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Cork-Bark, a Disease of Alpine Fir in British Columbia[1]

The purpose of this paper is to describe a striking disease of alpine fir [*Abies balsamea* (L.) Miller subsp. *lasiocarpa* (Hook.) Boivin] which causes considerable damage to trees of all ages in several localities in British Columbia. The disease has been noted by field collectors and others, but, to my knowledge, has not been described, except for two brief papers by Kennedy and Wilson (1954 a and b).

Symptoms

Cork-bark disease may occur as individual swellings or as series of contiguous swellings. A progressive decrease in the size of contiguous swellings up or down the trunk frequently suggests progress of the disease in that direction. New swellings may also arise separately, interpolated between existing ones (Figures 1-3). Both patterns may coexist on the same tree. Amalgamation of distinct swellings into a continuous corky area, where in progress, always seems to take place in an upward direction. Solitary swellings may occur as high as 25 feet above ground.

A branch or stem at an early stage of the disease begins to swell conspicuously until the original smooth bark appears taut. Deep longitudinal fissures then develop, starting from the middle of the swelling and extending from one end to the other (Figures 4 and 5). The young fissures, which originally are unbranched and straight, are separated by high bridges over which the original smooth bark remains continuous from above to below the infection. The narrowest part of the bridge corresponds to the highest part and, presumably, to the original level of infection. In extreme cases the two sides leading up to the summit form a distinct angle of approximately 120°; in other cases there is a smooth curve. The length of the original fissures is extremely variable. On the smallest branches or stems a fissure may extend in an unbranched condition for not more than an inch. The longest simple fissures seen (from Lake O'Hara) were nearly two feet in length; these occurred at some 25 feet above the ground on a tree about six inches in diameter just below the swelling. Maximum cork-thickness, occasionally up to four inches, seems to develop in swellings characterized by very long, simple fissures.

There appear to be two different ways in which an infection may develop. The first is characterized by a more or less regular, fusiform swelling around the stem (Figures 4 and 5). It is in this type that simple fissures become relatively long. The

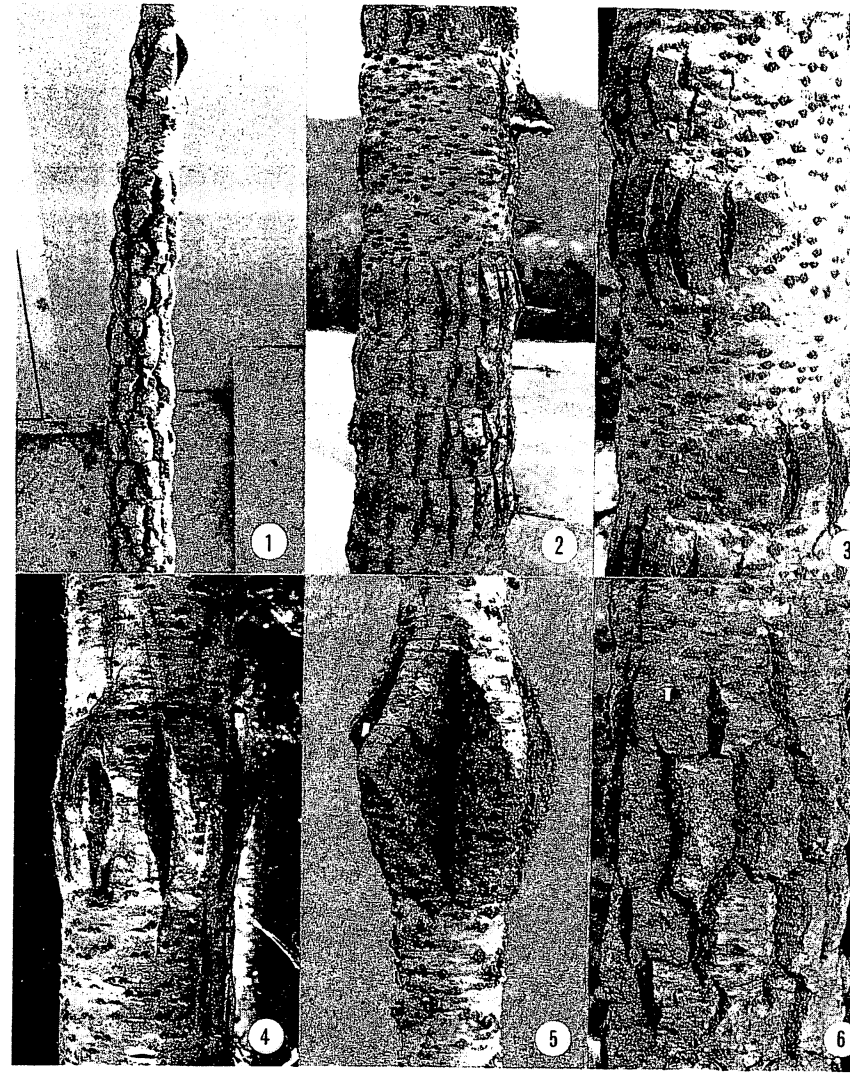

Figure 1-6. Cork-bark of alpine fir. Figures 1 and 5, both from Lake O'Hara, are about 3" diameter, figures 2, 3, 4 and 6, all from Bolean Lake, are about 7" in diameter.

second type is conspicuously one-sided (Figure 3) with deep fissures developing (one side of the trunk, while the other remains essentially normal. On a tree bearii a series of one-sided infections they face in various directions, giving the impressi(of being associated with individual branch-stubs or at least with successive whorls lateral branches of which only scars remain. This pattern is common especially (larger infected trees in the Bolean Lake area.

In most older infections, transverse fissures eventually connect adjacent longitudin

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ones. These transverse fissures sometimes are at right angles to the latter and may extend part way around the trunk. The overall effect in such instances is an arrangement of more or less rectangular units of bark. It may also happen, however, that the ends of longitudinal fissures fork symmetrically. If adjacent fissures fork simultaneously, their branches may fuse to form displaced longitudinal fissures, and a reticulate pattern of elongated hexagons results (Figure 6).

All these variations can often be seen in trees in which the disease appears to be progressing along the trunk (Figure 1). The basal part of such a tree has a rather irregular pattern of rectangles and polygons producing an extremely rough surface. The youngest, uppermost part of the infected portion tends to have the simplest pattern. The relative age of fissures, in this and all other variants, is clearly recognizable by the colour of the furrows, which progresses from a reddish-brown in recent fissures to a dull gray in older ones.

The number of longitudinal fissures per infection is extremely variable and may be a function of the size of the infected stem. The extremes of bark proliferation are found on infections where fewest longitudinal fissures exist. The pattern of recent bark increments (Figure 9) demonstrates a significantly greater inner bark production by the vascular cambium under the ribs than in the furrows. Each year two or three times as much inner bark is added in the ridges as compared to the furrows. Whether new cork cambia are actually initiated in the furrows, or whether cork cambia are restricted to the ribs, is unresolved. It is conceivable that a strong coherence of the bark within each rib, when amplified by the unusual activity of the vascular cambium below, brings about a radial split in the thinnest part of the bark each year. Resin exudation from the youngest part of a furrow is common, indicating possible rupture of the subjacent living tissues.

The disease is most spectacular on the bole of the tree but it may also attack lateral branches (Figure 8) far removed from bole infections. These swellings are long and slender, and have few fissures. Many, sometimes all, of the branches extending beyond the infection are killed.

At both localities visited, Lake O'Hara (Yoho National Park) and Bolean Lake (near Falkland), a great deal of mortality was associated with the disease. At Lake O'Hara, especially, nearly every dead tree had been heavily infected. Even dead trees less than two feet in height and less than one-half inch in diameter at ground level often had relatively heavy swellings (Figure 7). While no claim is made as to primary cause of mortality in these instances, it is quite possible that the cork-bark disease is responsible for the death of many trees.

Known Distribution of the Disease

The two infected areas visited by the writer are at Lake O'Hara (Yoho National Park) and Bolean Lake (near Falkland). In the Yoho locality, disease incidence is extremely high for about two miles below Lake O'Hara. In the Falkland locality, extensive stands of alpine fir immediately to the south and southwest of Bolean Lake are apparently free of the disease. Yet no more than a mile towards Blair Lake the disease becomes very conspicuous. In both localities disease incidence fluctuates greatly over short distances; a detailed survey has not been made to define the extent of the disease.

Kennedy and Wilson (1954a) referred to reports of the condition throughout the Cascades, but did not give specific information. Dr. Kennedy (letter to Dr. W. B.

Figure 7-11. Cork-bark of alpine fir, Lake O'Hara. Figure 7. Basal portion of dead tr slightly less than .5" in diameter. Figure 8. Lateral branch .5" in diame left fork above the swelling is dead. Figure 9. Section of infection wi flanges of bark each slightly more than one inch in depth. Figure 10. Inte mycelium in youngest portion of bark. X 315. Figure 11. Pycnidia of ? sp. on bark of swelling. X 10. Photographed December 18, 1967.

Critchfield, August 24, 1967) reports seeing similar trees in the Slave Lake : Alberta in 1955. As the two sub-species of *Abies balsamea* overlap (and j interbreed; Moss 1959) in this part of Alberta, the exact identity of the tree question. Mr. H. M. Craig (private communication) has observed the disea: Hixon, near Kelowna (Little White Mountain), at Willow River and Aleza La below the microwave tower at Blue River, North Thompson. Dr. T. C. Br (private communication) has collected cork-bark between Creston and Salmo.

reports suggest that we are concerned with a disease whose distribution far exceeds the two or three documented localities.

Cause of the Disease

The cause of the cork-bark disease of alpine fir has not been identified with certainty. At Bolean Lake, especially, a physical cause involving snow is out of the question, as affected portions are often too high for this. A variety of symptoms also speak against other climatic factors, such as excessive solar radiation, as possible causes.

Cork-bark material collected from Bolean Lake formed the basis of two papers on wood characteristics by Kennedy and Wilson (1954 a and b). These authors speak of cork-bark fir in the Pacific Northwest as if it constitutes one of two prevalent forms of alpine fir, the two types often occurring admixed in the same stand. Although not explicitly stated, the authors obviously accept the difference in bark type as an outcome of different genetic constitutions of the individuals concerned. Their two papers consist of statistical analyses of fiber length and specific gravity of the two supposed forms, and demonstrate some differences considered significant. As Kennedy and Wilson say, these cork-bark trees are not to be confused with cork-bark fir (sometimes called *Abies arizonica* Merr.) from the southern Rocky Mountains.

It is clear from the illustrations in Kennedy and Wilson's work that their material corresponds to the condition here described. The notion of genetically different individuals with respect to this bark anomaly can scarcely be entertained. Even though a causal agent has not been identified with certainty, the cork-bark condition bears all the marks of a serious pathogenic disease.

On a collection made at Lake O'Hara in 1966, a fungus occurred which was tentatively identified by Dr. Y. Hiratsuka of the Forest Research Laboratory, Calgary, as the imperfect stage (*Gelatinosporium abietinum* Peck) of a discomycete, *Dermea balsamea* (Peck) Seaver. A subsequent examination of collections from Lake O'Hara and Bolean Lake showed that a similar fungus appears to be constantly associated with the cork-bark condition. It is most evident when forming minute black pustules (pycnidia) on the old, smooth bark on the ribs of swellings (Figure 11). The transverse shallow cracks, which are a normal feature of such bark, are frequently crowded with pustules in a linear series, but the distribution of pycnidia over cork-bark areas shows considerable fluctuation. The photograph (Figure 11) shows some of the most crowded conditions seen. It is sometimes difficult to locate the pycnidia, but all material seen to date bears the fungus in its imperfect stage. The walls of the fissures sometimes produce many pycnidia, but these are easily overlooked because of the extremely irregular bark surface.

The sectioning of old bark of *Abies balsamea* is very difficult because of the great numbers of sclereids. A study of the structure of this proliferated bark and of the precise distribution of the fungus within it is a prerequisite to an elucidation of the disease. Microscopic observations of sectioned bark leave no doubt as to the presence of a fungus in the living parenchyma (Figure 10). In free-hand sections the abnormal bark shows an irregular alternation of a series of periderms mutually separated by regular files of sclereid-less phellem, and extensive areas of tissue where radial alignment has been disturbed by the formation of many groups of thick-walled sclereids. In some sections more than 20 distinct periderms are present in close succession to one another, the tissues separating them lacking sclereids altogether.

A four-foot length of infected trunk from Bolean Lake, left outside in Vancouv during the winter months, produced a number of apothecia in March and April whic almost certainly represent the perfect stage of the same fungus. The apothecia a peared both on the smooth outer bark surface of the swellings and in the walls of tl fissures. Their colour and shape were much like those of *Dermea pseudotsugae* (Fur 1967), except that they were distinctly stalked. In size, the apothecia are considerab smaller than those of *Dermea balsamea.* Ascospore characteristics point to systemat affinities with the genus *Dermea* (Groves 1954; Funk 1962). There is a distinct pc sibility that the fungus in question is an undescribed species. The final systemat assignment and appraisal of pathogenicity awaits a more detailed study.

Dermea is a genus of weak parasites on the bark of trees. *D. balsamea,* particular is known to be the causal agent of a dieback disease of eastern hemlock, *Tsuga can densis* (L.) Carr. (Groves 1946; Dodge 1932) and Balsam fir (*Abies balsamea* (L Miller subsp. *balsamea*). No cork-bark symptoms have been reported from the tv known eastern hosts. In the western localities inspected, hemlock is absent and *Pic glauca* subsp. *engelmannii* admixed with infected alpine fir shows no signs of the c sease. More recently, new species of *Dermea* have been described as parasitic (*Picea glauca* (Reid and Pirozynski 1966) and *Pseudotsuga menziesii* (Funk 1967 Proliferation of bark has not been reported as a symptom associated with any describ species of *Dermea.* Instead, the associated symptoms are lesions of dead, shrunk bark frequently girdling the affected branches, symptoms not seen in this cork-ba disease. In the related genus *Durandiella* a degree of cork proliferation has be reported associated with two species (Groves 1954; Funk 1962).

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Literature Cited

Boivin, B. 1959. *Abies balsamea* (Linné) Miller et ses variations. Natural. Canad. *86:* 2: 223.
Dodge, B. O. 1932. Notes on three hemlock fungi. Mycologia *24*: 421-430.
Funk, A. 1962. *Durandiella pseudotsugae* n. sp.; taxonomy, cultural characteristics, life histc and host response. Can. Jour. Bot. *40*: 331-335.
——— 1967. *Dermea pseudotsugae* n. sp., a causal agent of phloem necrosis in Douglas Can. Jour. Bot. *45*: 1803-1809.
Groves, J. W. 1946. North American species of *Dermea.* Mycologia *38*: 351-431.
——— 1954. The genus *Durandiella.* Can. Jour. Bot. *32*: 116-144.
Kennedy, R. W., and J. W. Wilson. 1954a. Studies on smooth and cork-bark *Abies lasiocar* I. Fibre length comparisons. Pulp & Paper Mag. Can. *55*(7): 130-132.
——— and ——— 1954b. *Idem* II. Specific gravity comparisons. *Ib* *55*(8): 119-121.
Moss, E. H. 1959. Flora of Alberta. Univ. Toronto Press, Toronto.
Raymond, F. L., and J. Reid. 1961. Dieback of balsam fir in Ontario. Can. Jour. Bot. : 233-251.
Reid, J., and K. A. Pirozynski. 1966. Notes on some interesting North American fungi. C Jour. Bot. *44*: 645-653.

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