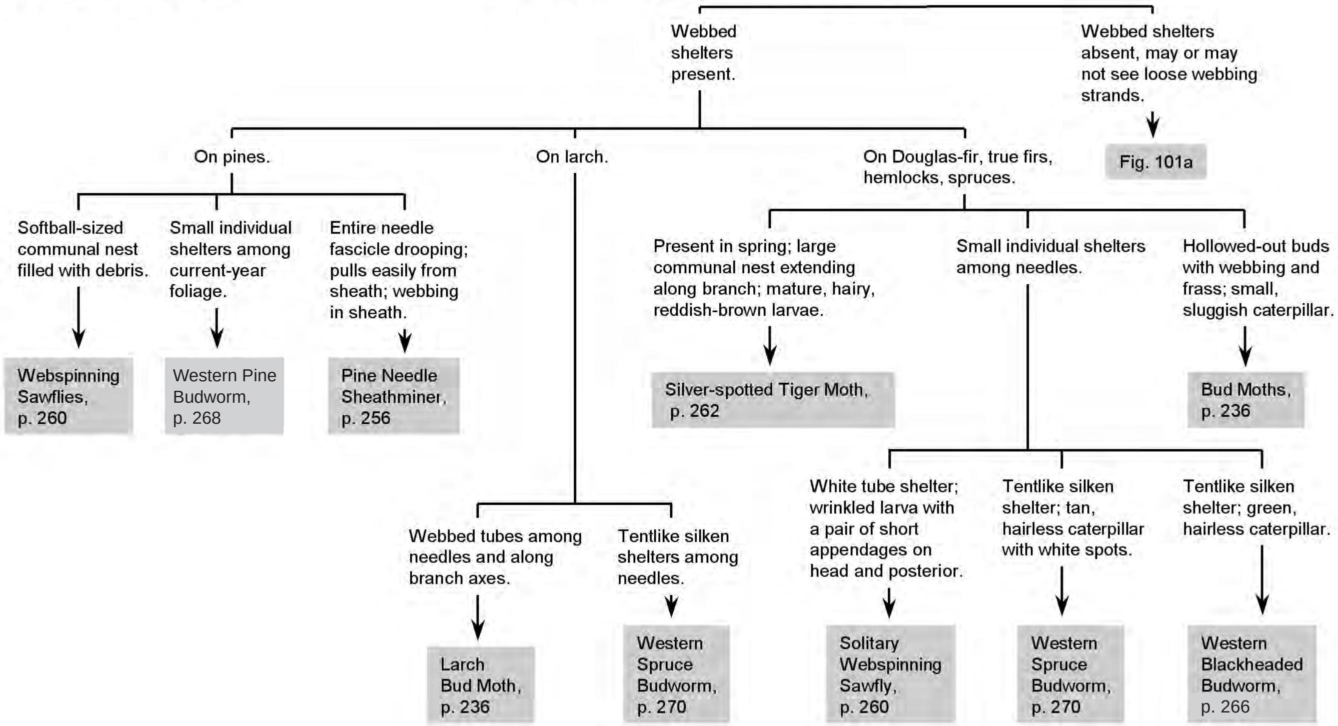


Figure 101b Defoliating Insects Key



BUD MOTHS

DOUGLAS-FIR BUD MOTH	*Zeiraphera hesperiana* (Mutuura & Freeman)
A SPRUCE BUD MOTH	*Zeiraphera pacifica* Freeman
SPRUCE BUD MOTH	*Zeiraphera canadensis* Mutuura & Freeman
LARCH BUD MOTH	*Zeiraphera improbana* (Walker)

Hosts: Varies according to bud moth species. Taxonomic confusion persists regarding the *Zieraphera* species on true firs and spruce. Outbreaks have occurred on the following host species in Oregon and Washington: Douglas-fir — *Z. hesperiana,* Sitka spruce — *Z. pacifica* and *Z. canadensis,* western larch — *Z. improbana*.

Distribution and Damage: Bud moths are found throughout Washington and Oregon. Young larvae bore into opening buds in spring, feeding on tender new needles as the stems elongate, sometimes causing growth reduction and crown distortion. On Douglas-fir and Sitka spruce, new foliage in some infested buds is consumed entirely before unfurling, while in other buds partially-eaten needles unfurl and die, causing the tree to turn red. On larch, bud moth larvae feed on new foliage and frequently gouge out one side of new shoots.

Identification: Infested trees turn red early in the season. Current-year foliage is chewed and discolored. Larvae may be present from May through July. Bud moth larvae are about 10 to 14 mm (3/8 to 1/2 in) long when mature. Larval behavior is sluggish. Adult bud moths are mottled, grayish to brownish moths with a prominent saddlelike, white to brownish-white patch located on the forewings when at rest, and a wingspread of 10 to 20 mm (about 3/8 to 13/16 in). **Douglas-fir:** Look for damaged or hollowed-out buds containing webbing and frass (Figs. 102a, b). Developing larvae feed under bud caps. Young Douglas-fir bud moth larvae have tan heads and dirty whitish-brown or pale yellow bodies. Older larvae have tan heads and brownish-yellow bodies with a broad brown dorsal stripe (Fig. 102d). **Sitka spruce:** Tree symptoms and larval habits are the same as for Douglas-fir. On Sitka spruce, however, dead needles drop off by midseason leaving little evidence of feeding. Larvae have tan heads and pale brown bodies. **Western larch:** Larvae feed in tubes of webbed needles or webbed tunnels along the branchlet axes (Fig. 102c). Younger larch bud moth larvae are yellowish brown with dark brown heads. Mature larvae have dusky-black bodies and blackish heads.

Agents Producing Similar Symptoms and Signs: Similar damage is caused by larch needle cast, larch needle blight, larch casebearer, larch sawfly, western spruce budworm, and Douglas-fir tussock moth. Bud moth larvae may be distinguished by their appearance and feeding habits.

Severity: Bud moths are generally considered to be of minor importance in Oregon and Washington. Outbreaks usually are brief and their effects on trees are not serious.

References: 83

- *Damaged, hollow buds containing webbing and frass.*
- *Chewed, discolored current-year foliage.*
- *Small, sluggish, pale tan to dusky-brown caterpillars lacking white spots.*
- *On larch: webbed tubes among needles and along branch axes.*

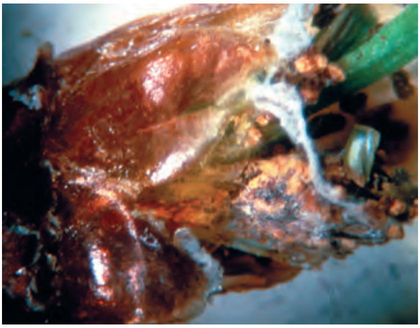


Figure 102a—Close-up of webbing and frass in Douglas-fir bud fed upon by *Z. hesperiana.*

Figure 102b—*Z. hesperiana* feeding damage to new growth of Douglas-fir. Note hollow buds, bud caps webbed to shoots, frass and webbing, and chewed needles.

Figure 102c—Defoliation caused by the larch bud moth. Note webbing and frass among needles.

Figure 102d—Douglas-fir bud moth larva.

DOUGLAS-FIR NEEDLE MIDGES

Contarinia pseudotsugae Condrashoff
Contarinia constricta Condrashoff
Contarinia coniculator Condrashoff

Host: Douglas-fir.

Distribution and Damage: Douglas-fir needle midges are found throughout Oregon and Washington. *C. pseudotsugae* is the most abundant. Larvae feed inside current-year needles, causing formation of small, discolored galls at the feeding site (Figs. 103a, b). Infected needles are shed prematurely. After several consecutive years of defoliation, twig dieback may occur.

Identification: On current-year needles, look for needle galls, which may be apparent beginning in June (Fig. 103b). A single needle may have several galls, each containing a single larva. Needles commonly are bent at the site of injury. Infested needles first turn yellow, then purple to brown before dropping in late summer and fall. Foliage remaining on the tree normally appears healthy. Midge species may be distinguished on the basis of gall characteristics. Galls of *C. pseudotsugae* are swollen on the lower surface and colored on both surfaces with yellow, pink, or purple (Fig. 103c-1). *C. constricta* galls first appear as patches of yellow discoloration with dark purple spots visible on both surfaces of affected needles (Fig. 103c-2). After about six weeks, these galls become dilated and flattened. *C. cuniculator* galls affect mainly the upper needle surfaces. The upper sides are dirty yellow with a glossy, waxy appearance (Fig. 103c-3). Douglas-fir needle midge larvae are minute, cream to orange maggots (Fig. 103d). In late fall or early winter, the maggots drop from the needles to overwinter in the soil beneath their host tree. Adult midges emerge in April or May, mate, and lay their eggs on the needles. The tiny, fragile, adult flies are about 3 mm (1/8 in) long. A pattern, usually evident in many Douglas-fir trees on a site, where sparse or missing needles are restricted to specific foliage cohorts representing one or sometimes several years, and where remaining foliage appears entire and healthy, may indicate previous high levels of needle midge activity.

Agents Producing Similar Symptoms and Signs: Rhabdocline needle cast, Swiss needle cast, Cooley spruce gall adelgid, and western spruce budworm cause similar-appearing damage and defoliation. Only Douglas-fir needle midges produce the characteristic needle galls.

Severity: Douglas-fir needle midges are of minor importance in forest situations. Occasionally, populations in forest stands will cause moderate to severe defoliation for one to several years. Needle midges are probably most important as pests of Christmas trees. Severe infestations can cause nearly all of the new foliage to drop and sometimes kill twigs.

References: General

- *Yellow to purple, swollen spots containing maggots on current-year needles.*
- *Needles bent at a place of swelling.*
- *Missing foliage restricted to one or several annual cohorts; retained foliage healthy.*

Figure 103a—Douglas-fir branch affected by Douglas-fir needle midges. The sparseness of last year's foliage complement (lower part of branch) indicates previous infestation, and the bent, galled current-year needles (top, middle) are a symptom of current infestation.

Figure 103b—Needles damaged by Douglas-fir needle midge. Note dilated, discolored gall sites and bent needles.

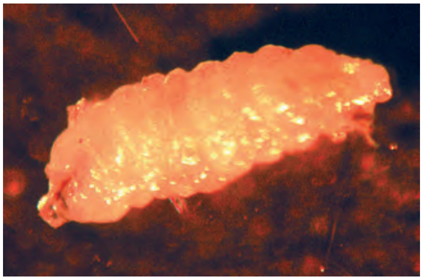


Figure 103d—Douglas-fir needle midge larva.

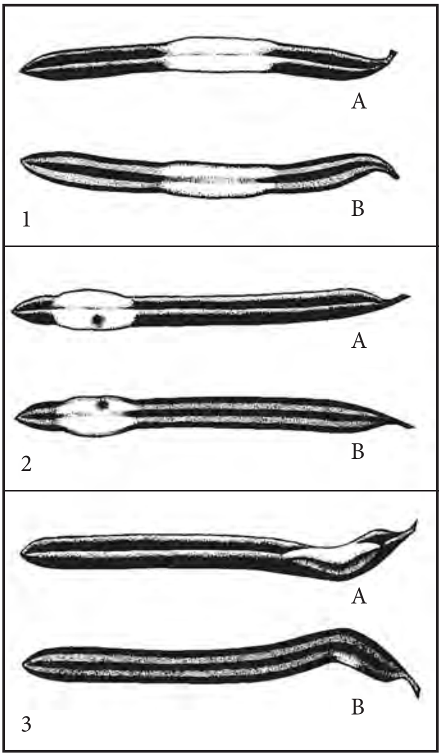


Figure 103c—Upper (A) and lower (B) surfaces of midge-damaged Douglas-fir needles showing characteristic galls:

1. *Contarinia pseudotsugae*
2. *Contarinia constricta*
3. *Contarinia coniculator*

DOUGLAS-FIR TUSSOCK MOTH

Orgyia pseudotsugata (McDunnough)

Hosts: Douglas-fir and true firs are the preferred hosts; many other trees and understory shrubs may also be defoliated during outbreaks, including pines, western hemlock, Engelmann spruce, and western larch.

Distribution and Damage: Douglas-fir tussock moth is found throughout Oregon and Washington. Impacts are greatest in host stands east of the Cascade Mountains crest. Larvae feed on host tree foliage, slowing tree growth and causing topkill and mortality. When populations are high, trees may become completely defoliated by August. Brown branch tips, bare twigs and damaged needles give heavily defoliated stands or host components a brown, dead appearance (Fig. 100g).

Identification: In spring, newly hatched larvae feed on the current year's foliage, causing it to shrivel and turn brown (Fig. 104a). After the new needles have been consumed, the larvae feed on old foliage. Defoliation occurs first in tree-tops and the outermost portions of branches, and then in the lower crown and farther back on the branches (Figs. 100e, 104b). Young larvae sometimes form silken caps of webbing in the tops of infested trees (Fig. 104c). Newly hatched larvae are about 3 to 6 mm (1/8 to 1/4 in) long, have dark bodies, and are covered by long, fine, light-colored body hairs. Mature larvae are about 25 to 32 mm (1 to 1-1/4 in) long (Fig. 104d). They have two long, black, hornlike tufts of hair projecting forward above their heads, and a single black tuft projecting backward on their posteriors. Toward the front, along the middle of the back, are four shorter, buff-colored tufts. The rest of the body, except for the legs and the head, is covered with short hairs radiating from small red, buttonlike spots. Pupation takes place inside brownish, spindle-shaped cocoons made of larval body hairs and silk (Fig. 104e). Adults emerge in July or August. Adult females are wingless and lay their eggs on the surface of their old cocoon in a mass of frothy gelatinous material (Fig. 104f). The egg masses and empty cocoons remain on the trees throughout the winter.

Agents Producing Similar Symptoms and Signs: Defoliation may resemble that of the western spruce budworm, but larvae and other life stages are easily distinguished. The distinctive pattern of defoliation, especially the fact that feeding occurs on old as well as new needles, also helps identification.

Severity: Heavy defoliation can retard tree growth and cause topkill and tree mortality. Defoliation also may make affected trees susceptible to bark beetle attack. Outbreaks generally do not last more than 3 to 4 years.

References: 90

- Messily chewed, discolored foliage.
- "Top-down" defoliation pattern.
- Hairy larvae with long black tufts at their head and rear ends.
- Silken "caps" on treetops.

Figure 104a—Current-year foliage damaged by the feeding of young Douglas-fir tussock moth larvae.

Figure 104b—"Top-down" defoliation is typical of the Douglas-fir tussock moth.

Figure 104c—Silken "cap" formed by young Douglas-fir tussock moth larvae.

Figure 104d—Mature Douglas-fir tussock moth larva.

Figure 104e—Spindle-shaped Douglas-fir tussock moth cocoon made of larval body hairs and silk.

Figure 104f—A frothy gray egg mass is laid on the surface of the female's old cocoon.

GRASSHOPPERS

SHORTHORNED GRASSHOPPERS Many species, Family Acrididae
MORMON CRICKET *Anabrus simplex* Haldeman

Hosts: A wide variety of conifers, broadleaf trees, shrubs, forbs, and agricultural crops.

Distribution and Damage: Grasshoppers are found throughout Oregon and Washington, especially in dryland areas. Grasshoppers of all sizes eat foliage and tender shoots (Fig. 105a, b, c). A migratory swarm can strip entire stands of forest nursery stock in a brief period of time.

Identification: Grasshoppers are highly mobile and transitory; usually the only evidence of their feeding is the tattered remains of chewed foliage and branches after a swarm has moved elsewhere.

Shorthorned grasshoppers are typical, commonly occurring grasshoppers (Fig. 105c). They have brown to gray elongate bodies with straight leathery forewings, fanlike, often brightly colored membranous hind wings that are used for flight, and powerful, enlarged hind legs. Their antennae are much shorter than their bodies, and the females have short, stout ovipositors.

Mormon cricket adults, although flightless, are capable of migrating up to one mile per day by crawling or hopping with their enlarged hind legs. They are about 25 mm (1 in) long, and have shiny, heavy bodies that may be dark brown, green, or reddish tan as they develop from nymphs to adults. Mormon crickets have hairlike, body-length antennae and the females have laterally flattened ovipositors that curve gently upward (Fig. 105d).

Agents Producing Similar Symptoms and Signs: Effects of grasshopper feeding may be confused with other defoliators. However, unlike caterpillars or sawflies, grasshoppers are random feeders with no systematic pattern to their feeding habits.

Severity: Various shorthorned grasshopper species, such as the migratory grasshopper, *Melanoplus sanguinipes* (Fabricius), and the Mormon cricket (not a true cricket) have been sporadic pests in forest nurseries and young conifer plantations that are located near suitable breeding sites, such as grassy fields on sandy soils.

References: General

✦ *Indiscriminately chewed foliage on young trees with no other signs present.*

Figure 105a—Grasshopper defoliation on a young Douglas-fir. Grasshoppers feed randomly, with no systematic pattern.

Figure 105b—Tattered remains of ponderosa pine foliage after being fed upon by the Mormon cricket.

Figure 105c—Shorthorned grasshoppers, *Melanoplus devastator*, feeding on Douglas-fir.

Figure 105d—Female Mormon cricket.

LARCH CASEBEARER

Coleophora laricella (Hübner)

Host: Western larch.

Distribution and Damage: Larch casebearer is found throughout the range of western larch in Oregon and Washington. The larvae defoliate larch by eating the inner tissues of needles, causing the needles to die and drop off the tree. Most damage occurs in the early spring when mature larvae are feeding on new foliage. Heavily defoliated trees replace dead foliage later in the season with a second flush of needles. Consecutive years of heavy defoliation cause growth loss, branch dieback, and can contribute to tree death.

Identification: Hollowed-out needles droop and appear yellow to reddish brown in spring (Fig. 106a). Heavily infested trees may appear yellow green to reddish brown (Fig. 106b). Defoliation is usually heaviest in the upper crown and decreases with height, and is most apparent in May or June. Tiny larvae bearing tubelike straw-colored cases are present in the foliage from late August until the following June (Figs. 106c, d). During winter, larvae cluster around buds at branch tips. They resume feeding in early spring. Mature larvae are about 5 mm (3/16 in) long and light brown in color. They pupate on the foliage in grayish cigar-shaped cases during late May and early June (Fig. 106e). Adult moths are silvery to grayish brown with no conspicuous markings and are about 6 mm (1/4 in) in length (Fig. 106e).

Agents Producing Similar Symptoms and Signs: Larch needle cast, larch needle blight, larch bud moth, western spruce budworm, and larch sawfly cause similar damage. Larch casebearer, larch needle cast, and larch needle blight often occur together on the same tree. Casebearers are distinguished by the timing and upper crown pattern of defoliation they cause, their cases, and by the hollow, shriveled condition of damaged needles.

Severity: The larch casebearer is a non-native species that was first discovered in the West in 1957. Larch usually is able to withstand repeated light to moderate defoliation because of its ability to produce a second flush of needles during the growing season. Continued heavy defoliation for five years or more, however, causes branch dieback, growth loss, and predisposition to death from other causes.

References: 85

- *"Fall color" in May or June.*
- *Drooping, yellow-red hollowed-out foliage.*
- *Larvae or pupae in needle cases on foliage or twigs.*
- *Upper crown is most severely affected.*

Figure 106a—Larch casebearer feeding causes needles to shrivel and discolor before dropping from the tree.

Figure 106b—Heavy larch casebearer feeding caused these western larches to turn yellow and orange in May.

Figure 106c—Larch casebearer larva in "case" constructed from a larch needle.

Figure 106d—Larch casebearer larva on larch needle cluster (upper right).

Figure 106e—The larch casebearer adult (top center) is a small, gray, inconspicuous moth. Pupation occurs in cigar-shaped gray-brown cases (bottom center).

LOOPERS

GREENSTRIPED FOREST LOOPER	*Melanolophia imitata* (Walker)
PHANTOM HEMLOCK LOOOPER	*Nepytia phantasmaria* (Strecker)
WESTERN HEMLOCK LOOOPER	*Lambdina fiscellaria lugubrosa* (Hulst)
LARCH LOOPER	*Macaria sexmaculata incolorata* Dyar

Hosts: Varies according to looper species; collective host range includes many coniferous and hardwood tree species. Western hemlock is a primary host for western hemlock looper and phantom hemlock looper; western larch is the primary host for larch looper; additional hosts of these and the greenstriped forest looper are listed in Table 12.

Distribution and Damage: Many looper species are found throughout Oregon and Washington, but outbreaks have been reported only for western hemlock looper, phantom hemlock looper, larch looper, and greenstriped forest looper. Of these four species, defoliation caused by the western hemlock looper has been the most severe and widespread. Phantom hemlock looper and greenstriped forest looper outbreaks tend to be sporadic and quite localized. Larch looper outbreaks have been recorded only in the extreme northeast corner of Washington near Newport and Northport. Young western hemlock looper larvae feed on new foliage, and older larval stages feed on both new and old foliage. Greenstriped forest looper larvae feed on both new and old foliage but prefer 1-year-old needles. Western hemlock, phantom hemlock, and greenstriped forest loopers are common associates. Heavy feeding by these looper species can cause growth loss, topkill, and tree mortality (Fig. 107a). Larch looper consumes current-year needles but does not cause topkill or tree mortality.

Identification: Infested trees have chewed foliage that turns yellowish red and then brown in one season (Fig. 107b). Western hemlock loopers tend to be wasteful feeders, consuming only chunks or portions of needles, or severing them at their bases (Fig. 107c). During western hemlock looper outbreaks, the ground below host trees may be littered with portions of green needles chewed at their bases. Only new foliage is damaged early in the season, later in the season both new and old foliage will show recent feeding damage. Although looper larvae are free feeders that do not construct webbed shelters, western hemlock looper larvae often produce abundant strands of loose webbing. Larvae crawl with a looping, or “inchworm” motion and are present on foliage from late June until August or September (Figs. 107d, e-g, j). Adult looper moths generally have whitish to light brown wings with darker markings, and wingspans of about 25 to 35mm (1 to 1-3/8 in) (Figs. 107h, i).

Agents Producing Similar Symptoms and Signs: Damage is similar to that caused by other defoliators. Larval locomotion and physical characteristics provide the best diagnosis.

Severity: See Table 12. Outbreaks of the western hemlock looper usually last three years, and have been most severe in coastal forests. Looper outbreaks can seriously damage stands that have a high proportion of western hemlock. Western hemlock trees are relatively intolerant of defoliation, and they tend to die when 75 percent or more of their crown is defoliated. Larch looper outbreaks are short-lived and cause little to no significant damage.

References: 13, 14, 83

- *Larvae that crawl with a looping motion.*
- *Sparse host tree crowns with partially chewed needles, discolored foliage.*
- *Ground below host trees littered with severed needles.*

Figure 107a—Western hemlock looper defoliation most commonly has been associated with stands older than 80 years. Complete defoliation can kill hemlock trees in one year.

Figure 107b—Western hemlock tree defoliated by the western hemlock looper.

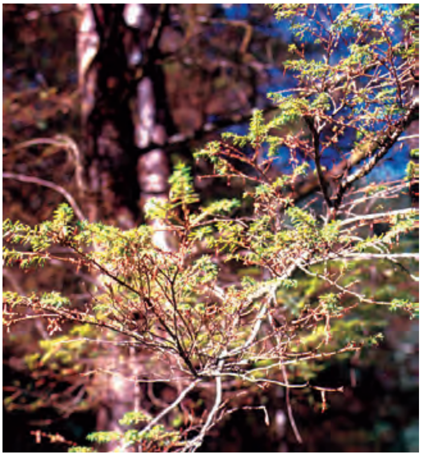
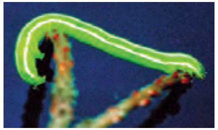


Figure 107c—Western hemlock looper feeding is characteristically "wasteful." Note sporadic pattern, bits of hanging dead needles, and live portions of needles still attached to branches.

Figure 107d—Young western hemlock looper larvae have alternating light gray and black bands.

Table 12—Hosts, description, and severity of four loopers in Oregon and Washington.

Common Name	Hosts	Mature Larva Description	Adult Moth Description	Severity
Greenstriped forest looper 	Douglas-fir western hemlock, western redcedar, true firs, and spruces.	Body deep apple green with a pair of white lateral stripes and a more faded yellowish stripe; unmarked green head; about 35 mm (1-3/8 in) long. Common, particularly in coastal forests, and normally abundant.	Mottled grey and brown wings with narrow wavy lines and small black marginal spots; wingspan of about 25 to 39 mm (1 to 1-1/2 in). Moths fly in spring.	Outbreaks are sporadic, relatively infrequent, and localized. Common associate of other loopers.
Phantom hemlock looper 	Western hemlock and Douglas-fir. Also recorded on western redcedar, Sitka spruce, true firs, and pines.	Body lime green with dark-edged yellow lateral stripes, green head with black dots; about 28 mm (1-1/16 in) long. Common.	Whitish wings marked with black, well-defined, wavy lines; top of the head is yellowish; wingspan of about 22 mm (1 in). Moths fly in fall.	Outbreaks are localized and sporadic. Often associated with outbreaks of western hemlock looper and western blackheaded budworm.
Western hemlock looper 	Western hemlock. Also found on associated western redcedar, Sitka spruce, true firs, Douglas-fir and western white pine.	Body green to brown, with complex markings and four dark dots on top of each abdominal segment; about 30 mm (1-3/16 in) long. Common.	Buff-colored wings with two wavy lines on the forewing and one wavy line on the hindwing; wingspan of about 35 mm (1-3/8 in). Moths fly in fall.	Heavy infestations that cause complete defoliation can kill trees in one year. Outbreaks usually associated with stands older than 80 years. Heaviest losses occur in old growth stands of hemlock.
Larch looper 	Western larch. Also recorded on Douglas-fir.	Body green, brown, maroon, or light gray, with variable patterns including off-white lateral stripes or light-colored dorsal chevrons extending down the sides; about 15mm (9/16 in) long.	Nondescript, variable, grayish to brownish wings with wavy lines and sometimes spots; wingspan of about 1.9 to 2.3 cm (3/4 to 1 in). Moths fly in summer.	Outbreaks are sporadic, localized and historically restricted to the extreme northeast corner of Washington. Causes little to no significant damage.

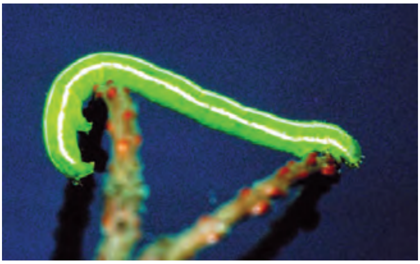


Figure 107e—Greenstriped forest looper larva.

Figure 107h—Phantom hemlock looper adult.

Figure 107f—Phantom hemlock looper larva.

Figure 107i—Western hemlock looper adult.

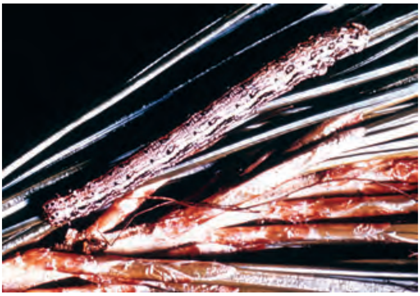


Figure 107g—Mature hemlock looper larva.

Figure 107j—Larch looper larva.

NEEDLE MINERS on PINE

Coleotechnites spp.

Hosts: Lodgepole pine, ponderosa pine.

Distribution and Damage: Pine needle miners are found throughout Oregon and Washington. Larvae live and mine inside needles, causing early needle drop and reduced tree growth. Tree foliage becomes sparse and stunted after several consecutive years of heavy defoliation.

Identification: Pine needle miner feeding causes the needle portion above the mined area to fade and die while the portion below the mine remains green (Fig. 108a). Hollowed-out portions may contain a single small larva or frass. Holding damaged needles so that light shines through them can aid detection of hollow areas and larvae. Tiny circular exit holes also may be present on affected needles. Needle tips die (Fig. 108b) and needles eventually break off where mined or drop prematurely. Larvae are hairless with black heads and yellow to red bodies, and may be most easily found during spring and early summer. The adults are small, gray, narrow-winged moths with wingspans of about 8 to 13 mm (5/16 to 1/2 in) and strongly fringed hindwings.

Agents Producing Similar Symptoms and Signs: Pine needle sheathminer causes similar damage, however, needles damaged by pine needle sheathminer pull easily from their sheaths while those damaged by *Coleotechnites* spp. do not. Lophodermella and Lophodermium needle casts of pines may superficially resemble needle miner damage.

Severity: Needle miners cause sporadic, often widespread defoliation of lodgepole pine in central Oregon, and local defoliation of ponderosa pine. Defoliation of lodgepole pine is most severe in extensive, pure stands. Defoliation predisposes trees to attack by bark beetles.

References: 53

- *Needles with discolored hollow tips and green bases; may contain a single larva, frass, or a tiny circular hole.*
- *Sparse, stunted, broken-off foliage.*

Figure 108a—Close-up of lodgepole pine needles mined by *Coleotechnites* sp. Note discolored tips with hollow interiors and tiny holes near needle tips.

Figure 108b—Pine needles that are fed upon by needle miners develop orange tips with an abrupt demarcation between living and dead portions.

PANDORA MOTH

Coloradia pandora Blake

Hosts: Ponderosa, lodgepole and Jeffrey pines are primary hosts; sometimes found on sugar pine.

Distribution and Damage: Pandora moth possibly is found throughout the ranges of its hosts in Oregon and Washington, but outbreaks have occurred only on the pumice soil areas of southcentral Oregon. Pandora moth outbreaks appear to be limited to pine areas with loose soils, which allow the larvae to bury themselves prior to pupation. Because this insect takes two years to complete its life cycle and all populations have synchronous life stages, defoliation occurs every other year. Larvae consume only older foliage. The usual result of pandora moth defoliation has been reduced growth rates. Adult moths are attracted to light, and sometimes become nuisances in populated areas near defoliated forest stands. During outbreaks adults often are reported in locations far beyond the outbreak area.

Identification: Tree crowns are sparse, with remaining foliage occurring mainly at branch tips (Figs. 100f, 109a, b). During defoliation years, affected stands appear reddish. Eggs hatch in August. Newly hatched caterpillars are about 6 mm (1/4 in) long, with black, shiny heads and spiny, black bodies. They feed gregariously on current-year foliage until late fall, (Fig. 109c) then disperse and feed individually. After overwintering at the bases of needles, the maturing larvae commence feeding as early as April and continue to feed until late spring on the same foliage cohort (now “old” foliage) without consuming the terminal buds. Mature larvae are easy to detect because of their large size, 57 to 76 mm (2-1/4 to 3 in) long, and distinctive coloration (Fig 109d). Their bodies have alternating dark brown and yellow transverse bands, and longitudinal white stripes on their backs and sides. There are dark, stout, branched spines on each body segment and their heads are orange brown. In June, the mature larvae crawl down tree trunks to pupate in loose soil. Adults, which are large, heavy-bodied moths with wingspans of 76 to 114 mm (3 to 4-1/2 in), emerge the following year in June or July. Forewings are brownish gray and hindwings are light pinkish gray, with a small dark spot near the center of each wing (Fig. 109e).

Agents Producing Similar Symptoms and Signs: Pandora moth damage is similar to that caused by other defoliators, especially the pine sawfly and pine butterfly. The pandora moth’s appearance, however, is quite distinct from other defoliators in all life stages.

Severity: Outbreaks occur sporadically and are variable in duration, occasionally lasting as long as 10 years. During outbreaks, feeding may be fairly heavy without causing serious damage. Trees seldom die as a direct result of pandora moth defoliation because the new growth is not consumed, and because most of the defoliation occurs in alternate years, giving trees an opportunity to recover. Heavy defoliation, however, may sometimes predispose trees to attack by bark beetles.

References: 8

- *Old foliage discolored, chewed, missing.*
- *Thin tree crowns with foliage mainly at the branch tips.*
- *Large brown and yellow banded caterpillars with white longitudinal stripes and dark, branched spines.*

Figure 109a—Sparse ponderosa pine crown with foliage concentrated near branch tips, caused by pandora moth feeding.

Figure 109b—Heavy defoliation by the pandora moth.

Figure 109c—Young larvae feed in clusters during the fall months.

Figure 109d—The mature, very large pandora moth larvae crawl down tree trunks to pupate in the ground every other year.

Figure 109e—Pandora moth adults are large and attractively colored.

PINE BUTTERFLY

Neophasia menapia (Felder & Felder)

Hosts: Ponderosa pine is the preferred host. Western white pine, lodgepole pine, Douglas-fir, and western larch are also fed upon.

Distribution and Damage: Pine butterfly is found throughout Oregon and Washington. Previous outbreaks in these states have occurred in areas where ponderosa pine was the predominant tree species. Larvae prefer to feed on old needles, but during outbreaks older larvae also will feed on new needles. Repeated heavy defoliation of ponderosa pine results in growth loss and tree mortality. Older pine trees are more susceptible to damage than younger trees.

Identification: Trees defoliated by pine butterfly have sparse crowns with foliage concentrated at the branch tips (Fig. 110a). Defoliated stands may appear reddish. Newly emerged larvae, pale green with black heads, begin feeding on old foliage in the spring when new shoots are about 5 cm (2 in) long. Young larvae feed in clusters on individual needles, with their heads pointing toward the tips. As they mature, the larvae disperse and feed singly on individual needles. Full-grown larvae are about 25 mm (1 in) long, with green heads and bodies, and two white lateral stripes (Fig. 110c). By August the pupae, also green with white stripes, may be found attached to the needles, stems, or branches. Adult butterflies emerge by mid-August (Fig. 110b). They are white with black wing markings near the outer edges, have a wing expanse of about 30 mm (1-3/16 in), and strongly resemble the common cabbage butterfly. Female butterflies may be distinguished from males on the basis of their more yellowish coloration and darker black markings on their hind wings. Pine butterflies are commonly seen each year fluttering around host tree crowns during August and September. Rows of emerald-green eggs may be found on the needles from September to June.

Agents Producing Similar Symptoms and Signs: Other defoliators, especially the pine sawfly and pandora moth, produce similar damage on pines. The pine butterfly is distinguished from other defoliators by larval and adult characteristics.

Severity: High levels of defoliation by pine butterfly may cause reductions in annual radial growth for several years following an outbreak. Large, old ponderosa pines may die following severe defoliation due to the effects of defoliation alone or because they are killed by bark beetles such as western pine beetle that are attracted to the weakened trees. Mortality in younger stands is usually negligible.

References: 74

- *Predominantly old foliage discolored, chewed.*
- *Thin tree crowns with foliage mainly at the branch tips.*
- *Green caterpillars with two white lateral stripes.*

Figure 110a—Pine butterfly defoliation. Note concentration of foliage near branch tips.

Figure 110b—Pine butterfly adults are commonly seen flying around pine crowns in late summer.

Figure 110c—Pine butterfly larva.

PINE NEEDLE SHEATHMINER

Zelleria haimbachi Busck

Hosts: Ponderosa pine, Jeffrey pine, and lodgepole pine are preferred hosts; may also feed upon other two- and three-needle pines.

Distribution and Damage: Pine needle sheathminer is found in Oregon and Washington wherever hosts occur. It affects current-year foliage. Larvae feed within needle fascicle sheaths, severing the needles and causing them to droop, die, and shed prematurely (Fig. 111a). Severe infestations can reduce tree growth. Pine needle sheathminer is found most commonly in young pine stands.

Identification: Newly emerging needles become chlorotic and stunted (Fig. 111b), and already elongated needles droop before needle death and premature shedding occurs (Fig. 111c). Needles fed upon by the sheathminer are easily pulled out of their sheaths, leaving the sheath attached to the twig. A small hole may be found in the sheath of each damaged fascicle, and webbing is present in or among the sheaths. During summer, heavily infested stands may have a yellowish to orangish cast when viewed from a distance. Later in the year, damaged needles drop from the tree, and the foliage on affected branch tips may appear sparse until new growth appears the following spring. The first larval stage of this insect is tiny and threadlike, with a shiny black head and a bright orange body. It is found inside needles during mid- to late summer and throughout the winter. In spring, larvae emerge from the needles and migrate to the base of the needle cluster where they spin silken webs and feed entirely within the needle sheath. When they grow too large for the sheaths, the larvae move outside into webbing they spin among the needle bases, and continue to feed in the sheaths by inserting their head and first few body segments. Mature larvae are small, reaching 14 mm (9/16 in) in length, and tan with two dull orange stripes (Fig. 111d). Green to brown pupae about 6 mm (1/4 in) in length may be found in webbing near the bases of needles by late July. Adult moths have a wingspan of about 12mm (1/2 in), light golden forewings with a broad white band down the center, and silvery white hindwings.

Agents Producing Similar Symptoms and Signs: Damage is similar to that caused by pine needle casts, needle miners on pine, and the gouty pitch midge. However, needle casts result in the shedding of both the needles and the sheaths. Branch tip needles killed by the gouty pitch midge and needle miners on pine do not pull easily from their sheath, as do those killed by the sheathminer.

Severity: Pine needle sheathminer is not considered to be a serious forest pest. No tree mortality has been associated with this insect. Defoliation may be potentially serious in progeny test sites, ornamental plantings, or Christmas tree plantations.

References: 82

- *Drooping or stunted, discolored current-year needles; premature needle drop.*
- *Webbing and frass in or around needle sheath; tiny hole in needle sheath.*
- *Dead needles pull easily from their sheaths.*

Figure 111a—Pine needle sheathminer damage on ponderosa pine.

Figure 111c—Stunting, drooping, and death of current-year needles is caused by pine needle sheathminer. Severed needles pull easily from their sheaths.

Figure 111d—Pine needle sheath-miner larva (black and white close-up).

Figure 111b—Pine needles that are damaged by sheathminer early in their development become stunted and chlorotic. Webbing is present among fascicle bases.

SAWFLIES, FREE-FEEDING

LARCH SAWFLY *Pristiphora erichsonii* (Hartig)

PINE SAWFLIES Several species of *Neodiprion,* including *N. nanulus contortae* Ross, *N. autumnalis* Smith, and *N. mundus* Rohwer

HEMLOCK SAWFLY *Neodiprion tsugae* Middleton

OTHER SAWFLIES Numerous species belonging to Family Diprionidae and Family Tenthredinidae

Hosts: Varies according to sawfly species: **Larch sawfly** — western larch. **Pine sawflies** — Jeffrey, lodgepole, ponderosa, knobcone, sugar, western white, and whitebark pines. **Hemlock sawfly** — western hemlock; sometimes mountain hemlock, Pacific silver fir, and Sitka spruce. **Other sawflies** — various conifers.

Distribution and Damage: **Larch sawfly** — Oregon and Washington within the range of western larch. **Pine sawflies** — Oregon and Washington. **Hemlock sawfly** — coastal forests of Oregon and Washington. **Other sawflies** — Oregon and Washington. Noble fir growing in the Cascade Mountains is occasionally defoliated by sawflies. Sawfly larvae consume the foliage of their respective host trees, weakening them and slowing their growth (Figs. 112a-c).

Identification: The larvae of most conifer-feeding sawflies feed mainly on old needles. They tend to be messy feeders, partially consuming needles and leaving needle stubs (Figs. 100a, 112b, c). Damaged foliage turns a reddish color as it dries. When population levels are low, defoliation tends to be spottily distributed, affecting scattered branches and trees, but may become more evenly distributed throughout a stand when populations increase to high levels. Larch sawfly adults lay their eggs in elongating larch branch terminals, often causing curling and distortion of the new tips that may persist for several years. Sawfly larvae are gregarious feeders (Fig. 112d) and can be found on the foliage between June and August. The colonies typically feed in tight clusters, resting on needles and twigs with their heads all pointing outward toward the tips. The larvae are hairless, with six or more pairs of prolegs and rear-tapering abdomens. Mature sawfly larvae are about 16 to 25 mm (5/8 to 1 in) in length and characteristically have black, shiny heads and dark yellow to green bodies that are sometimes paler beneath (Fig. 112e). As larvae mature, some develop longitudinal stripes. The free-feeding sawfly cocoon is tough and papery, light to dark brown, and cylindrical in shape with blunt, rounded ends. Cocoons are present in late summer and early fall and are usually found on or near defoliated trees, often occurring in loose duff beneath them.

Agents Producing Similar Symptoms and Signs: Sawfly defoliation is difficult to distinguish from that of other defoliators of older foliage; although, in the case of the larch sawfly, the presence of curled current-year shoots due to spring egg deposition and summer discoloration paired with the clusters of red, partially consumed needles left behind by young larvae is distinctive. Positive identification is usually based on larval characteristics; unlike other caterpillars, sawfly larvae have six or more pairs of abdominal prolegs (Fig. 100h).

Severity: Outbreaks of free-feeding sawflies usually last one to two years, and then collapse with little or no tree mortality. Local populations of the non-native larch sawfly may completely strip trees without causing permanent damage.

References: 9, 15, 41

- *Only old foliage affected (except for larch).*
- *No webbing.*
- *Foliage discolored, partially chewed; needle stubs.*
- *Clusters of free-feeding larvae with six or more pairs of abdominal prolegs.*

Figure 112a—Hemlock sawfly defoliation on a large western hemlock.

Figure 112b—Sawfly defoliation on young ponderosa pine.

Figure 112c—Sawfly defoliation on Douglas-fir. Note feeding preference for old foliage and partial consumption of needles.

Figure 112d—Young pine sawfly larvae feeding gregariously.

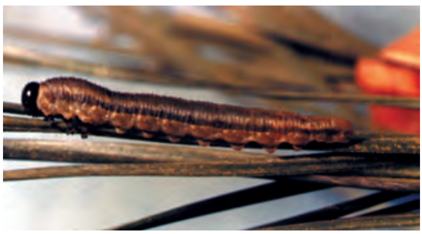


Figure 112e—Mature pine sawfly larva. Free-feeding sawfly larvae have six or more pairs of abdominal prolegs.

SAWFLIES, WEBSPINNING

Many species belonging to the *Acantholyda* and *Cephalcia* genera of Family Pamphiliidae

Hosts: Conifers. Host tree species vary according to sawfly species.

Distribution and Damage: Webspinning sawflies are found throughout Oregon and Washington. Larvae feed on the previous-year or current-year foliage of host trees, primarily on foliage produced the previous year. Unsightly nests made of webbing and debris are constructed by gregarious species.

Identification: Some webspinning sawfly larvae feed singly while others are gregarious. Gregarious species, also called false webworms, build communal softball-sized silken nests that become filled with frass and debris (Fig. 113a). The frass in the nests is green to brown with a distinctive elongate shape resembling wood fuel pellets. The solitary species build small, white, individual silk tube shelters alongside branchlets (Fig. 113b). A solitary webspinning sawfly on white fir that occasionally has reached epidemic proportions in southeastern Oregon feeds on new foliage only, consuming the entire needle except for a small stub (Fig. 113c).

In general, webspinning sawfly larvae resemble free-feeding sawfly larvae, but differ in having a more “wrinkled” appearance, a pair of slender, hornlike projections on their heads and last body segments and no prolegs on their abdomens (Fig. 113d). They spend most of their time in their silken nests and do not move around much on their host tres. Larvae or pupae overwinter in earthen cells in the soil. Adults emerge in spring and lay their eggs in host foliage. There is one generation per year, but it is common for some individuals to remain dormant in the soil for two or more years before emerging as adults.

Agents Producing Similar Symptoms and Signs: Other defoliators may cause similar damage, but the nest characteristics and physical characteristics of webspinning sawfly larvae are unique.

Severity: Webspinning sawflies are relatively uncommon insects. The effects of their feeding are usually minor.

References: General

- *Foliage discolored, partially chewed; needle stubs.*
- *Larva with wrinkled, rear-tapering abdomen, "horns" on head and posterior.*
- *On firs: small individual white silken tubes along branchlet axis.*
- *On pines: silken softball-sized nest of dead needles and frass.*

Figure 113a—Communal nest of a gregarious, webspinning sawfly on ponderosa pine.

Figure 113b—Silk shelter of a solitary webspinning sawfly, *Acantholyda* sp.

Figure 113c—Feeding by a solitary webspinning sawfly on white fir. Note partial consumption of foliage leaving needle stubs.

Figure 113d—Webspinning sawfly larva. Note wrinkled, rear-tapering abdomen and hornlike appendages on the head and posterior.

SILVER-SPOTTED TIGER MOTH

*Lophocampa argentata (*Packard) (previously known as *Halisidota argentata*)

Hosts: Douglas-fir is the principal host; also feeds on western hemlock, lodgepole pine, grand fir, Sitka spruce, western redcedar and several other conifers.

Distribution and Damage: Silver-spotted tiger moth is found in Oregon and Washington, most commonly in coastal areas. Larvae feed in early spring on host tree foliage without destroying buds and new foliage. Defoliation is usually spotty in distribution, both within the tree crown as well as across the landscape. Defoliation may be very heavy on one host tree while none of its neighbors are affected.

Identification: Unlike most common conifer defoliators, silver-spotted tiger moth caterpillars reach mature size and cause noticeable defoliation in early to mid-spring. Look for colonies of hairy brown caterpillars feeding in or near loose, debris-filled webbing (Fig. 114a). Each colony is usually restricted to a single branch. Young larvae are present in late summer and fall. They feed gregariously, forming loose webs containing chewed needles and frass in which they overwinter (Fig. 114b). The larvae resume feeding in early spring, and disperse to feed singly as they mature. Mature larvae are about 35 mm (1-3/8 in) long, reddish brown, with forward-projecting tufts of yellow and brown hairs, and dorsal tufts of black hairs flanked with yellow hairs (Fig. 114c). The adults, present in July and August, are yellowish brown, with heavy bodies and wingspans of 38 to 51 mm (1-1/2 to 2 in) (Fig. 114d). Their forewings, held rooflike over their bodies when at rest, are reddish brown with numerous silvery-white spots, and their hindwings are whitish with a few brown marks near the margins.

Agents Producing Similar Symptoms and Signs: Damage caused by the silver-spotted tiger moth is similar to that caused by other defoliators. It may be differentiated from many other defoliators by the large size of its larvae in early spring and summer when many other caterpillar larvae are either not present or quite small in comparison, the appearance and colonial habits of the larvae, and the presence of loose-webbed shelters in the branches.

Severity: Silver spotted tiger moth is not considered to be a major forest insect pest. Natural enemies usually keep populations in check.

References: 16

- *Defoliated branches with loose webbing, frass, and chewed needles.*
- *Colonies of hairy brown caterpillars noticed in spring.*
- *Spotty distribution.*

Figure 114a—Early spring silver-spotted tiger moth colony in a young Douglas-fir plantation.

Figure 114c—Mature silver-spotted tiger moth larvae feed singly.

Figure 114b—Young silver-spotted tiger moth larvae feed gregariously near loose, debris-filled webbing.

Figure 114d—Silver-spotted tiger moth adult.

WEEVILS, DEFOLIATING

Magdalis gentilis LeConte
Pachyrhinus elegans (Couper)
Pachyrhinus spp.

Hosts: Primarily ponderosa and lodgepole pines; also found on other pines and Douglas-fir.

Distribution and Damage: Defoliating weevils are found throughout Oregon and Washington. The adults feed upon foliage, causing needle damage, death, and premature drop. Damage caused by defoliating weevils is most often seen in young trees.

Identification: Damage is manifested as punctures in current-year needles (*Magdalis gentilis*) or as partially chewed, sawtooth-edged needles that break off and turn brown (*Pachyrhinus* spp.) (Figs. 115a, b). Adult weevils may be found feeding on the foliage throughout the summer. Look for adult weevils by examining the vicinity of characteristically damaged foliage. If none are apparent, rapping the branch over a flat surface may help to dislodge hidden weevils. Like all weevils, *Magdalis* and *Pachyrhinus* adults have elbowed antennae attached to a downward-curved snout. *Magdalis* adults are about 6 mm (1/4 in) long, black, and have prominent, curved beaks (Fig. 115c). *Pachyrhinus* weevils are the same size, but have short, broad beaks, and somewhat elongated bodies that are colored metallic blue-green, brass, gold, or bronze.

Agents Producing Similar Symptoms and Signs: Damage is easily mistaken for damage caused by other insects that chew the foliage. Positive identification may require examination of the insect doing the feeding.

Severity: Though often encountered, defoliating weevils are considered to be of minor importance.

References: General

- *Punctured new foliage or partially chewed, sawtooth-edged needles that break off and turn brown.*
- *Presence of adult* Magdalis *or* Pachyrhinus *weevils.*

Figure 115a—Feeding damage by *Magdalis gentilis* is characterized by puncture marks in current-year needles.

Figure 115b—Feeding damage by *Pachyrhinus* species is characterized by sawtooth-edged needles.

Figure 115c—Adult defoliating weevil, *Magdalis gentilis*.

WESTERN BLACKHEADED BUDWORM

Acleris gloverana (Walsingham)

Hosts: Western hemlock, Sitka spruce, true firs, Douglas-fir, Engelmann spruce, and mountain hemlock.

Distribution and Damage: Western blackheaded budworm is found throughout Oregon and Washington. Larvae feed on host tree foliage, slowing tree growth and causing topkill and mortality. New foliage is preferred, but during outbreaks larvae will eat old foliage after all of the new foliage has been consumed.

Identification: Heavily defoliated trees often have a reddish-brown, scorched appearance (Fig. 116a). Larvae mine old needles and bore into buds in the early spring, and then feed on the expanding foliage, living in constructed shelters of webbing and clipped needles (Fig. 116b). The larvae are wasteful feeders, and rarely consume entire needles.

Young larvae are pale yellow green with black heads; mature larvae are about 12 to 16 mm (1/2 to 5/8 in) long, with brown heads and green bodies (Fig. 116c). Larvae pupate in or near their webbed shelters from mid-July to mid-August (Fig. 116d). Adults are small gray moths about 19 mm (3/4 in) long, with mottled coloration and variable wing patterns.

Agents Producing Similar Symptoms and Signs: The damage is similar to that of other defoliators, especially the western spruce budworm and the Modoc budworm. However, western blackheaded budworm larval characteristics and host preferences are distinctive.

Severity: Although western blackheaded budworm outbreaks rarely cause significant damage east of the Cascade Mountains crest, in westside coastal forests they may cause significant levels of topkill and mortality. Large populations can cause extensive defoliation of hemlock and other host trees. Trees of all ages may be killed, topkilled, or severely weakened so that they are predisposed to attack by other agents. Outbreaks are sporadic and usually last 4 to 6 years.

References: 76, 83

- ✦ *Discolored, messily chewed, current-year foliage with webbing and frass.*
- ✦ *Green caterpillars with dark heads.*

Figure 116a—Feeding damage by western blackheaded budworm. Note wasteful feeding on current-year needles.

Figure 116b—Webbed shelter of a western blackheaded budworm larva.

Figure 116c—Western blackheaded budworm larvae have green bodies that lack light-colored spots.

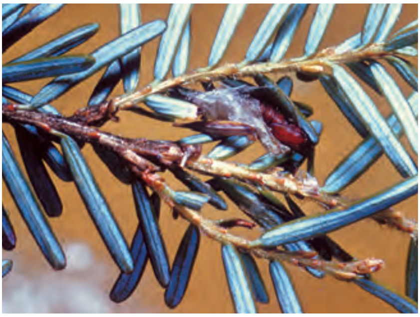


Figure 116d—Western blackheaded budworms pupate in or near their webbed shelters.

WESTERN PINE BUDWORM

Choristoneura lambertiana (Busck) (previously known as sugar pine tortrix)

Hosts: Ponderosa pine, lodgepole pine, sugar pine, and limber pine.

Distribution and Damage: The western pine budworm is found in Oregon, especially in the southwest and east of the Cascade Mountains crest. Larvae feed on host tree buds, current-year needles, and reproductive structures. Repeated defoliation can cause topkill and decreased seed production.

Identification: Defoliation is limited to new growth (Fig. 117). As larvae develop, they may consume nearly all of the new foliage. The western pine budworm is very similar to the western spruce budworm in appearance, life history, and habits. In spring, early instar larvae mine needle sheaths and staminate flowers. As the larvae grow, they feed on the elongating needles and construct nests of silk and webbed, chewed needles. Mature larvae are about 19 mm (3/4 in) long, and brown to rust colored with ivory spots. Pupae may be found in the silken nests during July or August. Moths appear in July or August and strongly resemble western spruce budworm moths.

Agents Producing Similar Damage: *C. lambertiana* is easily confused with the western spruce budworm, which is somewhat larger. However, western spruce budworm feeding on pines is incidental, and not likely to occur except in mixed stands of host and nonhost species. Western pine budworm damage may also be mistaken for that caused by pine needle sheathminer. Sheathminer larvae are orange and much smaller, and sever the needles at their bases, causing them to be easily pulled from the sheath.

Severity: Topkill may occur after several years of repeated, heavy defoliation, especially in understory trees.

References: General

- *Current-year foliage chewed and discolored, with webbing containing frass and debris.*
- *Olive-green to tan caterpillars with dark heads and white spots; look like western spruce budworm larvae (Fig. 118e).*

Figure 117—Western pine budworm feeding damage on current-year foliage of ponderosa pine.

WESTERN SPRUCE BUDWORM

Choristoneura occidentalis Freeman (= *C. freemani* Razowski)

Hosts: Douglas-fir, true firs, Engelmann spruce, and western larch. During outbreaks, larvae also may feed on understory non-host tree species, such as pines.

Distribution and Damage: Western spruce budworm is found throughout Oregon and Washington, however, most outbreaks occur east of the Cascade Mountains crest. Larvae consume current-year foliage. They also feed on flowers and developing cones, and sever the current-year shoots of western larch. Branch dieback and topkill begin to occur following two years of heavy defoliation (Fig. 118a). Sustained heavy feeding for four or five years can cause complete defoliation and tree mortality.

Identification: Look for chewed and discolored current-year foliage (Fig. 118b). Defoliation usually is most severe in the upper crown, outer branch tips, and on small, understory trees (Fig. 118c). Affected trees take on a scorched appearance as the summer progresses. Larvae mine old needles and bore into buds in early spring, then feed on expanding foliage. Larvae or pupae may be found on branch tips in silken shelters of webbed, chewed needles from June until August (Fig. 118d). The small larvae first seen in spring and early summer are light green to light brown with darker heads. Mature larvae are about 25 mm (1 in) long, and have brown heads with black markings and bodies that are tan and black with prominent ivory-colored spots (Fig. 118e, f). The pupae are shiny brown and about 19 mm (3/4 in) long (Fig. 118f). Adult moths are mottled rust brown and have a wingspan of about 22 mm (7/8 in). In August, female moths lay light green eggs in a shinglelike pattern on the undersides of needles. Larvae hatch in fall and seek sheltered spots on the trees in which to overwinter.

Agents Producing Similar Signs: Other larvae that defoliate firs, spruce, or larch may cause similar damage, but lack the distinctive coloration and spots of older western spruce budworm larvae. The western blackheaded budworm rarely causes appreciable damage in eastside forests. The Modoc budworm, *C. retiniana,* is another similar species that occurs in the Warner Mountains of California and Oregon. Mature Modoc budworm larvae and pupae are green rather than brown like western spruce budworm. On pines, western spruce budworm may be confused with the western pine budworm, which generally is smaller. Several other cone-infesting lepidopterans, including *Dioryctria* spp. and *Barbara colfaxiana,* cause similar cone damage.

Severity: Western spruce budworm outbreaks typically occur for many years over extensive areas, causing varying levels of decreased tree growth, tree deformity, topkill, and host tree mortality across the landscape. Tree mortality occurs only after three or more consecutive years of heavy defoliation. Understory trees are more seriously affected than overstory trees. Trees weakened by several years of budworm defoliation are often predisposed to attack by bark beetles, especially Douglas-fir beetle and fir engraver, and to infection by Armillaria root disease.

References: 24, 83

- *Current-year foliage chewed and discolored, with webbing containing frass and debris.*
- *Olive-green to tan caterpillars with dark heads and white spots.*

Figure 118a—Topkill of grand fir caused by western spruce budworm.

Figure 118b—Feeding and webbing of western spruce budworm occurs primarily on current-year foliage.

Figure 118c—Western spruce budworm defoliation is usually heavier in the tops of trees and in the understory. Current defoliation gives trees a scorched appearance.

Figure 118d—Young larvae of western spruce budworm in webbed "nests" containing chewed needles and frass.

Figure 118e—Mature western spruce budworm larva.

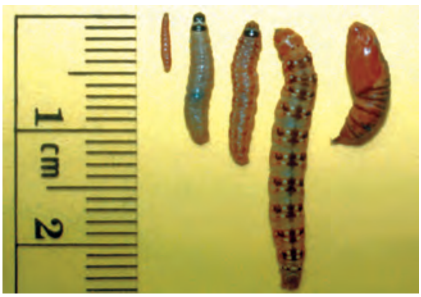


Figure 118f—Some western spruce budworm immature life stages (from left): third, fourth, fifth, and sixth instar larvae, pupa.

APHIDS and ADELGIDS

APHIDS Many species, Family Aphididae
ADELGIDS Many species, Family Adelgidae

Hosts: Aphid host species are found in most plant families; adelgids feed only on conifers.

Distribution and Damage: Aphids and adelgids are found throughout Oregon and Washington. They feed on foliage, buds, flowers, fruits, twigs, stems, and roots, using their piercing-sucking mouthparts to extract plant sap. Signs of feeding are often relatively subtle. For species that feed on foliage, typical feeding effects include chlorotic or necrotic spotting at feeding sites, needle twisting and stunting, and needle drop (Fig. 119a, 120c). Large populations can cause foliage yellowing and reduced growth, especially on small trees. Significant tree damage usually is manifested as an overall unthrifty appearance. A small number of species are capable of killing large trees.

Identification: Aphids and adelgids are small, soft-bodied insects that feed gregariously (Figs. 119b, c). Most are wingless, though winged individuals may occur in some species during some parts of the year. Color ranges from pale green to black, and some species are covered with a layer of white cottony wax (Fig. 119d). Aphids secrete “honeydew,” a nectarlike substance that attracts other insects, especially ants, bees, and wasps, and sometimes provides a growth medium for a black fungus called sooty mold. Foliage covered with honeydew appears shiny and may feel sticky. Aphids and adelgids that are commonly noticed feeding on conifer foliage in the Pacific Northwest include balsam twig aphid, *Mindarus abietinus* (Fig. 119a, Table 11), spruce aphid (Figs. 121a-d), and Cooley spruce gall adelgid (Figs. 120a-c). Similarly notable but feeding on twigs or bark are giant conifer aphids, *Cinara* spp. (Fig. 119c, e), hemlock woolly adelgid, *Adelges tsugae* (Fig. 119d, Table 8), and balsam woolly adelgid, *Adelges piceae* (Figs. 65a-e).

Agents Producing Similar Symptoms and Signs: Damage caused by aphids and adelgids can be difficult to distinguish from that caused by other sucking arthropods, needle midges, and needle diseases. The insects themselves may be mistaken for other small sucking arthropods such as mites, mealybugs, or scale insects.

Severity: Aphids and adelgids are commonly encountered on conifers growing in the Pacific Northwest. Some species can cause significant damage to ornamental conifers, Christmas tree plantations, and nursery stock. However, with the exception of the spruce aphid and the balsam woolly adelgid (which are capable of causing tree mortality), aphids and adelgids are not serious pests of conifers growing in natural forest settings.

References: 11, 20

- *Discolored foliage, needle twisting, stunting, and premature drop.*
- *Small, soft-bodied, pear-shaped insects, sometimes cottony, usually with no wings.*
- *Look for ants, a clear sticky glaze, or sooty mold on foliage.*

Figure 119a—Twisted, honeydew-glazed needles on grand fir caused by the balsam twig aphid, *Mindarus abietinus.*

Figure 119b—Adult aphid with wings. Note characteristic tubelike projections at rear of body and long, sucking mouthpart held under body.

Figure 119d—Hemlock woolly adelgids on western hemlock.

Figure 119c—Colony of giant conifer aphids on a young grand fir stem.

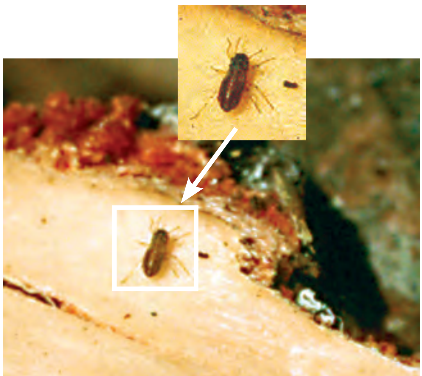


Figure 119e—Giant conifer aphids are dark colored, with long legs and large bodies.

COOLEY SPRUCE GALL ADELGID on DOUGLAS-FIR

Adelges cooleyi (Gillette)

Hosts: Douglas-fir (Alternate and primary hosts: Engelmann spruce, Sitka spruce, Brewer spruce, and ornamental spruces).

Distribution and Damage: Cooley spruce gall adelgid is found throughout Oregon and Washington. It has a very complex life cycle that includes several forms, alternate hosts, and may extend over two years. One form of this insect alternates successive generations between spruce and Douglas-fir. Other forms do not migrate to the alternate host; instead they cycle successive generations on spruce only, or on Douglas-fir. The adelgids feed by sucking plant fluids through their straw-like mouthparts. On Douglas-fir, Cooley spruce gall adelgid feeds on new needles, young shoots, and developing cones. Heavy infestations can cause discoloration and premature shedding of needles. On spruce, feeding causes formation of conelike galls (see p. 184).

Identification: Look for white cottony tufts on the undersides of needles during spring and summer (Fig. 120a). This is the characteristic appearance of feeding adult females, which are small, black, and soft-bodied under the waxy white secretions. These secretions provide cover and protection for the adelgids and their eggs (Fig. 120b). Black nymphs with white, waxy fringes may also be present. In May or June, young "crawlers" may be found on newly flushed foliage, appearing like specks of pepper to the unaided eye. As the growing season advances, heavily infested needles may appear chlorotic and misshapen and drop prematurely. Less severely infested needles often develop yellow spots at adelgid feeding sites (Fig. 120c).

Agents Producing Similar Symptoms and Signs: Damage is similar to that caused by Douglas-fir needle midges or aphids; it could also be mistaken for damage caused by a foliar disease such as Rhabdocline needle cast or Swiss needle cast. The presence of cottony tufts on the undersides of needles is the best distinguishing character.

Severity: Damage caused by this insect is mostly aesthetic. Young trees are more affected than older trees. Severe Cooley spruce gall adelgid infestation on young Douglas-firs growing on poor sites can cause heavy shedding of needles. Generally, infestations are of little importance under natural forest conditions, but they can cause significant damage to Christmas tree plantations, ornamentals, and nursery stock.

References: 11, 20

✦ *Small, white, cottony tufts on the undersides of Douglas-fir needles.*

Figure 120a—Douglas-fir seedling heavily infested with the Cooley spruce gall adelgid.

Figure 120b—Close-up of adult Cooley spruce gall adelgids.

Figure 120c—Yellow spotting of Douglas-fir needles caused by Cooley spruce gall adelgid.

SPRUCE APHID

Elatobium abietinum (Walker)

Hosts: Sitka spruce, ornamental spruces.

Distribution and Damage: Spruce aphid is found in coastal forests in Oregon and Washington and on many ornamental spruces, especially blue spruce, throughout both states. The species is native to Europe. Spruce aphids suck sap from old needles, causing them to discolor and drop prematurely. Successive years of heavy defoliation may kill branches or entire trees. On a heavily infested tree, the old needles may fade and drop off before the new foliage expands, causing the tree to appear dead for a period of time during spring. Buds are usually unaffected and flush normally, and the new needles are not fed upon much until the following fall. The lower, more shaded portions of host crowns are most subject to injury (Fig. 121a).

Identification: Only old needles are affected (Figs. 121b, d). Feeding effects are most apparent during April, May, and June, after the damaged needles have discolored or fallen and before the new foliage has fully expanded. Look for discolored previous-year foliage or sparse crowns; needle loss may be concentrated in the lower to mid crown. The aphids are difficult to see on foliage without magnification because they are very small, being less than 1.5 mm (1/16 in), and because their color matches that of the needles (Fig 121c). A good way to check for their presence is to tap the foliage over paper and look for small green aphids. Cast aphid “skins” and parasitized “mummies” (dead, swollen, golden-colored aphids) may also be present among the foliage.

Adults have yellow-green heads and red eyes. Most individuals are wingless. They feed gregariously and are found on the lower surfaces of needles. Although present on trees in coastal forests throughout the year, the aphids are most abundant and thus more easily found during late winter and early spring.

Agents Producing Similar Symptoms and Signs: Damage is similar to that caused by other defoliators, including foliar diseases caused by needle cast and rust fungi. Foliage retention patterns, the absence of fungal fruiting bodies on needle surfaces, and the characteristic features of the aphids themselves help to identify spruce aphid damage.

Severity: Spruce aphid outbreaks are sporadic and short-lived. Temperature patterns and fluctuations are thought to strongly influence population levels. Mild winters seem to favor the development of damaging populations. The spruce aphid is only one of several factors contributing to occasional extensive spruce mortality along the Pacific coast.

References: 11

- *Sitka or ornamental spruce with chlorotic or sparse interior foliage.*
- *Healthy green tips.*
- *Small green aphids on the undersides of older needles.*

Figure 121a—Injury caused by spruce aphid is more prevalent in the lower and more shaded portions of the crown.

Figure 121b—Bare crown interiors can result from several years of heavy feeding by spruce aphid.

Figure 121c—Spruce aphids feed on the undersides of spruce needles.

Figure 121d—Discoloration of Sitka spruce foliage caused by spruce aphid. Emerging foliage is unaffected *(photo taken in April)*.

ERIOPHYID MITES

Many species, Family Eriophyidae

Hosts: A wide variety of plants, including conifers and broad-leaved trees.

Distribution and Damage: Eriophyid mites are found throughout Oregon and Washington. All parts of a host plant are subject to infestation, including leaves, buds, stems, flowers and fruits. Eriophyid mites suck fluids from plants, causing a variety of symptoms and growth abnormalities, including stippling, russeting, stunting and twisting of the foliage, gall and blister formation, internal bud injury, and necrosis of buds, needles or growing tips. In sufficient numbers, they can weaken and stunt host trees.

Identification: Eriophyid mites are too small to see well without the aid of a microscope. Adults have no antennae and only two pairs of legs, unlike other mites, which have four pairs. They have translucent, elongate, wormlike bodies, and are slow moving. Due to the difficulty of detecting these mites under field conditions, field diagnosis relies primarily upon damage characteristics. Eriophyid mites often cause galls on the leaves of broad-leaved trees, e.g., red fuzzy patches on vine maple leaves are galls caused by a species of eriophyid mite. On conifers, damage symptoms include rosetted bud and needle clusters that resemble small witches brooms, chlorotic and distorted or dwarfed needles, galls, and premature foliage drop. Several species of the genus *Trisetacus* attack pines beneath the sheaths of current-year needles, causing the needles to become twisted, shortened, and eventually to turn yellow and drop off (Figs. 122a, b). In the coastal region of Oregon, the Douglas-fir bud mite, *Trisetacus pseudotsugae*, infests the buds of Douglas-fir, causing them to swell, develop abnormally, then die, eventually resulting in stunting when seedlings are attacked. Yew big bud mite, *Cecidophyopsis psilaspis*, an introduced species, similarly inhabits the buds of Pacific yew, causing needle and shoot distortion, and enlargement and death of buds (Figs. 122c, d).

Agents Producing Similar Symptoms and Signs: Damage caused by eriophyid mites may be confused in some instances with injury caused by air pollution, drought, or herbicide application (not covered in this guide), and generally resembles that caused by some other sucking and gall-making insects. On pines, pine needle sheathminer, gouty pitch midge, and Diplodia tip blight may produce similar symptoms. Microscopic inspection is usually required to confirm eriophyid mite damage.

Severity: Mite infestations are usually of minor importance under normal forest conditions.

References: 21

- *On pines: Twisted, shortened, and deformed needles that drop prematurely.*
- *On Douglas-fir: Abnormally swollen and dead buds.*
- *On Pacific yew: Abnormally swollen and dead buds, distorted needles and shoots.*

Figure 122a—Pine bud mite causes needle discoloration, twisting and drooping.

Figure 122b—Needle distortion and shedding on ponderosa pine tree caused by eriophyid mites.

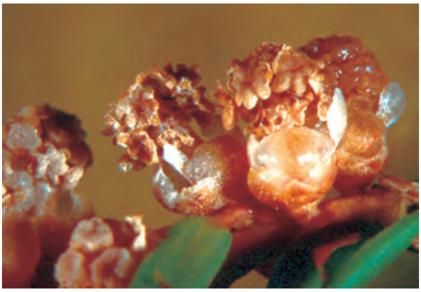


Figure 122c—Enlarged, discolored Pacific yew buds caused by yew big bud mite, *Cecidophyopsis psilaspis.*

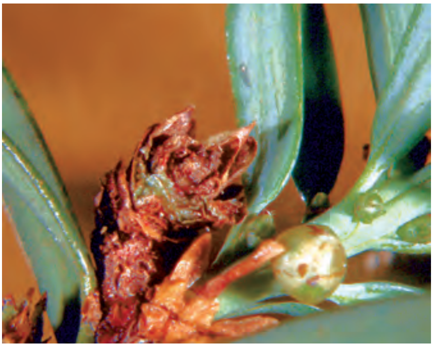


Figure 122d—Eriophyid mite feeding caused these yew buds to become enlarged, shrivel, and die.

SPRUCE SPIDER MITE

Oligonychus ununguis (Jacobi)

Hosts: Conifers; commonly occurs on spruces, Douglas-fir, junipers, true firs, hemlocks, Alaska yellow-cedar, western redcedar, and coniferous ornamentals.

Distribution and Damage: Spruce spider mites are found throughout Oregon and Washington. They suck fluid from needles, causing needle stippling, discoloration, and premature shedding. Seedlings and small trees are sometimes killed by heavy infestations. Large trees usually are not killed, but some growth reduction may occur during severe infestations.

Identification: Infested foliage first appears faded or may have a "dusty" or grayish appearance. Close inspection of needles reveals stippling and bronzing that may be more concentrated towards the bases of the needles. As the infestation continues, foliage may change from dingy yellow to rusty brown and ultimately drop off. Spruce spider mites spin extremely fine silken webbing among the needles and around the twigs. Their webbing has a characteristic "dirty" appearance due to the accumulation of cast mite skins and hatched eggs (Figs. 123a, b). The tiny, spiderlike mites are difficult to see with the unaided eye. When searching for mites, shake foliage over a white paper and look for tiny, moving creatures. Adult mites range in color from dark green to nearly black, have four pairs of legs, and no antennae (Fig. 100i). The winter is spent in the egg stage under loose bud scales and at the bases of needles, and the round, reddish-brown eggs hatch in May to early June. The spruce spider mite completes up to eight generations per year. Early generations feed on old foliage, and later generations feed on current-year shoots. Webbing becomes more abundant as the season progresses, and infestations usually become evident during summer and fall.

Agents Producing Similar Symptoms and Signs: Spider mite damage may be confused with air pollution injury, and is similar to that caused by some other mites, aphids, scale insects, needle midges, and some needle fungi. The presence of fine dirty webbing and the spiderlike shape of the mites themselves, however, are diagnostic.

Severity: The spruce spider mite is a common pest of ornamental conifers and Christmas trees, and sometimes becomes epidemic in forest settings. Dry weather conditions, as well as broad-spectrum chemical insecticide applications that reduce population levels of natural enemies favor population buildup. High humidity, strong winds, and heavy rain during the growing season help to keep numbers down. Outbreaks normally subside within one year.

References: General

- *Needle discoloration, often stippled or blotchy; premature needle drop.*
- *Extremely fine, silken webbing that contains tiny debris.*
- *Presence of tiny spiderlike mites.*

Figure 123a—Light spruce spider mite infestation on Douglas-fir branchlet. Note fine, particle-filled webbing among needles.

Figure 123b—Close-up of webbing and needle stippling caused by the spruce spider mite.

BLACK PINELEAF SCALE

Dynaspidiotus californicus (Coleman)

Hosts: Ponderosa pine, sugar pine, Jeffrey pine, lodgepole pine; sometimes Douglas-fir.

Distribution and Damage: Black pineleaf scale is found throughout Oregon and Washington. The scale insects suck fluid from needles, causing needle discoloration, stunting, and death (Fig. 124a). Dense populations can reduce shoot growth and cause branch dieback. Trees may be weakened and killed when severe infestations occur for several consecutive years.

Identification: Thin tree crowns are among the most obvious characteristics of black pineleaf scale infestation. In ponderosa pine, foliage sparseness caused by this scale frequently is more pronounced in a tree's lower and midcrown. Branches may develop a bushy-tipped appearance as damaged older needles are prematurely shed. Severely infested trees may exhibit extreme needle shortening. There is also considerable reddish or yellowish discoloration of needles, especially in the middle third of their lengths (Fig. 124b). The grayish black scale coverings of the insects are readily visible on the needles. The scale coverings are about 2.5 mm (3/32 in) long, broadly oval in outline and cone shaped in profile, with a central, yellowish-brown nipple (Fig. 124c). The living insects and their eggs beneath the scales are yellow. Black pineleaf scales have one generation per year and do not move once they have settled and begun feeding. They may be found throughout the year on living and recently shed needles.

Agents Producing Similar Symptoms and Signs: Black pineleaf scale may be confused with other agents that cause foliage discoloration, such as needle casts, pine needle scale, aphids, air pollution, winter desiccation, and drought. Thinning crowns due to black pineleaf scale may be confused with similar symptoms caused by root disease or other defoliators. However, the presence of scales and their color and shape are diagnostic.

Severity: Infestations of black pineleaf scale are often associated with excessive amounts of road dust, industrial air pollution, insecticide treatment, or other factors negatively affecting tree vigor or population levels of natural enemies. Usual feeding effects are to weaken trees and slow their growth, though trees may die after several consecutive years of heavy infestation. Heavy defoliation may also predispose trees to bark beetle attack.

References: 26

- *Small, black scale insects on needles.*
- *Thin tree crowns with foliage mainly at the branch tips.*
- *Discolored needles, especially in the middle third of their length.*
- *Stunted needles.*

Figure 124a—Black pineleaf scale infestation on ponderosa pines (hillside) adjacent to commercial fruit orchards regularly sprayed with insecticides (foreground).

Figure 124b—A pattern of yellowish to reddish discoloration that is especially prevalent in the middle third of needles is characteristic of black pineleaf scale infestations.

Figure 124c—Close-up of black pineleaf scales.

PINE NEEDLE SCALE

Chionaspis pinifoliae (Fitch)

Hosts: Ponderosa and lodgepole pines; sometimes found on Douglas-fir, spruce, and cedar.

Distribution and Damage: Pine needle scale is found in Oregon and Washington where hosts occur. Insects suck fluid from needles, and heavy infestations cause the foliage to turn yellowish brown (Fig. 125a). Trees are sometimes killed when heavy infestations occur for several consecutive years.

Identification: Small white "bumps," or scales, on the needle surface characterize pine needle scale infestations (Fig. 125b). A smooth shell-like covering protects an immobile, soft-bodied scale insect residing beneath. The scale covering is 2.5 mm (3/32 in) long, elongate-oval, and white with a yellowish apex. Pine needle scale can be found on the surfaces of infested needles any time of the year. Rusty-brown eggs may be found under the scales in winter. Trees sometimes are so heavily infested that the foliage appears white (Fig. 125c).

Agents Producing Similar Symptoms and Signs: Pine needle scale may be confused with other agents that cause foliage discoloration, such as pine needle fungi, black pineleaf scale, aphids, the Cooley spruce gall adelgid on Douglas-fir, winter desiccation, and drought. However, the presence of the scales themselves, their color, smoothness, and shape, are diagnostic.

Severity: Infestations are often associated with occurrence of excessive amounts of road dust, industrial air pollution, insecticide treatment, or other factors negatively affecting tree vigor or population levels of natural enemies. Usual effects are to weaken trees and slow their growth, though trees may die after several consecutive years of heavy infestation.

References: General

✦ *White scale insects on needles.*

Figure 125a—Discolored foliage on ponderosa pine infested with pine needle scale.

Figure 125b— Pine needle scales appear as small white oblong bumps on needle surfaces.

Figure 125c— Foliage heavily infested with pine needle scale may appear white.

SPONGY MOTH (formerly known as gypsy moth)

Lymantria dispar (Linnaeus), includes three subspecies: Spongy moth (*L. d. dispar*), Asian spongy moth (*L. d. asiatica*), and Japanese spongy moth (*L. d. japonica*). Asian and Japanese spongy moths and three other *Lymantria* species native to Asia are commonly referred to as 'flighted spongy moth.'

Hosts: Larvae prefer hardwoods but may actually feed on several hundred different species of trees and shrubs, including conifers.

Distribution and Damage: Spongy moths are non-native forest pests. Currently there are no established populations in Oregon or Washington. However, travelers regularly introduce them from other portions of the world. As a result, local, isolated infestations continue to occur sporadically in both states. In the eastern United States, where the spongy moth has become well established, larvae feed upon host tree foliage, sometimes completely stripping entire stands. Defoliation in the West generally has been limited to recreational, wildland-urban interface, and urban areas.

Identification: Larvae feed from early spring to mid-June or early July. The first larval stage chews small holes in leaves, and the second and third stages feed from the outer leaf edge toward the center. Larvae of all ages are hairy (Fig. 126a). Older larvae are sooty colored to brownish gray, with a double row on their backs of five pairs of blue dots followed by six pairs of red dots (Fig. 126b). Mature larvae are 38 to 64 mm (1-1/2 to 2-1/2 in) long. Pupae are naked and dark reddish brown with some reddish hairs. They may be found in midsummer attached by silken threads to the undersides of bark flaps, in crevices, under branches, on the ground, or almost anywhere that the larvae rest. In late summer, female moths deposit feltlike masses of buff-colored eggs clothed in yellowish hairs on tree trunks, branches, cars, trailers, ships, etc. (Fig. 126c). The egg masses overwinter and hatch the following spring. The female moths have a 51 cm (2 in) wingspan, large, buff-colored bodies, and white wings with dark wavy lines and dots along the outer edges. The smaller male moths have a wingspan of 38 mm (1-1/2 in) and brown wings with dark irregular banding and dark margins (Fig. 126d). Spongy and flighted spongy moths are difficult to differentiate. Female spongy moths cannot fly, but female flighted spongy moths, hybrid females (spongy x flighted spongy), and males of all species are active fliers.

Agents Producing Similar Symptoms and Signs: Spongy moth defoliation resembles that of other defoliators. Their characteristic egg masses, larvae, and adults distinguish spongy moths.

Severity: Spongy moth defoliation is potentially serious. Tree mortality may result when severe or repeated defoliation is coupled with other stressors such as drought, other insects, or diseases. The spongy moth is a major pest of eastern forest and urban areas, where it became established after introduction from Europe in 1869. Possible introduction of flighted spongy moths is a special concern because they are such voracious feeders, show much more preference for conifer hosts, and are considerably more mobile than the spongy moth. In the Pacific Northwest, continuous extensive monitoring programs and aggressive insecticide treatments have so far been successful in preventing establishment.

References: 56

- *Defoliated hardwoods and other tree and shrub species.*
- *Hairy, soot-colored caterpillars.*
- *Feltlike buff-colored egg masses.*

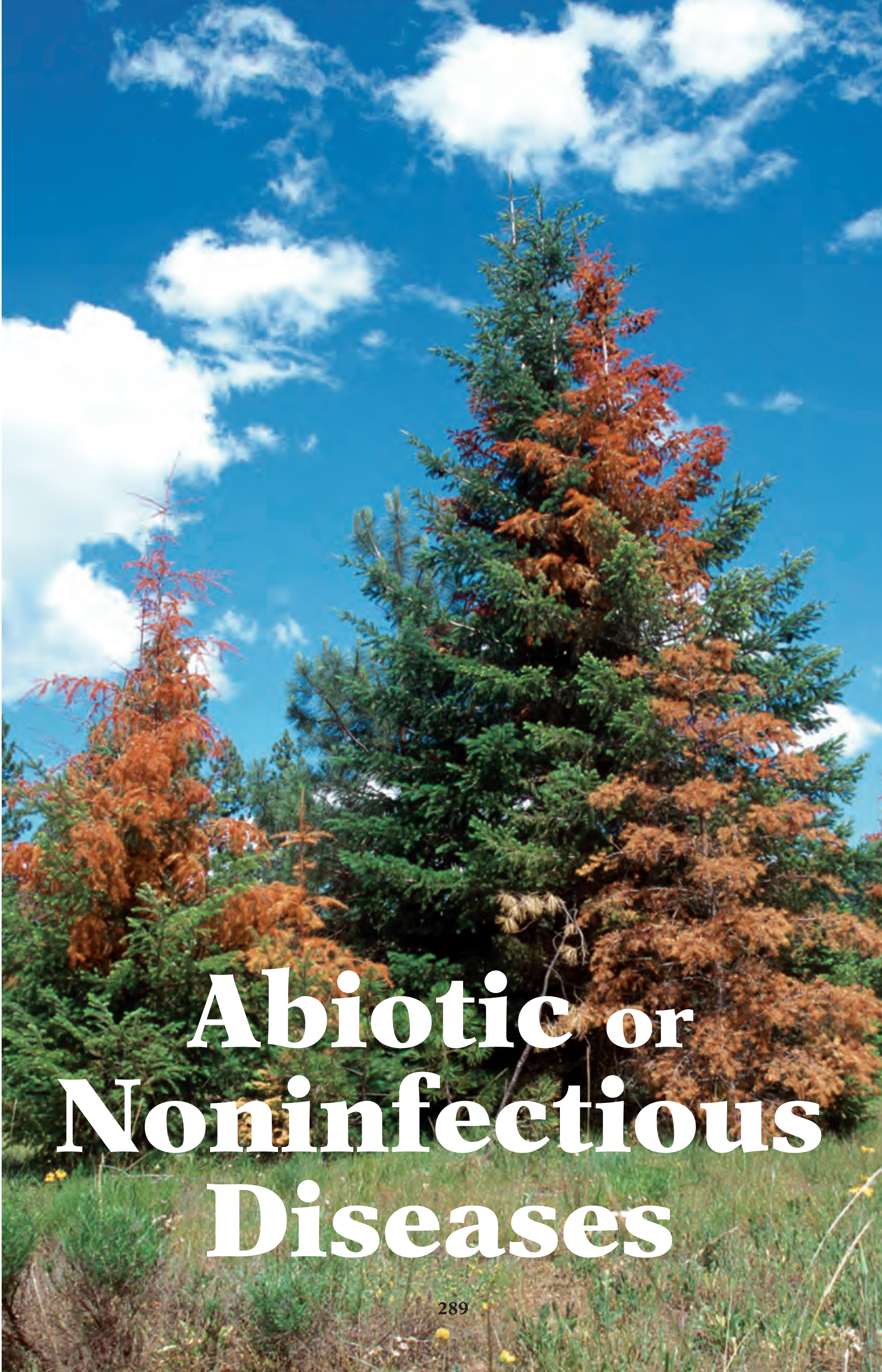
Figure 126a—Spongy moth larvae are hairy and soot-colored with lighter markings.

Figure 126b—Mature spongy moth larva.

Figure 126d—Male spongy moths are brown. They are active fliers.

Figure 126c—Female spongy moth and buff-colored egg mass. Spongy moth females cannot fly.

The following may also damage foliage:



Abiotic or Noninfectious Diseases

AIR POLLUTION

Hosts: All conifers; ponderosa pine and Jeffrey pine will often be the first species to show injury.

Distribution and Damage: Light to moderate air pollution damage is commonly found, especially on ponderosa pines, in the eastern portion of the Columbia River Gorge, but may occur in any area exposed to sufficient pollutant levels. Damage occurs when susceptible plants are exposed to photochemical smog, direct emissions from automobile exhaust, toxic gases emitted from smelters, reduction plants, coal-burning industries power plants, or acid deposition. Damage is usually evident as burned or discolored foliage.

Identification: Symptoms and severity of damage vary by species, concentrations and types of pollutants, duration of exposure, and distances from sources. Symptoms include chlorosis and premature needle fall or death, diminished growth, and in some cases, progressive decline in tree health (Fig. 127a). Conifer needle discoloration may be seen as mottling, chlorotic specks and/or tip dieback (Fig. 127b). Foliage, buds, branches, and entire trees may be killed. Air pollution sources should be identified when ascribing damage to this cause.

Agents Producing Similar Symptoms and Signs: Other abiotic injuries such as drought or winter damage may be confused with air pollution damage. Needle symptoms such as chlorotic speckling and premature needle drop may be confused with damage caused by sucking insects. Careful evaluation of signs, symptoms, patterns, and context is necessary to reach an accurate diagnosis; knowledge about the location of pollution sources and history of exposure is essential when identifying air pollution as the cause of damage.

Severity: Severe damage due to air pollution has not been identified in Oregon and Washington. Damage is most likely to be greatest near urban-forest interfaces or downwind from pollution sources.

References: General

- *Identify pollution source.*
- *Mottling of foliage or tip dieback.*

Figure 127a—Air pollution injury to pines in the San Bernardino Mountains of southern California.

Figure 127b—Spotting or mottling of pine foliage caused by air pollution.

DROUGHT/WATER STRESS

Hosts: All conifers.

Distribution and Damage: Drought damage may be seen throughout Washington and Oregon. Damage occurs most frequently on dry aspects, shallow soils, "droughty soils," or during long periods of drier-than-normal weather. Foliage dies on drought-damaged trees; shoots and branches may suffer dieback, topkill often occurs. Seedlings and recently planted trees are at greatest risk and most often affected. Growth loss may result from loss of foliage and damage to cambium.

Identification: Drought causes wilting, chlorosis, and reddening of foliage (Figs. 128a, b). Often there is an irregular, random, patchy pattern of flagging in the crown. Foliage may appear shrunken. Symptoms usually progress from the top of the tree down and from the outside in (Fig. 128b). New foliage may be shed. Stem and branch tissue dies in patches or at the tips and may shrink. Tops may be killed. Bark beetles, twig and root-feeding weevils, canker fungi, and root diseases are often associated with drought-weakened trees. Young trees killed amongst older trees affected by bark beetles may indicate drought stress.

Agents Producing Similar Symptoms and Signs: Root diseases, bark beetles, frost damage, chronic needle cast, and some mechanical injuries may cause similar symptoms. Branch and stem cankers and branch and stem insects are often associated with drought stress. It may be difficult to separate drought damage from that caused by other stress-related organisms.

Severity: Drought may be locally or regionally severe, depending on intensity and duration.

References: General

- *Young tree death with no evidence of other agents in stands.*
- *Knowledge of weather and site conditions.*
- *Trees exhibiting dieback and bark beetle attack.*

Figure 128a—Drought damage on young ponderosa pines.

Figure 128b—Symptoms of drought or water stress on plantation Douglas-fir in western Oregon.

FROST

Hosts: All conifers. Douglas-fir and true firs are most often damaged.

Distribution and Damage: Frost damage occurs occasionally throughout the Region. It is often chronic at higher elevations, on large flats, or in other locations where cool air pools. If frost occurs before bud break, some buds may be killed. After bud break, new needles and soft succulent shoots may be damaged. Frost cracks occur on main stems of thin-barked species, particularly true firs, during periods of sudden cooling. These cracks can provide entrance courts for decay fungi, or, in the case of *Echinodontium tinctorium*, initiate fungal growth. Callus tissue forms over the surface of the crack in the first season but cracks usually repeatedly split and heal for several years.

Identification: New foliage will first appear faded and yellow. After a week or so, damaged foliage will turn red to reddish-brown and usually droops (Figs. 129a, b). Trees that are repeatedly damaged have a bushy appearance. Damage often occurs on more than one species in a stand. Cracks on the main stems that are caused by frost usually do not extend more than 6 m (20 feet) from the ground (Fig. 129c). Callus growth that extends out from the crack like a long rib is common.

Agents Producing Similar Symptoms and Signs: Western spruce budworm and Douglas-fir tussock moth defoliation may cause similar-appearing damage to foliage, however, no chewed needles will be apparent on frost-damaged shoots. Repeated grazing by animals will cause similarly bushy trees. Bole injuries caused by lightning, sunscald, or mechanical injury sometimes may appear similar to frost cracks, which can be distinguished by their length, width, and position on the bole.

Severity: Frost damage may be locally severe.

References: General

- ✦ *Drooping, reddened buds and new needles.*
- ✦ *Several species affected in a stand.*
- ✦ *Long cracks with callus growth or evidence of healing/cracking cycle.*

Figure 129a—Douglas-fir with frost damage. Trees that are repeatedly damaged take on a shrubby or bushy appearance.

Figure 129b—When frost occurs soon after bud break, new needles and succulent shoots may be damaged.

Figure 129c—Frost crack.

HAIL

Hosts: All conifers.

Distribution and Damage: Hail injury can occur throughout Washington and Oregon. Damage may be very local, affecting only trees in small areas or strips in a single drainage. Trees are most severely damaged when new growth is in progress. The worst damage occurs in the upper portions of trees and on branches on the windward side. Douglas-fir is reported to be more prone to hail injury than other conifer species.

Identification: Immediately after a hail storm the ground will be littered with foliage and small branches. Numerous small wounds may be visible on the uppersides of branches (Figs. 130b, c). Wounds may be substantial enough that branch and branch tip dieback result (Fig. 130a). Topkill and one-sided crowns may still be visible years after hail damage has occurred.

Agents Producing Similar Symptoms and Signs: Strong winds or winter injury may change tree crown shapes. Drought, snowbreak, cold injury, bark beetles, weevils, and canker fungi may cause branch and branch tip dieback or topkill. The wounds caused by hailstones or the foliage and branch loss visible immediately after the storm will separate hail injury from other damaging agents.

Severity: Hail damage can be locally severe.

References: General

- *Numerous small wounds on upper sides of branches.*
- *Topkill and damage to windward sides of trees.*

Figure 130a—Hail damage may result in branch and tip dieback. Damage can be severe in localized areas.

Figure 130b—Hail damage is often identified by the small wounds on upper sides of branches.

Figure 130c—Hail damage.

MECHANICAL INJURIES

SNOWBREAK

Heavy, wet snow or ice accumulations can often cause bending of small stems and top breakage in larger trees (Figs. 131a, b). Stems usually straighten after a few years, but snowbending can significantly reduce height growth the year after injury. Prolonged or repeated bending may alter stem form. Top breaks in younger trees result in production of forked or multiple leaders. Top breaks in older trees may serve as entrance courts for decay fungi.

LIGHTNING

Lightning injury to taller trees is usually identified by the torn bark and thin layer of wood that extends spirally from the top of the bole down the tree stem, often all the way to the ground (Fig. 131c). Affected tree tops may be killed immediately. Some trees, such as white fir, readily explode or shatter. Bark beetles often infest trees injured by lightning. Small circular groups of conifers surrounding the lightning-struck tree may be scorched and killed by the lightning's electrical discharge. Lightning injury can be distinguished from frost cracking by the jagged edge, spiral pattern, and length.

FIRE INJURY

Fire damage to conifers is usually most severe when trees are actively growing. Tree survival after fire is dependent upon the amount of bud and twig mortality, foliage loss, and cambial injury. Extensive heat injury to foliage may occur without much damage to buds and twigs. Species with thick bark have greater insulating capacity than thinner barked species; thick bark protects the cambium from damage. Cambial injury is usually greatest on the lee side of a tree and on the uphill sides of trees on slopes. Internal fire scars result when new tissue grows over the injured cambium. Open fire scars result when wound callus cannot cover the injured area (Fig. 131d). Young trees of all species are more susceptible to fire injury than older trees with well-developed bark structure.

PHYSICAL / LOGGING WOUNDS

Heavy equipment can cause damage to conifers by removing the bark or by severing portions of roots (Fig. 131e). Injured trees are more prone to decay and bark beetle attack. Serious loss of root strength makes trees vulnerable to windthrow.

- *Stem breaks, bole scars, charring.*
- *Knowledge of weather events, fire history, logging activities.*

Figure 131a—Snow damage resulting in topbreaks.

Figure 131b—Snow damage in lodgepole pine.

Figure 131c—Lightning injury.

Figure 131d—Fire scar on ponderosa pine.

Figure 131e—Logging wound on white fir.

SUNSCALD/HEAT INJURY

Hosts: All conifers.

Distribution and Damage: Sunscald or heat injury may occur throughout Washington and Oregon. The foliage of coastal or shade tolerant species that has developed under cool conditions may be injured by sudden temperature increases. Developing shoots that experience a sudden temperature rise in late spring may be injured. High temperatures in spring, summer, and fall combined with low moisture and dry winds may result in extensive topkill in large trees. The cambium on south or southwest sides of thin-barked species such as white pines, hemlocks, true firs and young Douglas-fir may be damaged when exposed quickly to heat and sun. Cankers often develop in these species after they have been thinned. Growth loss may occur from substantial foliage loss. Injured stems may be prone to breakage.

Identification: Tip browning of coastal or shade tolerant species may indicate high temperature injury. Heat-injured shoot tips droop, turn red (Fig. 132c), and break off. Cambial tissue is shrunken and discolored immediately after sun injury (Fig. 132b). Bark in areas of injury dries and cracks and healing is often slow (Fig. 132a).

Agents Producing Similar Symptoms and Signs: Tip browning may be confused with damage by defoliating insects, foliar fungi, cold and winter injury, chemical damage, or on pines, gouty pitch midge. Shoot tip dieback may be confused with frost damage. Cankers caused by fungi, drought damage, and bark beetle or weevil activity on stems may look very similar to sunscald.

Severity: May be locally severe.

References: General

- *Knowledge of weather, site condition, and harvest activities.*
- *Drooping, reddened shoots.*
- *Thin-barked species affected on south/southwest sides.*

Figure 132a—Injury on trunk due to sunscald.

Figure 132b—Sunken, discolored areas on trees of thin-barked species such as western hemlock may result from sudden exposure to the sun.

Figure 132c—Heat injury to ponderosa pine.

WINTER INJURY

Hosts: All conifers.

Distribution and Damage: Winter injury occurs throughout Oregon and Washington. Several types of winter-related injuries may affect trees. Severe cold may directly kill portions of the cambium resulting in branch or tip dieback, topkill, or patches of dead tissue on the main stem. Affected areas may be invaded by secondary organisms such as canker fungi, bark beetles, or wood borers. Severe cold may also directly discolor or kill foliage. Warm sunny days that occur when soils are very cold or frozen may result in drying and subsequent death of foliage. In such cases water is rapidly lost from the transpiration stream or is unavailable due to the soil conditions. When this type of injury is associated with temperature inversions that occur in mountainous terrain, many trees may be affected in a band or strip at or near the inversion boundary resulting in "red belt." Winter drying may also be associated with tree parts not protected by snowpack. Abrasion by ice crystals of the waxy coating that protects conifer needles may also result in needle desiccation. Winter injury may occur locally throughout the region; however, it is often most visible in the Columbia River Gorge, near east-west mountain passes after long periods of cold east winds, or in the valleys west of the Cascades.

Identification: Branch dieback, topkill, and whole tree mortality of small trees particularly on exposed sites. Reddish-brown foliage may be found predominantly on the windward side of tree crowns, on the southwest side of trees or in elevational bands on mountainsides where temperature inversions are common (Figs. 133a, b). Damage occurs most often in the tops or upper portions of affected trees (Fig. 133c). Damaged needles may be shed during the spring following injury leaving a thin crown or dead branches.

Agents Producing Similar Symptoms and Signs: Needle casts may produce similar symptoms; however, damage by fungi typically is concentrated in the lower portion of the crown rather than the upper portion. Canker fungi, bark beetles, and wood borers may be associated with cambial damage due to cold temperatures.

Severity: Winter injury is sometimes locally severe, causing considerable needle loss and even mortality.

References: General

- *Reddish-brown foliage on windward sides.*
- *Trees affected in an elevational band.*

Figure 133a—Winter injury on young ponderosa pine. Note the reddened needles.

Figure 133b—Winter injury in ponderosa pine plantation.

Figure 133c—Douglas-fir topkill caused by severe cold.

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Recommended Online References

There are excellent additional forest entomology and pathology references available on the Internet. Many of these sites can be accessed directly through the Pacific Northwest Region Forest Health Protection website:

www.fs.usda.gov/main/r6/forest-grasslandhealth

Glossary

abdomen – Posterior or hindmost portion of an insect's three main body divisions.

abiotic – Nonliving factors such as temperature, moisture, and wind.

adult – Full-grown, sexually mature insect; usually has wings, in contrast to larvae or nymphs, which lack wings.

aecia – Plural form of aecium. One of the many types of fruiting bodies formed during the life cycle of rust fungi; a cup-like structure producing aeciospores.

anamorph – Imperfect state of a fungus; produces asexual spores.

annual – An event that occurs once a year, or something that lasts one year or season; also, completing the life cycle in one year.

apical – Of, relating to, or situated at an apex.

Ascomycete – A class of fungi that produces spores in a saclike structure called an ascus.

arthropod – An invertebrate animal characterized by an exoskeleton, segmented body, and paired, jointed limbs; includes insects, arachnids, and crustaceans.

Basidiomycete – A class of fungi that produces spores in or on the outside of a structure called a basidium.

blight – A disease or injury that results in rapid discoloration, withering, cessation of growth, and death of parts without rotting.

boring dust – Tiny particles of bark or wood produced by insects as they tunnel in woody plant structures.

brood – All of the bark beetle offspring, produced by a group of females of the same species within the same timeframe, that hatch and mature at about the same time (e.g., all the beetles that emerge from an infested tree); also applies to the offspring of an individual female.

broom – An abnormal proliferation of branches or twigs on a single branch.

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 left is predominantly lignin.

buff – Off-white, cream to yellow-tan color.

cambium – Layer of actively dividing cells between the xylem (sapwood) and the phloem (inner bark) of trees, which forms additional conducting tissue, therefore increasing the girth of a stem, branch, or trunk.

canker – An oval or circular killed area on a stem or branch; usually with a shrunken surface.

chlorotic/chlorosis – Yellow appearance of normally green foliage caused by loss or lack of chlorophyll.

cm – Centimeter, a unit of length; also centimeters. 2.54 centimeters = 1 inch.

cocoon – A covering composed partially or wholly of silk, constructed by a larva as a protection to the pupa.

cohort – A group of individuals having a common statistical factor such as age, e.g., all of the foliage produced during the same year.

conk – The large, often bracketlike fruiting bodies of wood-consuming fungi (Basidiomycetes).

complement – The set of foliage produced by evergreen trees during one growing season.

context – The interior or body portion of a conk or a mushroom. The context supports the reproductive structures.

cryptic – Hidden or concealed; not readily apparent.

cubical decay – Decayed wood breaking up into distinct cubes.

dbh – Diameter at breast height. Tree diameter measured at 4.5 ft from the ground.

decay – The decomposition of wood by fungi.

decline – Gradual reduction in health and vigor as a tree is in the process of dying slowly.

defoliation – Premature removal of foliage.

defoliator – An insect or pathogen that feeds on the living tissues or plant sap in foliage; physically removes needles or portions of needles, or causes tissue necrosis and premature needle drop.

delaminating decay (laminate decay) – Selective, more extensive decay in the springwood than the summerwood causing the wood to separate into sheets or laminae along annual rings.

desiccation – Rapid drying of plant parts.

dieback – Dead apical parts, usually twigs or limbs; also the process of dying from the outside in.

disease – A prolonged disturbance of the normal form or function of a tree or its parts.

distal – Near or toward the free end of an appendage; far from the point of attachment or origin.

distress cones (stress cones) – A cone crop produced as the result of tree stress; often associated with root diseases. Cones may be produced relatively early in the tree's life and are often very numerous and small in size with high percentages of nonviable seeds.

dorsal – Refers to the upper surface of an organism, appendage, or part.

ectotrophic mycelium – Fungal growth on the outside of a root or within the fissures of root bark.

egg gallery – Tunnel constructed under the bark of host trees by adult beetles for the purpose of laying eggs. Egg galleries maintain a fairly constant width with increasing length, but are sometimes associated with wider constructions, such as entrance points and nuptial chambers.

egg niche – A small recess constructed in woody plant tissue by a female insect for the purpose of egg deposition.

elytra – Leathery front wings of beetles which cover the membranous hind wings when the insect is not in flight; not used for flying.

elytral declivity – The posterior, down-sloping portion of the elytra.

entrance court – The point of invasion of a disease organism into its host.

ephemeral – Lasting a very short time.

epicormic – Branches of foliage arising abnormally along a trunk as the result of release of dormant buds or the differentiation of buds from callus.

etched – Lightly imprinted on a surface.

exotic – An introduced, or non-native, insect or pathogen.

exudate – Material that has oozed to an outer surface through minute openings.

fascicle – An individual needle bundle or cluster on coniferous species.

flagging – Conspicuous recently dead or dying shoots or branches on a live tree that have discolored foliage still attached.

forewings – On insects having two pairs of wings, the pair of wings closest to the head.

frass – Solid insect excrement, particularly of larvae; particles are usually rounded pellets.

free feeder – Refers to the feeding habit of the immature stages of many defoliating insects; free-feeding larvae live in the open upon foliage surfaces without constructed webbed shelters and do not reside in the interior of needles, buds, or expanding shoots.

fruiting body – Any of a number of kinds of reproductive structures that produce spores.

ft – Foot, a unit of length; also feet. 1 foot = 12 inches.

fungus (*pl.* fungi) – A member of the group of saprophytic and parasitic organisms that lack chlorophyll, have cell walls made of chitin, and reproduce by spores; includes molds, rusts, mildews, smuts, mushrooms. Fungi absorb nutrients from the organic matter in which they live. Not classified as plants; instead fungi are placed in the Kingdom: Fungi.

gall – Abnormal proliferation of plant tissue, stimulated by insects, pathogens, or abiotic influences.

gallery – A tunnel constructed by an insect in which it lives, feeds, or deposits eggs.

gelatinous – Resembling gelatin or jelly.

gouting – Abnormally thickened or swollen branch tips or branches, caused by insects, pathogens, or abiotic influences.

gregarious – Living or feeding in groups.

grub – A thick-bodied, usually sluggish, larva; usually refers to the larva of a beetle.

hard pines – Pines having 2 or 3 needles per fascicle (rarely 5 to 8); needle cross-section shows 2 fibrovascular bundles; wood is hard, with an abrupt transition from springwood to summerwood; cone scales are usually thick at the apex and have a short spine; species native to Oregon and Washington include ponderosa pine, Jeffrey pine, knobcone pine (Oregon only), and lodgepole pine.

heart rot – A decay restricted to the heartwood.

heartwood – Central mass of tissue in tree trunks; contains no living cells but functions as mechanical support.

hidden decay – Decay present in wood without outwardly visible signs or symptoms.

hindwings – On insects having two pairs of wings, the pair of wings farthest from the head.

honeydew – Clear, sugary, liquid excretion of aphids or scales. Becomes sticky and shiny when dried.

hyphae – Microscopic filaments of fungal cells.

hysterothecia – Elongated fungal fruiting bodies that open with a slit, found in Ascomycete fungi. Common to many needle cast fungi.

in – Inch, a unit of length; also inches. 1 inch = 2.54 centimeters.

incipient decay – The earliest stages of wood decay in which the wood may show discoloration but is otherwise not visibly altered.

infection – The act of a pathogen establishing itself on or within a host.

infection factor –Used to describe three levels of relative susceptibility to dwarf mistletoe infection and represented as a range of the percentages of infected trees, e.g., 50-90%. Based upon the percentage of infected trees (for each host species) growing within 6 m (20 ft) of a heavily parasitized host; meaningful only in stands with trees older than 30 years.

laminae – Individual sheets or layers of wood resulting from preferential decay of springwood.

larva (*pl.* larvae) – An immature form of an insect that undergoes complete metamorphosis, such as a caterpillar, grub, or maggot.

larval gallery – Tunnel constructed by developing beetle larvae as they feed under the bark. Larval galleries tend to grow wider with length.

lateral – A branch that arises from a whorl along the vertical axis of the conifer tree bole and extends outward to form an angle that typically ranges between 45 and 225 degrees.

lesion – A localized zone of dead or dying tissue.

longitudinal – Placed or running lengthwise with the axis of the tree bole or limb.

m – Meter, a unit of length; also meters. 1 meter = 3.28 feet.

maggots – Small, headless, legless, white to creamy larvae belonging to the order Diptera (flies).

maturation feeding – A period of feeding, by recently pupated, sexually immature adults of some insect species (especially beetles) upon specific plants or plant parts, that is essential for completion of reproductive development.

mm – Millimeter, a unit of length; also millimeters. 10 millimeters = 1 centimeter.

molt – A process of shedding the outer layer; when molting, insects shed their exoskeleton (sometimes improperly called "skin").

mushroom – A fleshy fruiting body of a fungus, often with a gilled pore surface.

mycelium (*pl.* **mycelia)** – The collective mass of vegetative elements, or hyphae, of a fungus.

mycelial fan – Dense mass of mycelium which takes the form of a thick mat that is fan shaped.

mycelial felt – Dense mass of mycelium which takes the form of a thick mat.

necrotic – Dead; usually refers to cells or tissue killed by injury or disease.

necrosis – Localized death of living tissue, usually resulting in darkening of the tissue.

needle fascicle sheath – The thin, somewhat papery, tubular covering that surrounds the base of a pine needle fascicle.

notch – Abrupt, rounded protuberance of a bark beetle egg gallery wall; has no egg niches or larval galleries. Usually marks the point of entry to the egg gallery from the outer bark surface and sometimes is used as a nuptial chamber.

nuptial chamber – An open, cavelike area constructed in the inner bark beneath the entrance hole by the male of some bark beetle species where mating takes place and from which the egg galleries originate. When viewed with the bark removed, nuptial chambers appear as enlarged areas at junctions or at the beginnings of egg galleries.

nymph – An immature form of an insect that undergoes incomplete metamorphosis; nymphs resemble the adults except for size and wing development.

Oomycete – A class of microscopic soil and water organisms that have a mobile, swimming spore stage called a zoospore and a thick-walled sexual spore called an oospore.

overwinter – To survive through winter; term commonly used when describing the life stage in which an insect passes the winter months.

ovipositor – A tubular or valved structure used by an insect to lay eggs, usually concealed, but sometimes extended far beyond the end of the body.

parasite – An organism living on or in and nourished by another living organism.

pathogen – An organism that causes a disease.

pathogenic – Being capable of causing disease.

patch attack – An attack by bark beetles that does not completely girdle the tree but is concentrated along one side or within a relatively confined area on the bole, resulting in death of only a portion of the bole; also called a strip attack.

perennial – An organism that lives from year-to-year; persisting for several years.

pitch – A resinous exudate of various conifers.

pitch nodule – A small lump of pitch attached to a conifer branch or bole.

pitch tube – A globular mass of resin, boring dust, and frass that forms on the bark of pine trees at bark beetle entrance holes.

pitch streamers – Long, thin flows of pitch on the tree bole.

pith – The soft, spongelike center of stems and branches of woody plants.

phloem – Conductive tissue found between the sapwood and outer bark of trees or other woody plants.

phytophagous – "Plant-eating."

pocket rot – A characteristic pattern of rot that occurs in distinct, scattered pockets rather than in columns.

pore – The open end of a tube in which certain spores of higher fungi are produced.

pore layer (pore surface) – The surface of a fruiting body on which the pores are found.

posterior – The hind or rear part of the body.

primary – Organisms which are capable of invading apparently healthy hosts and causing mortality.

proleg – The fleshy, unjointed appendages found on the abdomens of caterpillars and some sawfly larvae; also called "false legs."

propagale – Any structure having the capacity to give rise to a new plant or fungus, whether through sexual or asexual reproduction. This includes seeds, spores, and any part of the vegetative body capable of independent growth if detached from the parent.

pseudothecia – Tiny, round to flask-shaped fruiting bodies containing asci and ascospores and produced by certain Ascomycetes.

punk knot – Soft, decayed branch stubs that usually indicate the presence of decay in a tree.

pupa (*pl.* pupae) – The inactive transitional stage between the larval and adult portions of the life cycle that occurs in insects with complete metamorphosis. Characterized by an outer covering formed by the larva as it changes into a pupa.

pupal cell – Cavity at the end of the larval gallery in which pupation occurs.

pupate – To change from a larva into a pupa; to pass through the pupal stage to adulthood.

pustule – Blisters of an infecting fungus that mature into fruiting structures.

reproduction – The act or process of giving rise to offspring; also, young seedling trees in a forest.

resinosis – Reaction of a tree to invasion by pathogens, insects, or abiotic injury which results in flow of resin on the outer bark or accumulation of resin within or under bark.

rhizomorph – A specialized thread- or cord-like structure made up of parallel hyphae with a protective covering.

ringshake – Rupture in wood that occurs between growth rings, or less frequently, within an annual growth ring; sometimes called windshake.

rosetted – Clustered leaves or needles positioned in crowded circles or spirals on an axis with greatly shortened internodes.

russeting – A brownish, roughened area on plant tissue surfaces caused by injury.

saprot – Decay of the sapwood.

sapwood – The outer conducting layers of wood, which contain living cells and reserve material.

sclerotized – Hardened.

score – To mark deeply, forming a groove.

secondary – Organisms that are limited to invading hosts predisposed by stress or attack by some other more aggressive organism.

setal base – Tiny circular area on the outer surface of an organism from which the hairlike structure called a seta originates.

setal hyphae – Hyphae with hair or toothlike protrusions that may be visible with the naked eye or under low magnification.

sheath – See needle fascicle sheath.

slash – Woody debris such as logs, bark, and branches left after logging activities.

soft pines – Pines having usually 5 (sometimes 1 to 4) needles per fascicle; needle cross-section with one fibrovascular bundle; cone scales usually thin at the apex and without a spine; soft wood having a gradual transition from springwood to summerwood; species native to Oregon and Washington include western white pine, sugar pine, limber pine (Oregon only), and whitebark pine.

solitary – Living or feeding alone.

spore – A microscopic reproductive cell or cells.

spore tendril – A long, curling string of spores in a gelatinous matrix which oozes from a fruiting body.

sporulate – To release spores.

springwood – Also known as "early wood." The less-dense, larger-celled portion of an annual growth ring formed by a tree during the early part of the growing season. Springwood is usually lighter in color than summerwood.

stippling – The minutely spotted, speckled chlorosis of green foliage caused by the feeding of sucking insects and mites.

stringy rot – Decay that results in the heartwood being reduced to fibrous material.

strip attack – An attack by bark beetles that does not completely girdle the tree, but is concentrated along one side or within a relatively confined area on the bole; results in death of only a portion of the bole; also called a patch attack.

stunted – Checked growth, dwarfed, abnormally shortened leaders and needles.

successful bark beetle attack – Bark beetle attacks occurring on an individual tree during a single growing season that result in tree mortality. For the purposes of coding during forest vegetation surveys, a successful attack occurs when bark beetle attacks on a tree bole are judged to be of sufficient density to cause death within one year as a direct result of those attacks. Successfully attacked trees often display one or more of the following attributes: copious amounts of orange-red boring dust on the bole, large numbers of pitch tubes, or fading, chlorotic, or red crowns.

summerwood – Also known as "late wood." The dense, smaller-celled portion of an annual growth ring formed by a tree during the latter part of the growing season. Summerwoood is usually darker in color than springwood.

suppressed – Trees with crowns overtopped by larger trees and that receive no direct sunlight from above or from the sides.

telia – Plural form of telium. One of the many types of fruiting bodies formed during the life cycle of rust fungi; produce teliospores.

terminal – The main, or primary, growing tip of a conifer.

topkill – Death of the upper crown of a tree; usually caused by insects, pathogens, or weather events.

transverse – Lying or running at right angles to the axis of the tree bole or limb.

tubercle – A small rounded prominence.

unsuccessful bark beetle attack – Bark beetle attacks occurring on an individual tree during a single growing season that do not result in tree mortality. For the purposes of coding during forest vegetation surveys, an unsuccessful attack occurs when bark beetle attacks are judged to be of insufficient density to cause tree death within one year as a direct result of those attacks.

uredia – Plural form of uredium. One of the many types of fruiting bodies formed during the life cycle of rust fungi; produce urediospores.

vascular tissue – Plant tissue that conducts sap.

wetwood – A discolored, watersoaked condition of the heartwood of some conifers presumably caused by bacterial fermentation.

white rot – Decay caused by fungi that attack all chief constituents of wood and leave a whitish or light colored residue.

wingspan – Width of wings when extended as if for flight.

xylem – The woody tissue of the stem, branches, and roots that transports water and nutrients.

zone line – Black or brown lines of fungal hyphae in decayed wood that resist the advance of other fungi.

Index

Host-pest lists are included in this list and highlighted to facilitate use. Host-pest lists include principal damage agents and commonly associated generalists. See specific agent descriptions for occasional and rare host associations. **Text section headings** are listed in **bold** type.

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Submitting Insects and Diseases for Identification

For quick assistance with identification, digital photos of symptoms, signs, or damage agents may be submitted online to the Forest Health specialists for your area (see Technical Assistance Sources, p. 325). Contact information for Forest Health specialists in Oregon and Washington can be found at www.fs.usda.gov/main/r6/forest-grasslandhealth.

Physical samples can be either hand delivered or shipped. When submitting samples to specialists, use the following procedures to collect, package, and ship specimens:

Specimen Collection

Collect adequate amounts of material.

Include the following information:

- Location of collection (land unit name, township, range, section *OR* longitude/latitude *OR* street address and city)
- Date collected
- Name of collector
- Host description (species, age, condition, number or percentage of plants affected)
- Description of area (e.g. old or young forest, urban setting, ridgetop or creek bottom)
- Unusual conditions (e.g. frost, poor soil drainage, misapplication of fertilizers or pesticides)

Specimen Packaging for Transport

In general, pack specimens to protect them against breakage.

Insects: Insects can be killed by placing them in a container in the freezer at least 15 minutes. If sending through the mail, pack them in sealed rigid containers with cushioning so they withstand rough treatment.

Larvae and other soft-bodied insects: Ship in small screw-top containers with at least 70 percent isopropyl (rubbing) alcohol. You cannot mail more than 1 pint of alcohol per shipment. Make sure the containers are sealed well. Include on or in each vial adequate information, or a code relating the sample to the written description and information. Labels inserted in vials should be written in pencil or India ink. Ballpoint pen ink is not permanent.

Pupae and hard-bodied insects: Ship either in alcohol or small boxes. Place dead specimens between layers of tissue paper in the shipping boxes. Pack carefully to avoid movement of the material within the box. Do not pack insects in cotton.

Needles or foliage: Do not ship in plastic bags. Sprinkle lightly with water before wrapping in newspaper. Pack carefully to avoid movement of the material within the shipping box. Include with the general information a description of which year's needles are affected (current-year needles, 1-year-old needles, 2-year-old needles, etc.).

Mushrooms and conks (bracket fungi): Do not ship in plastic bags. Pack and ship immediately, or first air-dry and then pack. To pack, wrap specimens in dry newspaper and pack into a shipping box with more newspaper. If on wood, include some decayed wood. Be sure to include all collection information.

continued next page

Wood and decayed wood: Do not ship in plastic bags. Either pack and ship immediately, or first air-dry and then pack. To pack, wrap specimens in dry newspaper and pack into a shipping box with more newspaper. Be sure to include all collection information.

Shipping

Ship as quickly as possible, especially if specimens are fresh and not air-dried. If samples cannot be shipped rapidly, then store in a refrigerator.

Include address inside shipping box. Label the outside with the address of your local Forest Health Protection Service Center office (*see below*).

Mark on the outside: **Fragile: Insect-Disease specimens enclosed. For scientific purposes only. No commercial value.**

TECHNICAL ASSISTANCE SOURCES

For Federal Lands

USDA Forest Service Forest Health Protection
www.fs.usda.gov/main/r6/forest-grasslandhealth

Blue Mountains Forest Insect and Disease Service Center
USDA Forest Service
Wallowa-Whitman National Forest
1550 Dewey Ave. Suite A
Baker City, OR 97814

Central Oregon Forest Insect and Disease Service Center
USDA Forest Service
Deschutes National Forest
63095 Deschutes Market Road
Bend, OR 97701

Southwest Oregon Forest Insect and Disease Service Center
USDA Forest Service
Medford Interagency Office
3040 Biddle Road
Medford, OR 97504

Wenatchee Forest Insect and Disease Service Center
USDA Forest Service
Forestry Sciences Laboratory
1133 N Western Avenue
Wenatchee, WA 98801

Westside Forest Insect and Disease Service Center
USDA Forest Service
Mount Hood National Forest HQ
16400 Champion Way
Sandy, OR 97055

Pacific Northwest Regional Office
USDA Forest Service, SPTF
Forest Health Protection
1220 SW Third Avenue
Portland, OR 97204

TECHNICAL ASSISTANCE SOURCES

For State and Private Lands

Oregon—tinyurl.com/ODF-ForestHealth

Washington—www.dnr.wa.gov/ForestHealth

Oregon Department of Forestry
Forest Health Program
Private Forests Division
2600 State Street
Salem, OR 97310

Washington Department of Natural Resources
Forest Health and Resiliency Division
1111 Washington Street SE
Olympia, WA 98504

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