Larix lyallii Parl. Alpine Larch

Pinaceae Pine family

Stephen F. Arno

Alpine larch *(Larix lyallii)*, also called subalpine larch and Lyall larch, is a deciduous conifer. Its common name recognizes that this species often grows higher up on cool exposures than any other trees, thereby occupying what would otherwise be an alpine tundra. Both early-day botanical explorers and modern visitors to the high mountains have noted this tree's remarkable ability to form pure groves above the limits of evergreen conifers. Alpine larch inhabits remote high-mountain terrain and its wood has essentially no commercial value; however this tree is ecologically interesting and esthetically attractive. Growing in a very cold, snowy, and often windy environment, alpine larch usually remains small and stunted, but in windsheltered basins it sometimes attains large size-maximum 201 cm (79 in) in d.b.h. and 29 m (95 ft) in height. This species is distinguished from its lower elevation relative western larch *(Larix occidentalis)* by the woolly hairs that cover its buds and recent twigs, and frequently by its broad, irregular crown.

Habitat

Native Range

Alpine larch (fig. 1) occupies a remote and rigorous environment, growing in and near the timberline on high mountains of the inland Pacific Northwest. Although alpine larch is found in both the Rocky Mountains and the Cascades, the two distributions are separated at their closest points by 200 km (125 mi) in southern British Columbia. This and smaller gaps in the species' distribution generally coincide with an absence of suitable high mountain habitat.

In the Rocky Mountains alpine larch extends from the Salmon River Mountains of central Idaho, latitude 45" 28' N. northward to latitude 51" 36' N. several kilometers past Lake Louise in Banff National Park, AB. [A fossil larch, probably of this species, grew between 1000 and 1250 A.D. near the Athabasca Glacier (Columbia Icefield) 90 km (56 mi) northwest of today's northernmost known isolated alpine larch tree *(18)*.] Within this distribution, alpine larch is common in the highest areas of the Bitterroot, Anaconda-Pintler, Whitefish, and Cabinet Ranges of western Montana. It is also found in lesser

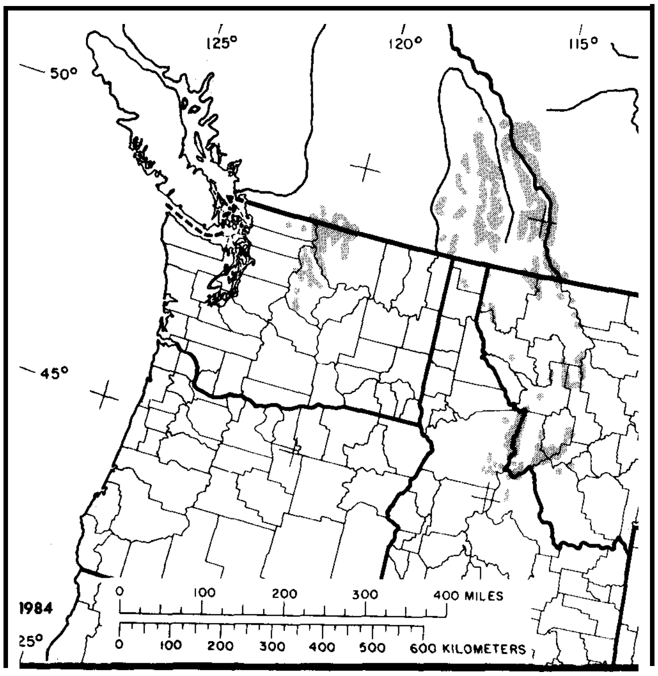

Figure *l-The native range of alpine larch.*

amounts atop numerous other ranges and peaks in western Montana and northern Idaho (4). In British Columbia and Alberta, alpine larch is common along the Continental Divide and adjacent ranges, and in the Purcell and southern Selkirk Ranges.

In the Cascade Range alpine larch is found principally east of the Cascade Divide and extends from the Wenatchee Mountains (47" 25' N.) in central Washington northward to about 21 km (13 mi) inside British Columbia (49" 12' N.). Within this limited distribution covering a north-south distance of only 193 km (120 mi), alpine larch is locally abundant in the Wenatchee, Chelan, and Okanogan ranges.

Climate

Alpine larch grows in a very cold, snowy, and generally moist climate. The following description is based on weather records from several sites in and near alpine larch stands *(2)*. For more than half of the year, mean temperatures are below freezing. The cool "growing season," as defined by mean temperatures of more than 6" C (42" F) *(6)*, lasts about 90 days, and occasional frosts and snowfalls occur during the summer. July mean temperatures range from about 9° to 14" C (48" to 58" F). Long-term

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record low temperatures for late June through mid-August are near -5” C (23” F), whereas corresponding record highs are near 27° C (80” F). January mean temperatures range from about -14” C (7” F) in Alberta to -7” C (20” F) in the northern Cascades. Long-term record low temperatures have undoubtedly reached -50” C (-58” F) in some stands near the Continental Divide in Alberta and Montana.

Mean annual precipitation for most alpine larch sites is between 800 and 1900 mm (32 and 75 in), the larger amount being more prevalent near the crest of the Cascades. Most stands in the Montana Bitterroot Range evidently receive 1000 to 1500 mm (40 to 60 in). About 75 percent of this precipitation is snow and sleet.

Typically, the new snowpack begins to accumulate by late October. By mid-April, it reaches a maximum depth averaging about 2.1 m (7 ft) in stands near the Continental Divide and 3.0 to 3.5 m (10 to 11 ft) farther west. Maximum water content of the snowpack is attained in May and reaches about 75 cm (30 in) in stands near the Continental Divide and 100 to 125 cm (40 to 50 in) farther west. The snowpack does not melt away in most stands until early July. Average annual snowfall is probably about 1000 cm (400 in) in most stands west of the Continental Divide. Small amounts of stunted alpine larch grow on wind-exposed ridgetops and other microsites where snow accumulation is much less than the averages indicated above.

The inland Pacific Northwest often has a droughty period for a few weeks in late summer. This drought effect is minor in most alpine larch sites; however, dry surface soils may prevent seedling establishment in certain years. A modest quantity of rain falls through July and August, averaging 25 to 50 mm (1 to 2 in) per month in the United States, much of it associated with thunderstorms. In the Canadian Rockies summer precipitation is greater, 50 to 90 mm (2.0 to 3.5 in) per month, and more of it comes in Pacific frontal systems. Summertime relative humidity in alpine larch stands remains consistently higher than that recorded at lower elevations.

Most alpine larch stands annually experience winds reaching hurricane velocity, 117 km/h (73 mi/h) or more, during thunderstorms or during the passage of frontal systems. Ridgetop stands are exposed to violent winds most frequently,

Soils and Topography

Although soil development in alpine larch stands varies, most soils are immature. Generally alpine larch sites have undergone intense alpine glaciation during the Pleistocene and have been deglaciated for less than 12,000 years. Chemical weathering is retarded by the short, cool summer season. Also, nitrogen-fixing and other microbiotic activity that might enrich the soil is apparently restricted by low soil temperatures and high acidity.

Throughout its distribution, alpine larch commonly grows on slopes covered with granite or quartzite talus (boulders), which have not been previously occupied by vascular plants. The species also grows in cracks in massive bedrock. These undeveloped soils would probably be classified *(31)* as fragmental and as loamy skeletal families within the order Entisols *(Cryorthents).* Such substrates have been referred to as azonal soils, and more specifically as Lithosols in earlier classifications.

On sites that have appreciable soil development or fine material (including recent moraines), the soils are still rocky and immature. These would be classified as Inceptisols-usually Typic Cryochrepts *(17).*

On some sheltered slopes, deposits of volcanic ash in soil profiles are sufficiently thick to require recognition as Andic Cryochrepts, in a medial over loamy skeletal family *(15).* Some of the best-developed ash-layered soils beneath alpine larch stands are Typic Cryandepts, which nearly fit the description of zonal Brown Podzolic soils in high elevation forests given by Nimlos *(19).* These soils are strongly acidic and have a distinct, well-developed cambic B horizon.

Throughout the range of alpine larch, pH values were found to be very acidic, ranging from 3.9 to 5.7 in the mineral soil (B horizon) *(2).* Bitterroot Range sites had an average pH of 4.6. Such strongly acid, shallow, rocky, and cold soils are extremely infertile.

Alpine larch grows on several types of geologic substrates but has an affinity for acidic rock types, being most abundant on granitic and quartzite substrates and absent or scarce on nearby limestone or dolomite *(4,21).* This distribution contrasts markedly with that of several other cold-climate conifers, including Siberian larch *(L. sibirica)* and tamarack *(L. laricina),* which often grow on basic, calcium-rich sites *(16,23).*

Alpine larch achieves its best growth in high cirque basins and near the base of talus slopes where the soils are kept moist throughout the summer by aerated seep water (fig. 2). It can also tolerate boggy wet-meadow sites having very acidic organic soils. The species is most abundant on cool, north-facing slopes and high basins where it forms the uppermost band of forest (fig. 3). It also covers broad ridgetops and grows locally under relatively moist soil conditions on south-facing slopes. In the Canadian Rockies, where summer rainfall is more abundant, it is often found on south slopes. The extreme lower and upper altitudinal limits of subalpine larch, over its

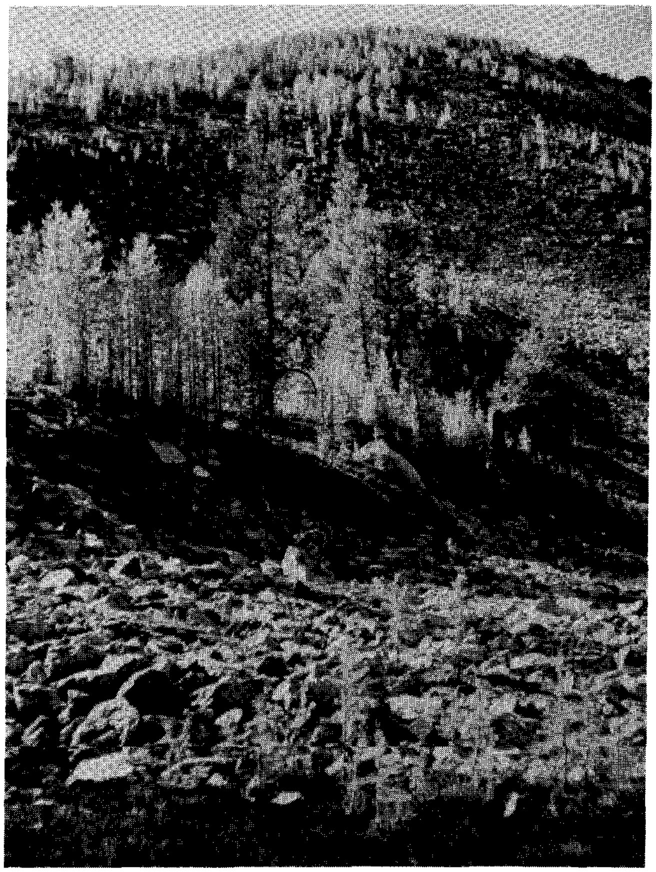

Figure 2—*Alpine larch on talus in a high basin, 2530 m (8,300 ft) elevation, on Lolo Peak, near Missoula, MT.*

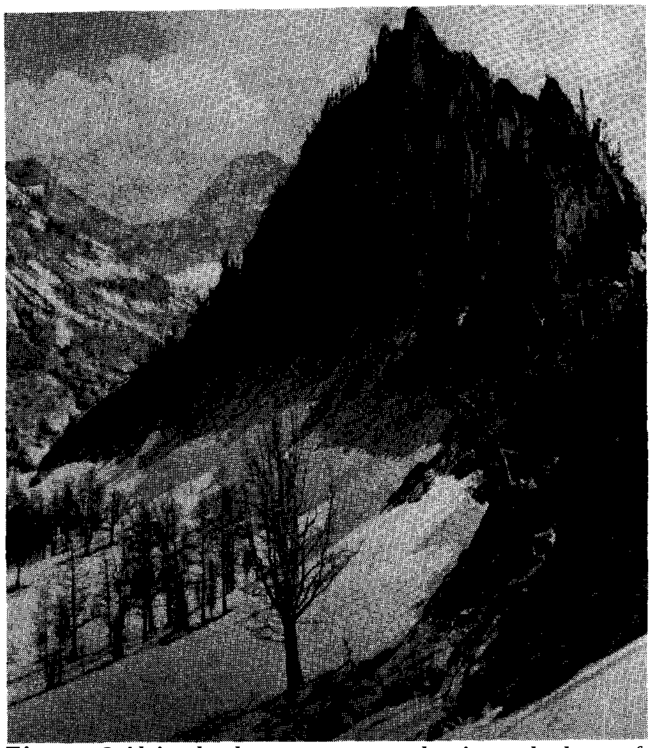

Figure 3-*Alpine larch on a snowy, rocky site at the base of a northfacing cliff:*

entire geographic range, are apparently 1520 and 3020 m (5,000 and 9,900 ft). The lowermost individuals are found in shady cirques and canyons in the North Cascades, while the highest limits apply to scattered stunted trees on Trapper Peak in the Montana Bitterroot Range (2).

In the Bitterroot Range, alpine larch is abundant above 2290 m (7,500 ft) on northern exposures. It extends lowest on north-facing talus slopes, free from other competing conifers. But, even when moist, open, boulder-covered slopes extend down the mountainsides to the 1370 m (4,500 ft) canyon bottoms, alpine larch rarely colonizes them below 1980 m (6,500 ft).

In the Anaconda-Pintler Range of southwestern Montana, alpine larch forms a narrow band between elevations of about 2560 and 2800 m (8,400 to 9,200 ft). Northward in the Rockies, the elevation of its timberlines decreases gradually. Stands in northwestern Montana, Alberta, and southeastern British Columbia are generally found between 1980 and 2380 m (6,500 and 7,800 ft) and in the northern Cascades, between 1830 and 2290 m (6,000 and 7,500 ft).

Associated Forest Cover

Alpine larch grows in pure stands and also in association with whitebark pine *(Pinus albicaulis)*, subalpine fir *(Abies lasiocarpa)*, and Engelmann spruce *(Piceu engelmannii)* near their upper limits. Alpine larch stands are primarily considered a variant forest cover type within Whitebark Pine (Society of American Foresters Type 208) *(26)*. The species is also associated with the upper elevations of Engelmann Spruce-Subalpine Fir (Type 206), especially in the Canadian Rockies. Near the crest of the Cascades, alpine larch is often associated with mountain hemlock *(Tsuga mertensiana)* and subalpine fir.

In Montana, stands above forest line (where subalpine fir is severely stunted) make up the *Larix lyullii-Abies lasiocarpa* habitat types classified by Pfister and others *(20)*. Alpine larch stands below forest line (in the subalpine fir zone> are classified generally as an edaphic (rock substrate) climax within the broader *Abies lasiocarpa/Luzula hitchcockii* habitat type, *Menziesiu ferrugineu* phase.

Four species dominate in the undergrowth of most alpine larch stands throughout the Pacific Northwest: grouse whortleberry ***(Vaccinium scoparium);*** smooth woodrush ***(Luzula hitchcockii);*** mountain arnica ***(Arnica latifolia)***; and red mountain heath ***(Phyllodoce empetriformis)*** (2). But undergrowth beneath larch stands on bogs, recent moraines, alpine tundra, or rockpile sites, is distinctively different. Often shrublike (krummholz) subalpine fir and whitebark pine form an undergrowth layer beneath the larch on relatively cold or wind-exposed sites.

Life History

Reproduction and Early Growth

Flowering and Fruiting-Alpine larch is monoecious; male and female flowers (strobili) are borne separately on short, woody spur shoots scattered among the leaf-bearing spur shoots. Strobili are normally monosporangiate. Buds producing the strobili begin to swell by the end of May, and the wind-dispersed pollen is shed from the small yellowish male strobili in June, when there is still several feet of snow on the ground in most stands *(2,21,30).* Female strobili develop into purplish cones 4 to 5 cm (1.5 to 2.0 in) long by September. Frost damage, especially to female strobili, may account for low seed production in most years. The importance of other factors limiting pollination, fertilization, and seed development is unknown.

Seed Production and Dissemination-Large seed crops are infrequent. In Montana they occur about 1 year out of 10, and even modest-sized crops occur in about the same frequency. Appreciable quantities of seed are not produced until trees are at least 80 years old. Dominant trees, several hundred years of age, produce the largest crops.

Most of the relatively light, winged seeds fall from the cones in September and are wind disseminated *(30).* Cleaned seeds number between 231 500 and 359 500/kg (105,000 and 163,000/lb).

A heavy seed crop in one area of the Washington Cascades was largely consumed by larvae of an unidentified fly (Diptera) *(2).*

Seedling Development-Germination of alpine larch seed has been poor in several tests but is improved by soaking the seeds for 24 hours in 3 percent hydrogen peroxide solution *(8,21,24,30).* Such treatment may inhibit root development, however (25). There are usually five cotyledons, although four or six may appear; they are narrow, pointed, and 1.0 to 1.5 cm (0.4 to 0.6 in) long. Germination is epigeal.

First-year germinants of alpine larch are seldom found in natural stands. In one area the smallest seedlings observed were 4 cm (1.6 in) high and proved to be about 10 years old *(4).* Several cotyledon-stage seedlings were found on an Alberta site in 1977 following a good seed year ***(21).***

Small openings in cirques often contain dense, even-aged groves, termed "reproduction glades," of alpine larch seedlings or saplings. This suggests that successful reproduction occurs rarely, and only under ideal conditions. The location of reproduction glades suggests that germination is most successful on a moist mineral soil surface, on northern exposures or in cirques not fully exposed to afternoon sun. Germination probably takes place in July soon after snowmelt.

Seedlings and basal branches of saplings have juvenile leaves that last through two summers. Until the plants are 20 to 25 years old, this evergreen, or "wintergreen," foliage constitutes 25 to 30 percent of the total leaf biomass *(21,22).* Physiological studies suggest that this wintergreen foliage is important for tree establishment because it is less susceptible to drought stress in summer.

Height growth is exceedingly slow for the first 20 to 25 years but accelerates rapidly thereafter *(21,22).* This pattern of early growth apparently allows the seedlings to become well established and develop an extensive root system while still being protected from winter and spring desiccation by the snowpack.

This species is very difficult to cultivate even in the relatively cool climates at lower elevations in the Pacific Northwest or in England. Seedlings have been raised at Kew Gardens *(12)*, but they have not grown well, leading to the conclusion that a colder climate than that of Britain is required for alpine larch. Apparently, daytime high temperatures and surface drought are lethal. The species seems to require full light, but low temperatures. Bud dormancy is thought to influence the lack of adaptation to lower elevations *(17).*

Vegetative Reproduction-Subalpine larch does not reproduce from sprouts. Techniques for reproduction from rooted cuttings have not been reported. Layering (rooting of lower branches that are compressed against moist ground) has long been known in some other species of ***Larix*** *(11)* and in its associate, subalpine fir, but alpine larch is known to spread by layering only in a few severely stunted trees or krummholz (4).

Sapling and Pole Stages to Maturity

Growth and Yield-Alpine larch is a very slow-growing, long-lived tree. Vigorous saplings 1.2 m (4 ft) tall are about 30 to 35 years of age. Dominant trees attain small to moderate dimensions, depending upon site conditions, in a typical 400- to 500-year life span. Average ages for dominant alpine larch of different diameters are as follows (2):

D.b.h.		Total age: Average site	Total age: Very good site
cm	*in*	*years*	
13	5	150	75
25	10	250	125
38	15	350	175
51	20	500	225
99	39	—	450

The largest diameter shown is not attained on "average" sites.

Although from four to five centuries is a common life span for dominant trees, many individuals attain 700 years, and the oldest are estimated to be about 1,000 years (2). Complete ring counts are not possible on the oldest trees because of extensive heart rot. On average sites (high on north-facing slopes) the dominant trees grow 12 to 15 m (40 to 50 ft) in height and 30 to 61 cm (12 to 24 in) in d.b.h. In moist cirque basin sites on granitic or quartzite substrates, dominant trees reach 23 to 29 m (75 to 95 ft) in height and 61 to 124 cm (24 to 49 in) in d.b.h. The largest recorded alpine larch, in the Wenatchee National Forest of Washington State, is 201 cm (79 in) in d.b.h. and 29 m (95 ft) tall (1). The tallest reported alpine larch is an exceptional 46 m (152 ft) in Montana's Cabinet Range (3).

Alpine larch (fig. 4) typically grows in open, parklike groves, less than 0.2 ha (0.5 acre) in size, interspersed with natural openings of various sizes. Stocking within the small groves is at the rate of 125 to 200 mature trees per hectare (50 to 80/acre) (2).

No site index or yield data have been developed for alpine larch stands; however, data from other Montana forest habitat types (20) suggest that annual yield capability would be only about 0.7 to 1.4 m^3/ha (10 to 20 $ft^3/acre$) on sites having better than average productivity. Defect is very high for all species in alpine larch communities. Essentially no commercial timber harvesting has been done, even in the best developed stands, nor does any seem likely in the future.

"Poor" alpine larch sites produce stunted larch generally 5 to 11 m (16 to 36 ft) tall at maturity.

Figure 4—*Mature alpine larch in Deerlodge National Forest, MT.*

Many of these sites lie above the tree line for evergreen conifers and would be classified as alpine tundra were it not for the occurrence of this unusual tree.

Rooting Habit-Alpine larch roots extend deep into fissures in the rocky substrate. Trees are well anchored by a large taproot and large lateral roots and are very windfirm. The crown and trunk of old trees may break off in violent winds, but the tree itself is seldom uprooted.

Richards (21) found that subalpine larch "seedlings" 16 to 25 years old and only 20 to 40 cm (8 to 16 in) tall had taproots penetrating 40 to 60 cm (16 to 24 in) and laterals descending 20 to 60 cm (8 to 24 in) at about 45" from the horizontal. Mycorrhizal development was found on all trees, but shallow roots had a higher degree of mycorrhizal association than deep roots. ***Cenococum graniforme*** has been identified as an ectotrophic mycorrhiza of subalpine larch (29).

Reaction to Competition-Alpine larch is the most shade-intolerant conifer growing at these high elevation sites and is classed as very intolerant. Its evergreen associates attain their best development in forests below the lower limits of larch. An exception is whitebark pine, another timberline inhabitant, which, however, is most abundant on warm exposures and microsites and thus tends to complement rather than compete with larch (4). Alpine larch foliage requires higher light intensities than its evergreen associates to maintain active growth through photosynthesis *(21,22)*. Thus it is unable to compete with a ***vigorous*** growth of evergreens. Instead, alpine larch owes its existence to its superior hardiness, especially on cool exposures. At the highest elevations alpine larch fills a vacant niche and represents the potential climax. The larch's ability to grow at higher elevations than evergreen conifers on certain sites is partly related to its superior resistance to winter desiccation-dehydration of foliage during warm, sunny periods when the roots are still frozen or chilled *(21,22)*. Winter desiccation in conjunction with lack of summer warmth are thought to be primary factors limiting the ascent of tree growth on high mountains *(5,28)*. Above the limit of trees, the growing season is so short that new growth cannot adequately harden-off (fully developed cuticle), and thus it succumbs to desiccation in winter.

Alpine larch is less vulnerable to winter desiccation than its associated conifers because its leaves are deciduous and its buds are woody and protected *(2,21)*. Thus there is little tendency for larch to grow in a shrubby or krummholz form, unlike its evergreen associates. Its deciduous foliage requires a large amount of moisture throughout the summer compared to the evergreens; consequently, it occupies relatively moist sites.

In the middle of its zone of occurrence [between "forest line," the general upper limit of contiguous forest, and "tree line," the general limit of erect evergreen conifers *(5)*], natural openings and severe climate allow alpine larch to share climax status with subalpine fir, Engelmann spruce, and whitebark pine. These evergreens often develop in the shelter of a large "patriarch" larch, sometimes growing up through the larch crown as if it were a trellis.

On the better sites where alpine larch grows, subalpine fir is the potential climax dominant. Engelmann spruce is usually a minor component of stands containing subalpine larch; it often attains large size but, unlike subalpine fir, seldom regenerates abundantly.

Occasionally alpine larch seeds in and regenerates on a burned area within the subalpine forest, 100 to 150 m (330 to 490 ft) below its usual elevational limits. But the species grows more slowly than the accompanying lodgepole pine *(Pinus contorta* var. *latifolia)* and is crowded out by that species and by subalpine fir and Engelmann spruce.

Damaging Agents-Violent winds in alpine larch stands often damage crowns in conjunction with loads of clinging ice or wet snow. Nevertheless this tree's deciduous habit and supple limbs make it more resistant to wind damage than its associates. Death usually occurs when advanced heart rot has so weakened the bole that high winds break off the trunk. The quinine fungus *(Fomitopsis officinalis)*, which causes brown trunk rot, produces the only conks commonly found on living trunks. This fungus is evidently the source of most heart rot.

Other diseases and insects generally cause little damage to alpine larch. Needle blight fungi, *Sarcotrochila alpina,* has severely infected trees on Mount Frosty in Manning Provincial Park, BC *(33)*. Needle cast fungi, *Lophodermium laricinum,* have also been reported on alpine larch. Alpine larch is listed as a host of two fungi, *Lachnellula occidentalis* and *L. suecica (13)*, which may be capable of causing stem cankers, but neither has been noted as a serious disease problem.

Isolated witches'-brooms (dense branch-clusters with associated branch swelling) are found widely scattered in alpine larch stands. These could be caused by dwarf mistletoe, fungal infection, or perhaps even genetic aberration. The western larch dwarf mistletoe *Arceuthobium laricis* was reported in two early 1900's collections on alpine larch, but its status on this species is poorly known *(14)*.

Snow avalanches and snowslides are an important source of damage in many stands, but again this species is better adapted to survive these disturbances than its evergreen associates. Alpine larch poles up to 13 cm (5 in) thick and 6 m (20 ft) tall can survive annual flattening by snowslides only to straighten again when the snow melts in summer (4). As larch poles exceed this size their strong trunks and lack of dense foliage make them resistant to breakage in snowslides. Because of this superior resistance, alpine larch often occupies snowslide sites (forming a "disclimax" because of disturbance) within the subalpine forest proper.

Fire is an occasional but quite localized cause of injury or death in alpine larch stands. Large fires are infrequent in these cool, moist, and rocky sites where fire spreads poorly because of the light and discontinuous fuels. Unlike its thick-barked, fire resistant relative, western larch *(Larix occidentalis)*, alpine larch has thin bark and has low resistance to surface fire.

Special Uses

Alpine larch's primary values seem to be in watershed protection, wildlife habitat, and outdoor recreation and esthetics. The ability of this larch to occupy steep north slopes and snow chutes where other trees scarcely grow suggests that it helps to stabilize snow loads and reduce the severity of avalanches *(27)*. Scientists from several countries (Switzerland, Iceland, Japan, and New Zealand) who are interested in avalanche control or forest establishment on cold sites have obtained alpine larch seed from the USDA Forest Service.

A diverse assemblage of birds and mammals is associated with alpine larch communities (2). Grizzly bears often dig winter dens in alpine larch stands in Banff National Park (32). The greatest use of these habitats by most wildlife species is as summer range, when timberline vegetation is succulent, temperatures cool, and water abundant. Mountain goats, bighorn sheep, hoary marmots, pikas, mule deer, elk (wapiti), black and grizzly bears, red squirrels, and snowshoe hares are among the mammals that feed in alpine larch stands. Blue grouse apparently feed heavily on alpine larch needles. The trees provide some concealment and thermal cover in an otherwise open habitat. Woodpeckers and other cavity-nesting birds and mammals nest in the larger, hollow-trunk trees.

Hikers and photographers are attracted by the natural beauty of alpine larch stands. The tree's foliage is a translucent bright green in summer and turns lemon yellow and finally golden in September before it falls in October.

The unusual hardiness of this species, its adaptations to survival in a harsh climate, on rugged topography and sterile substrates, should make it of special interest for scientific study and for reclamation plantings on high-elevation sites.

Genetics

Races, varieties, or subspecies of alpine larch are not known. The species' restricted environmental tolerances and geographical and altitudinal distributions may have limited the opportunity for development of genetic variation.

Apparent natural hybridization of alpine larch and western larch has been documented in western Montana *(8,9,10)*. Although these species occupy a similar geographic area, they inhabit different altitudinal zones and are usually separated from each other by 150 to 300 m (500 to 1,000 ft) of elevation at their closest proximities. Nevertheless, their distributions occasionally overlap slightly in north-slope snowslide chutes or talus rockpiles. Apparent natural hybrids have been identified in two overlap areas using a hybrid-index formula. The two species were also artificially cross-pollinated and the resulting seed and that from control species was planted. Distinct morphological differences were noted among the two species and the putative hybrid. The two species also vary in external and internal characteristics even when they grow side by side, confirming their genetic difference *(8,9)*.

An interesting mixture of both larch species and various intermediate (hybrid) forms occurs on a rocky site in the Carlton Ridge Research Natural Area in the Lolo National Forest south of Missoula, MT *(10)*.

The chromosome complement of subalpine larch is 2N=24, similar to that of most other trees in the pine family *(Pinaceae) (7)*.

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