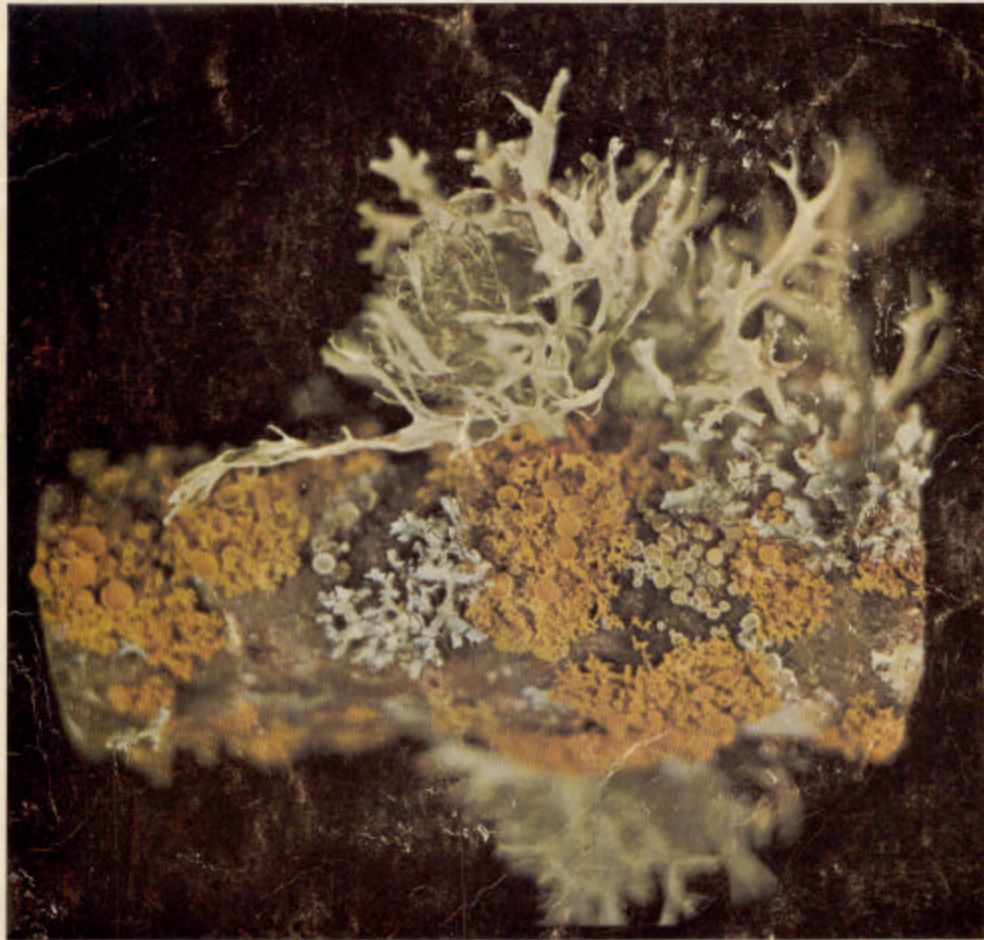


a guide to
AIR QUALITY



MONITORING
with LICHENS

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AIR QUALITY MONITORING
with LICHENS

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COVER:

Close up of lichens on an oak twig (4.5 times life size). Four common lichens are evident: A = Xanthoria polycarpa; B = Physcia adscendens; C = Ramalina farinacea; and D = Lecanora confusa. (Photo by the author) (Drawing by Elizabeth Buhr)

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PREFACE

With the help of this GUIDE, an intelligent and patient person without previous training in biology should be able to identify the lichens which require clean air, and then use this information to evaluate air quality at one or more sites.

The method was developed for use in the Willamette Valley in Oregon and has also been tested in southwestern Washington. Many of the lichens occur elsewhere, even in eastern North America and western Europe, but extensive testing and modification will be required before the GUIDE can be recommended for use outside the Pacific Northwest.

Despite the single authorship, many people have made important contributions to production of this GUIDE. Dr. Lawrence Pike suggested the use of lichens on twigs and made most of the original identifications of the critical lichens. A group of undergraduate students under the leadership of Steven Carpenter, funded by a grant from the Student Originated Studies program of the National Science Foundation, conducted the field research on which the GUIDE is based. Robert F. Denison devised and tested the scale. Nancy Hathaway and Terrill J. Chang contributed original drawings of twigs. Susan M. Carpenter drew the lichens. Finally, Terrill Chang and Anna Marin designed the format and typed the final copy.

TABLE OF CONTENTS

Preface	iii
List of Illustrations	vii
General Information about Lichens and Air Pollution	1
What is a lichen?	1
Do lichens harm trees?	1
Lichens need water and minerals	1
Air pollution	2
Lichens and air pollution	2
Why examine lichens on branches?	4
Why use five year-old and ten-year-old twigs?	6
How can we tell the age of a twig?	6
Mapping Lichens and Air Quality in the Willamette Valley	8
Map of Lichens Indicating Air Quality in the Willamette Valley, Oregon (Summer 1972)	9
How to Use the Guide	27
Equipment	27
Selecting the tree	27
Selecting branches	27
Finding five and ten-year-old twigs	27
Identifying the lichens	28
Which form should you use?	28
Estimating lichen cover	28
Using Form #1	29
Using Form #2	30
Air Quality Evaluation Form #1	31
Air Quality Evaluation Form #2	35
Glossary	37
Bibliography	38
Index	39

LIST OF ILLUSTRATIONS

Fig. 1	<u>Quercus garryana</u> (Oregon White Oak)	Page 3
2	<u>Fraxinus latifolia</u> (Oregon Ash)	5
3	Growth Stages of a Twig	7
4	Map of Lichens Indicating Air Quality in the Willamette Valley	9
5	<u>Evernia prunastri</u> (Wrinkled Evernia)	10
6	<u>Hypogymnia physodes</u> (Inflated Hypogymnia)	11
7	<u>Hypogymnia tubulosa</u> (Tubular Hypogymnia)	12
8	<u>Lecanora</u> sp. (<u>L. carpineae</u> , <u>L. confusa</u> , <u>L. pacifica</u>)	13
9	<u>Lepraria membranacea</u> (Powdery Paint Lichen)	14
10	<u>Lobaria pulmonaria</u> (Lungwort)	15
11	<u>Parmelia subaurifera</u> (Papery Bronze Parmelia)	16
12	<u>Parmelia sulcata</u> (Net-Marked Parmelia)	17
13	<u>Physcia adscendens</u> (Hair-Tipped Physcia)	18
14	<u>Physcia aipolia</u> (Hoary Physcia)	19
15	<u>Platismatia glauca</u> (Ragged Platismatia)	20
16	<u>Ramalina farinacea</u> (Mealy Ramalina)	21
17	<u>Ramalina leptocarpha</u> (Moose Antler Ramalina)	22
18	<u>Ramalina menziesii</u> (Fishnet Lichen)	23
19	<u>Rinodina marysvillensis</u> (Marysville Rinodina)	24
20	<u>Rinodina archaea</u> (Old Rinodina)	24
21	<u>Usnea subfloridana</u> (Bushy Cord Lichen)	25
22	<u>Xanthoria polycarpa</u> (Golden Xanthoria)	26

GENERAL INFORMATION ABOUT LICHENS AND AIR POLLUTION

WHAT IS A LICHEN?

A lichen is a plant. It has no leaves, stems, or roots, but like other plants it makes its own food using energy from sunlight. Lichens resemble mosses: both are small and grow on trees or rocks as well as on the ground. Mosses are made up of slender, green stems with tiny, transparent, green leaves. Lichens, however, come in many forms: paint-like crusts; scalloped, wrinkled sheets; lace-like pads; bushy tufts; unkempt strands of black, gray or green "hair"; but they are never made up of stems and leaves.

A lichen is a fungus, but it contains one or more kinds of algae which make its food. The body of a lichen is formed by the fungus. It consists of materials similar to those in a mushroom. Inside the lichen is a layer of green or blue-green algae. The algae make food, both for themselves and for the fungus. The partnership between the algae and fungi in lichens is a classical example of a relationship known as symbiosis.

DO LICHENS HARM TREES?

Lichens which grow on trees and shrubs do not harm them. Although the lichens are attached to the bark or penetrate a short distance, they do not enter the inner bark where food is transported, and hence do not rob the tree of nourishment. Neither do lichens cause disease.

In winter in the Willamette Valley, the oak and ash trees seem to be choked with lichens. Although we might expect these lichens to shade the leaves and thus harm the trees, this does not occur. In the spring when new leaves emerge, they grow only at the ends of twigs, where there are no lichens. Thus, the leaves grow on the "outside" of the tree and shade the lichens on the older twigs and branches, rather than the lichens shading the leaves. In addition, lichens grow in the winter, after the leaves have fallen from the trees and no longer block light from reaching the lichens. Thus, the leaves and lichens take turns: leaves use sunlight in summer; lichens use it in winter.

LICHENS NEED WATER AND MINERALS

Lichens, like other plants, need water and minerals in order to grow. Lichens growing on trees get both water and minerals from the

air. When a lichen is wet from rain or dew it grows actively, but when it dries out in summer, it stops growing. However, the lichen does not die, but instead lies dormant until the next rain starts it growing again.

Minerals in the air such as tiny, dust-like particles of soil are carried by the wind to the surface of lichens. There, dissolved in rainwater, they are taken up by the lichen and used for growth. Small amounts of airborne minerals, the amounts found in clean air, are beneficial to the lichens. However, it is possible to get too much of a "good" thing. Large amounts of minerals, such as the amounts found in polluted air, will poison the lichens and kill them.

AIR POLLUTION

Many kinds of pollutants are found in the air. Some, like sulfur dioxide, are gases. Others, like carbon, occur as very small particles. Some pollutants are found at low levels in clean air and only become annoying or poisonous when they occur at abnormally high levels. Others are seldom, if ever, found in clean air.

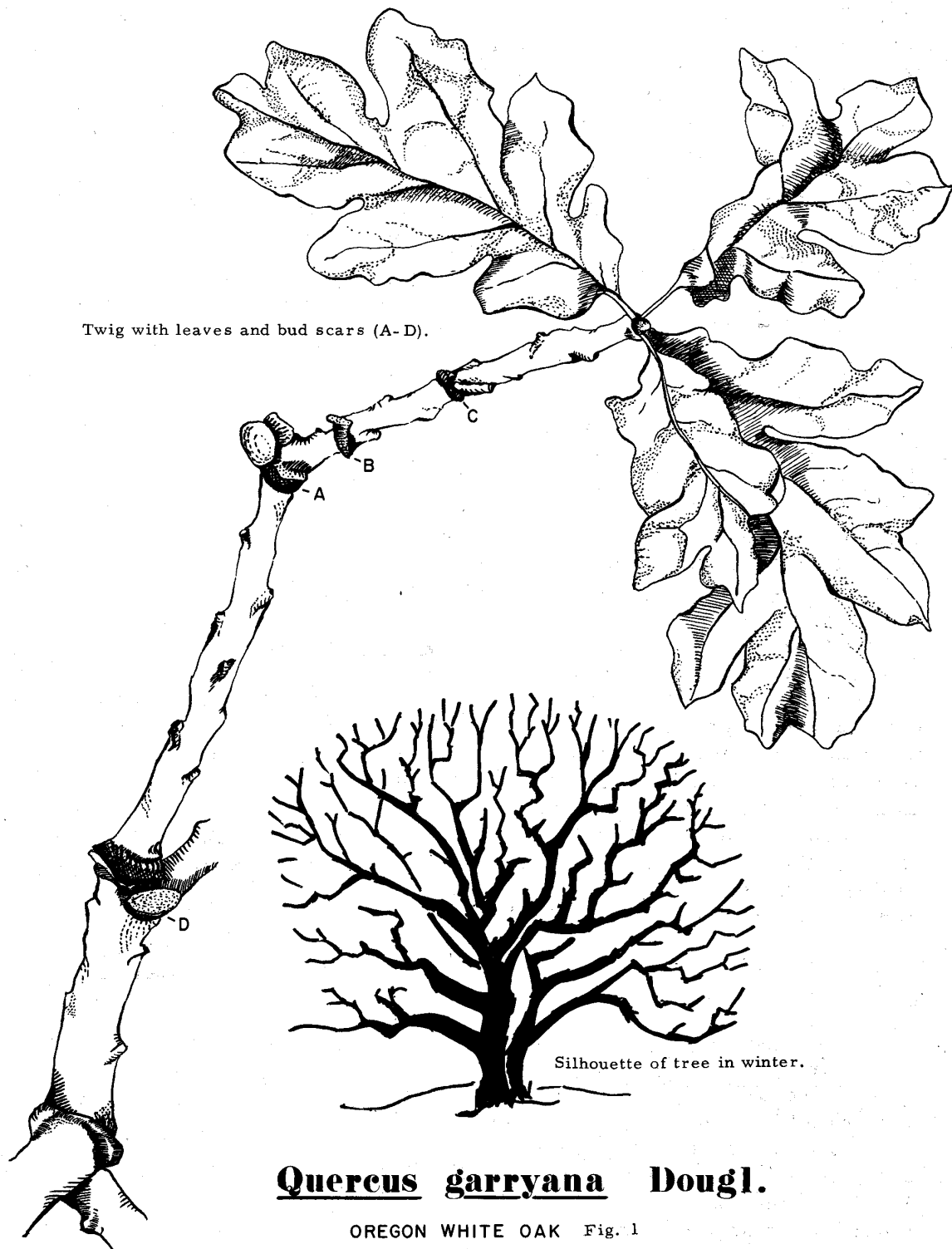
Since air pollution occurs in so many forms, it is difficult to design equipment which can measure all the types of pollution and measure it everywhere, day and night. As a consequence, most measurement is done near known sources of pollution and is limited to measurement of only one kind of pollutant.

Whether we live in a city or way out in the country, each of us would like to have the assurance that the air in our own neighborhoods is clean. We need a measuring device that is cheap, that can be used anywhere, and that responds to many kinds of airborne pollutants. Lichens, especially those which grow on trees, provide a partial but very useful substitute. They are cheap, they can be found in most areas of the Willamette Valley, and they are sensitive to many different kinds of pollutants. This guide is intended to show you how to use lichens to measure air pollution.

LICHENS AND AIR POLLUTION

More than a century ago William Nylander, a European scientist, noticed that lichens found on trees in the countryside around Paris were not found on the same kinds of trees inside the city. He thought that lichens had grown there once, but had later been killed by pollutants.

In the past ten years scientists in Sweden, Great Britain, Canada and the United States have studied the effects of airborne pollution on



lichens and have developed ways to use lichens to detect pollution. (A selected bibliography of technical reports of this work is included in this guide.) These scientists have found that some kinds of lichens are more easily killed by air pollution than others. Thus, in places where the air is very dirty, no lichens survive; in areas with slightly cleaner air one or two very resistant lichens can grow; in cleaner areas five or six species are found; in the cleanest areas a dozen or more species of lichen thrive. By learning which lichens are most sensitive to air pollution and which ones are most resistant, you can judge the quality of the air by examining the lichens.

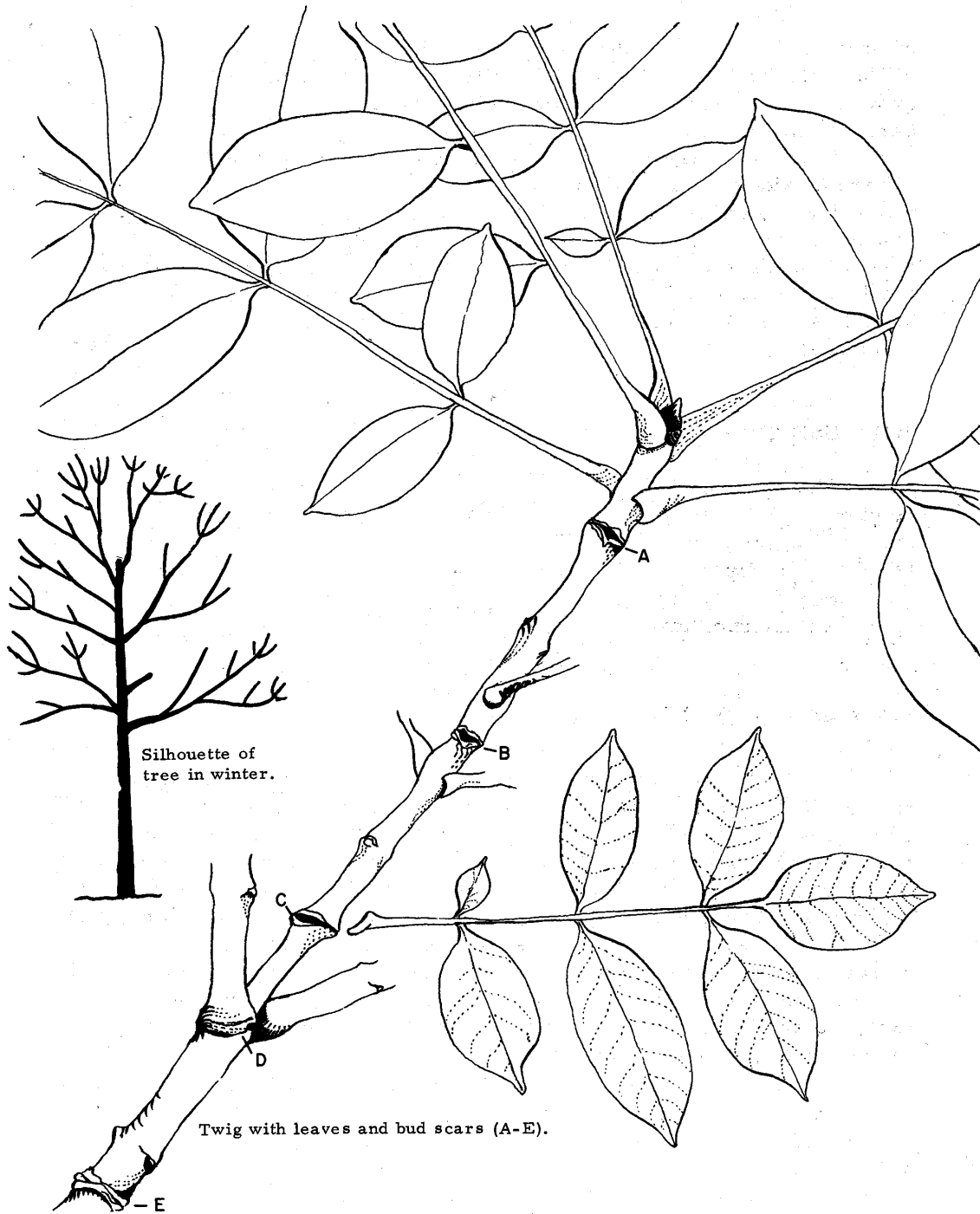
The scale used in this GUIDE is based on data from 170 sites in the Willamette Valley. The two most resistant (Class 1) lichens, Xanthoria polycarpa and Parmelia sulcata, were found almost everywhere except for downtown Portland and a very few isolated industrial sites. In areas with slightly cleaner air, these two species were accompanied by three slightly more sensitive (Class 2) lichens: Ramalina farinacea, Parmelia subaurifera, and Usnea subfloridana. In still cleaner areas, these species as well as the still more sensitive Class 3 lichens (Lepraria membranacea and Evernia prunastri) were present. Finally, in the cleanest areas Class 4 lichens (Lobaria pulmonaria and Physcia aioplia) were found in addition to the other species. In evaluating the air quality of a site, one should note the most sensitive lichens present (those of the highest class), because they indicate the air quality at that site. If no lichens are present, the air is very dirty. If only Class 1 lichens are present, the air quality is only slightly better. However, if all classes of lichens are present, including the very sensitive Class 4 lichens, then the air is very clean.

It should be noted that the lichen method will not tell you how much of a particular pollutant is present. It is only an indicator, although a very sensitive indicator, which can reassure you when the air is clean and warn you when it is not. Other methods must be used to determine which pollutants are present and to measure the exact amount.

WHY EXAMINE LICHENS ON BRANCHES?

Environmental factors other than air quality determine whether a lichen can grow in a given spot. By using only the lichens on branches of oak and ash trees we can limit, or even eliminate, the influence of factors other than air quality.

The chemical composition of the substrate, the surface on which a lichen grows, determines which lichens, if any, can grow there. For example, some species of lichens grow on granitic rocks, while others grow only on limestone. The chemical composition of the bark



Fraxinus latifolia Benth.

OREGON ASH Fig. 2

of branches of oak and ash trees varies little from place to place in the Willamette Valley. Therefore, differences we observe in the lichens growing on branches are not caused by these negligible differences in bark composition.

There are major differences in amounts of light and moisture on different sides of a tree trunk. Moisture varies because rainwater flows down channels in the bark of the trunk, leaving intervening areas relatively dry. On the other hand, small branches well up in the tree receive similar amounts of light and moisture whether they are on the north or the south side of the tree. By examining the lichens on branches we can limit differences caused by variation in light and moisture.

WHY USE FIVE-YEAR-OLD AND TEN-YEAR-OLD TWIGS?

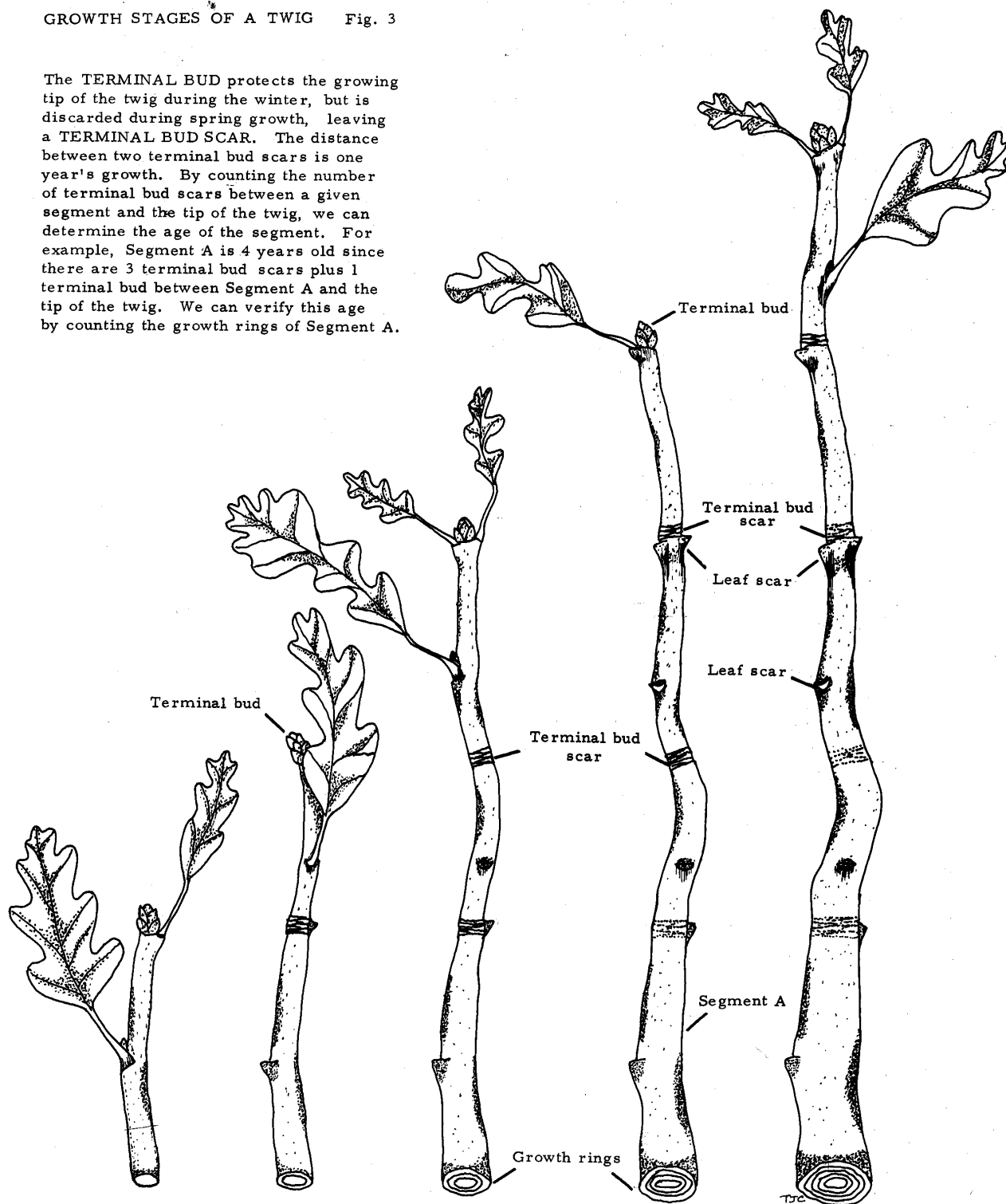
The kinds of lichens found on an exposed surface are determined, in part, by how long the surface has been exposed. New twigs have no lichens growing on them. Those lichens which do grow after a year or two are replaced after a while by different species and are in turn replaced by others. By examining the lichens on branches of the same age, we can eliminate differences due to length of time of exposure.

HOW CAN WE TELL THE AGE OF A TWIG?

Every branch is composed of segments of different ages. The tips of the twigs grew this year; the next segment grew last year; the next grew the year before that; and so on. The boundary between one year's growth and the next is marked by a ring of scars which encircle the twig (see Fig. 3). These are the scars of bud scales which formed a terminal bud protecting the growing point of the twig during the winter, and which fell off, leaving the scars, when the twig resumed growth the following spring. We can determine the age of any segment by counting the number of rings of scars between it and the tip of the twig, since each ring of scars represents a winter that has passed since the segment was formed.

GROWTH STAGES OF A TWIG Fig. 3

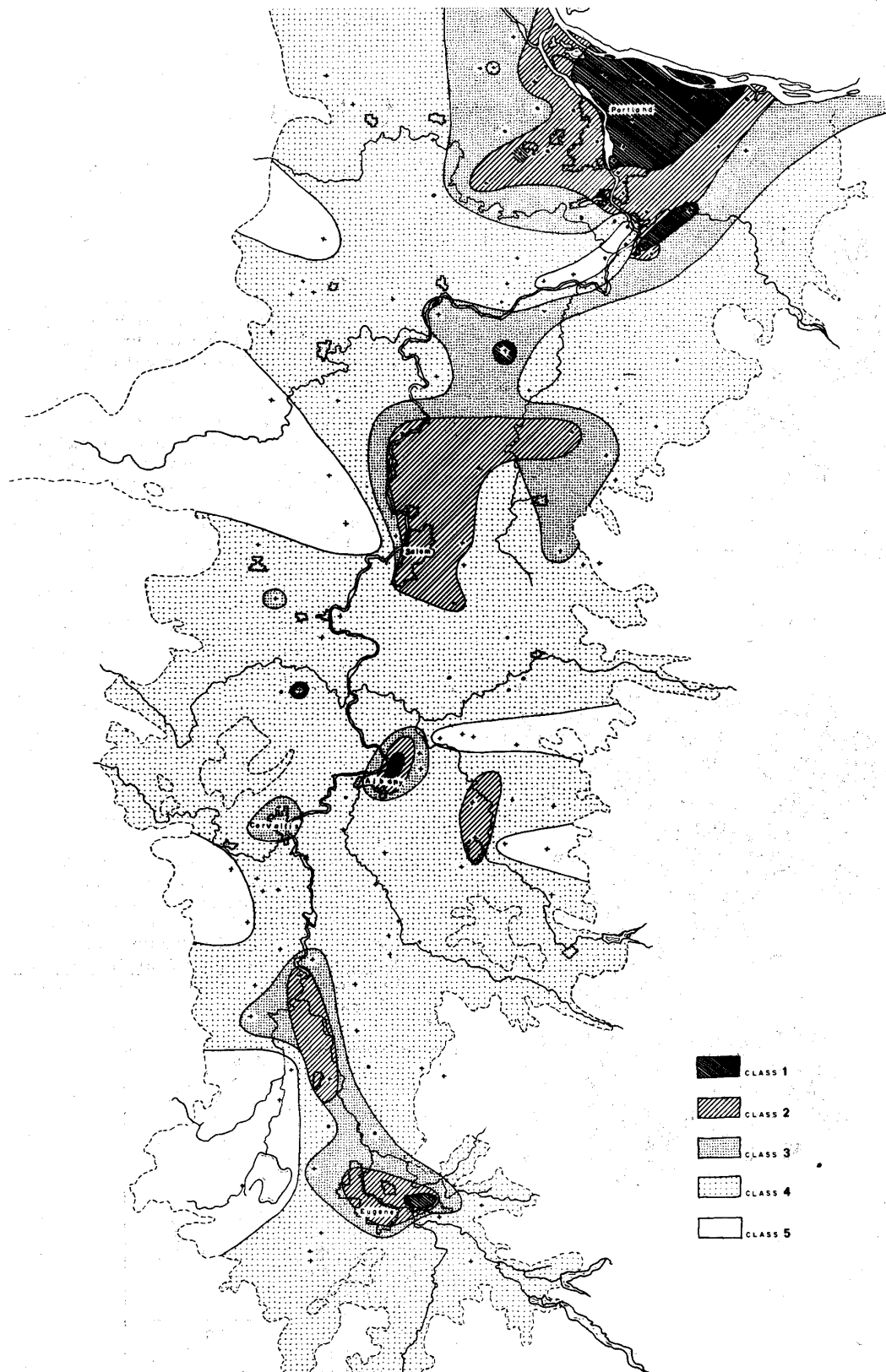
The TERMINAL BUD protects the growing tip of the twig during the winter, but is discarded during spring growth, leaving a TERMINAL BUD SCAR. The distance between two terminal bud scars is one year's growth. By counting the number of terminal bud scars between a given segment and the tip of the twig, we can determine the age of the segment. For example, Segment A is 4 years old since there are 3 terminal bud scars plus 1 terminal bud between Segment A and the tip of the twig. We can verify this age by counting the growth rings of Segment A.



MAPPING LICHENS AND AIR QUALITY IN THE WILLAMETTE VALLEY

This map is an example of the kind of large-area mapping which is possible with the method outlined in this GUIDE. It is based on data gathered in 1972 by six Oregon State University students, Steve Carpenter, Bob Denison, Andy Merzenich, Dave Newman, Mark Scherzinger, and Chris Shonnard, during a Student Originated Studies project supported by the National Science Foundation. Data on lichens from approximately 170 sites were obtained using a format similar to Form #1 found in this GUIDE. The data were then plotted on a map of the Willamette Valley. The map is based on a slightly different scale of lichen classes than the one described in this GUIDE: the map scale contains fewer species of lichens and does not recognize a "Class 0".

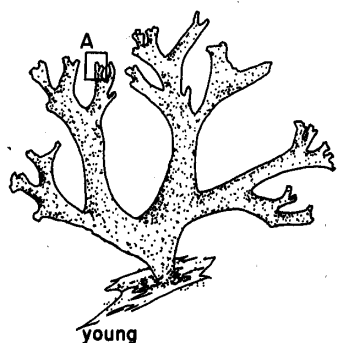
An updated version of this map will be made using data from readers who return copies of Form #1 with data on sites which they sampled.



MAP OF LICHENS INDICATING AIR QUALITY IN THE WILLAMETTE VALLEY, OREGON (SUMMER 1972) Fig. 4

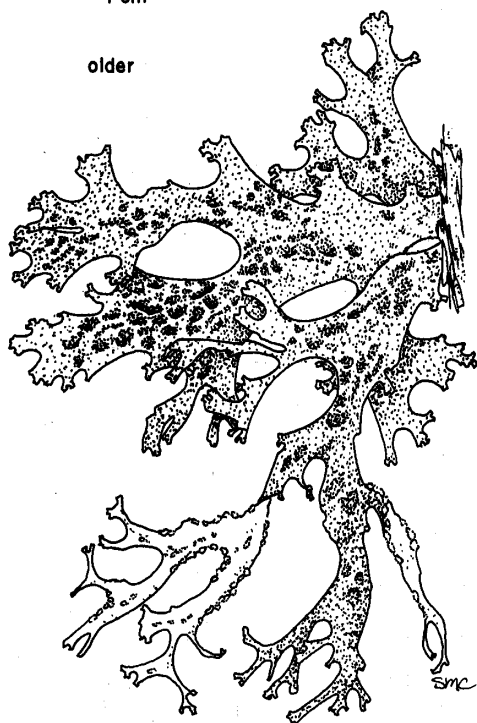
Evernia prunastri (L.) Ach.

WRINKLED EVERNIA Fig. 5



1 cm

older



General Appearance: Medium-sized, bushy or hanging thallus, with flat, strap-like branches, olive green to greenish-gray; the thallus 3-8 cm (1 - 4 in) long.

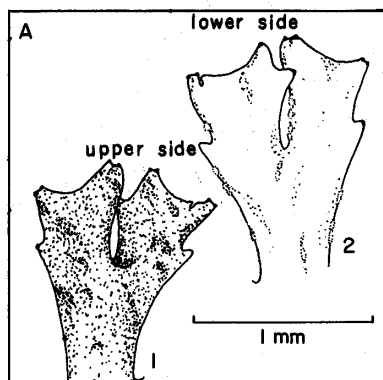
Thallus: Fruticose to almost foliose, often with the upper surface darker colored than the lower (Fig. A), attached at a single point, composed of flat, irregular branches which remain flexible even when dry. The branches 1 - 5 mm (.04 - .2 in) wide, 0.5 - 1.5 mm thick, often forked at the tips. Upper surface usually wrinkled, dark olive green to grayish yellow green when dry, becoming brighter, sea green to pale greenish yellow when wet. Lower surface usually lighter colored than upper surface.

Apothecia: Lacking

Soredia: Present, formed in circular soralia on the underside of the thallus.

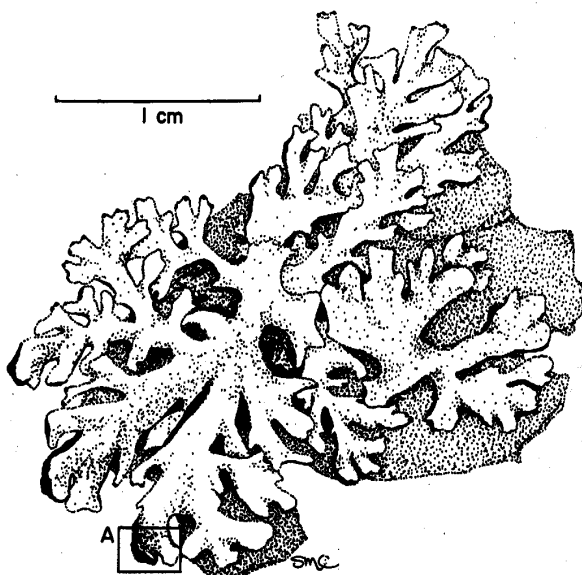
Isidia: Lacking.

Comments: This species differs from the other common fruticose lichens in having differentiated upper and lower surfaces. Older thalli sometimes have a puckered appearance resembling a miniature Lobaria pulmonaria but Evernia prunastri has much narrower branches with pointed tips.

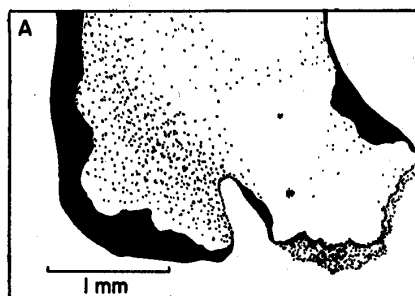


Hypogymnia physodes (L.) Nyl.

INFLATED HYPOGYMNIA Fig. 6



General Appearance: Rough, medium-sized patches composed of irregular, flattened, overlapping branches; pale gray or greenish-gray on upper side and black below; patches 3-8 cm (1-3 in) broad; hollow when sliced with a razor blade so therefore appearing inflated.



Thallus: Foliose, composed of irregular flattened, overlapping branches which are only loosely attached to the bark; the branches are 1-4 mm (.04-.15 in) wide and comparatively thick and hollow; upper surface smooth, dull pale gray to greenish-gray when dry; similarly colored when wet; lower surface black or very dark brown, often wrinkled, lacking rhizines.

Apothecia: Rare.

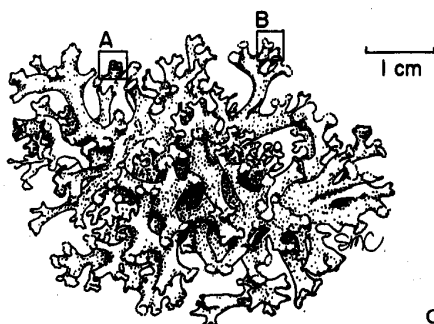
Soredia: Common; formed on the underside of the tips of branches; when they protrude from underneath, they appear as crescent-shaped masses (Fig. A).

Isidia: Lacking.

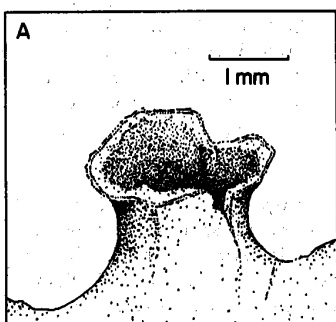
Comments: See comments under Hypogymnia tubulosa.

Hypogymnia tubulosa (Schaer.) Hav.

TUBULAR HYPOGYMNIA Fig. 7



General Appearance: Rough, medium-sized patches composed of irregular, flattened, overlapping branches with rounded edges like flattened hollow tubes; pale gray or greenish-gray on the upper side and black below; the patches 3-8 cm (1-3 in) broad.

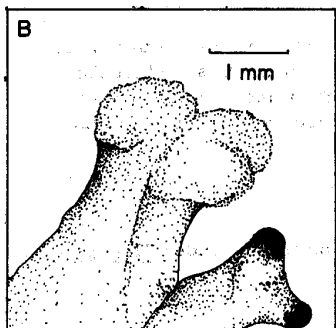


Thallus: Foliose, composed of flattened overlapping branches which are only loosely attached to the bark; the individual branches are 1-4 mm wide and relatively thick (0.5-1.5 mm) but hollow; upper surface smooth, dull pale gray to greenish-gray when dry, similarly colored when wet; lower surface black or very dark brown, often wrinkled; lacking rhizines.

Apothecia: Rare.

Soredia: Common, formed in ring-shaped soralia at the ends of branches (Figs. A & B).

Isidia: Lacking.

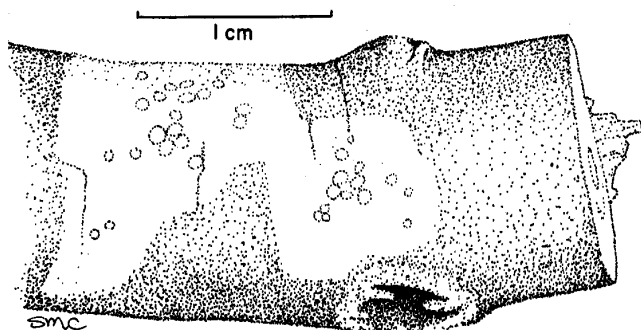


Comments: Hypogymnia tubulosa and Hypogymnia physodes are differentiated from the other pale gray foliose lichens on our list by their thicker hollow branches with black lower surface. The branches lack rhizines and thus are easily lifted from the bark. In H. tubulosa the soredia are formed in ring-shaped soralia at the ends of branches; whereas in H. physodes the soralia are lip-shaped or crescent-shaped or on the undersides of the tips of branches.

Lecanora

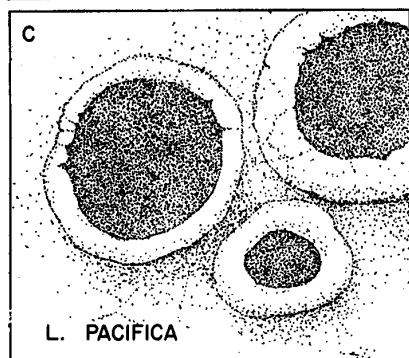
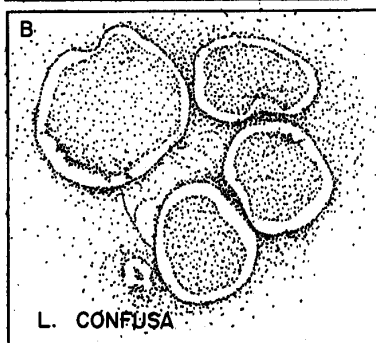
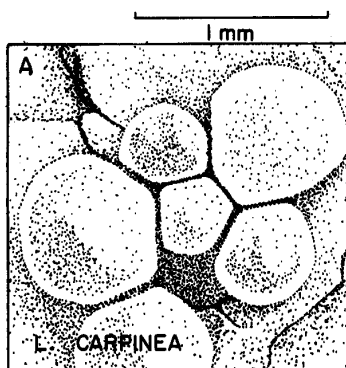
Fig. 8

Three species of *Lecanora* occur commonly on twigs in our area: *Lecanora carpinea*, *L. confusa*, *L. pacifica*. All three are very similar in general appearance, so we have shown them on a single page. The picture at the top shows the general appearance of all three species; the lower pictures emphasize differences in the apothecia.



General Appearance: (all the species) Whitish to pale gray patches on the bark consisting of a paint-like film inseparable from the outer bark; the patches usually 0.5 - 3 cm (1/8 - 1/4 in) across.

Thallus: (all three species) Thallus crustose, the lower surface embedded in the bark. Upper surface whitish, dull, smooth or divided into irregular polygons which often appear outlined in black. (Use a hand lens)



Apothecia: (all three species) Apothecia present, disk-shaped, 0.3 - 1.0 mm (.01 - .04 in) wide, with a whitish thalline margin.

Lecanora carpinea: Apothecial disk flat or slightly convex, pale pinkish when dry and similarly colored when wet; thalline margin often indistinct on older apothecia and present as minute lumps around the margin of younger ones. (Use a hand lens) Apothecia clustered close together and appearing as polygons.

Lecanora confusa: Apothecial disk flat or slightly concave, pale olive-green when dry, similarly colored when wet; thalline margin easily seen but thinner than in *L. pacifica*.

Lecanora pacifica: Apothecial disk flat or slightly concave, blackish to dark olive brown when dry, lighter-colored, olive to yellow-green when wet; thalline margin thick.

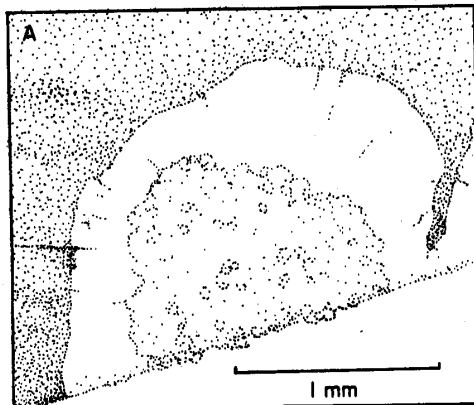
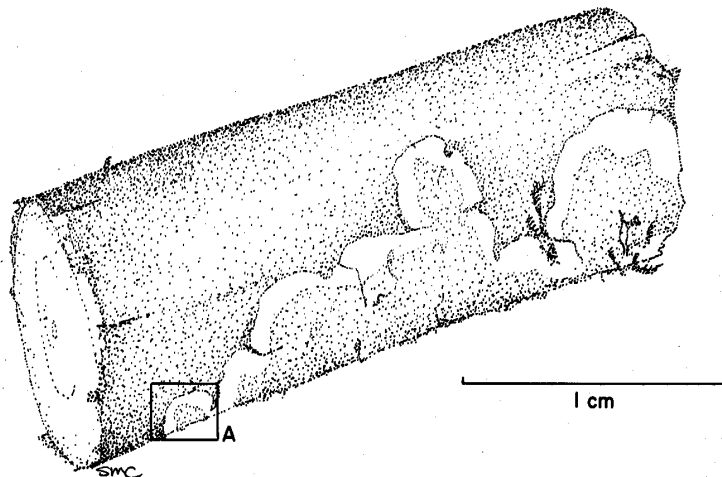
Soredia: (all species) Lacking.

Isidia: (all species) Lacking.

Comments: In the genus *Lecanora*, species are distinguished by their apothecia which are almost always present on their whitish to grayish crustose, paint-like thalli. *Lepraria* species have a similar thallus but it is colored blue-green or yellow, and always lacks apothecia. *Rinodina* species resemble *Lecanora* species but have a blackish thallus.

Lepraria membranacea (Dicks.) Vain.

POWDERY PAINT LICHEN Fig. 9



General Appearance: Irregularly shaped, powdery patches, pale blue-green or blue-gray with white margins; the patches 1 - 3 cm ($3/8$ - $1\ 1/4$ in) across.

Thallus: Thallus crustose, powdery, superficial, not embedded in the bark but so fragile and powdery that it cannot be peeled off; pale blue-green or blue-gray with a white margin.

Apothecia: Lacking.

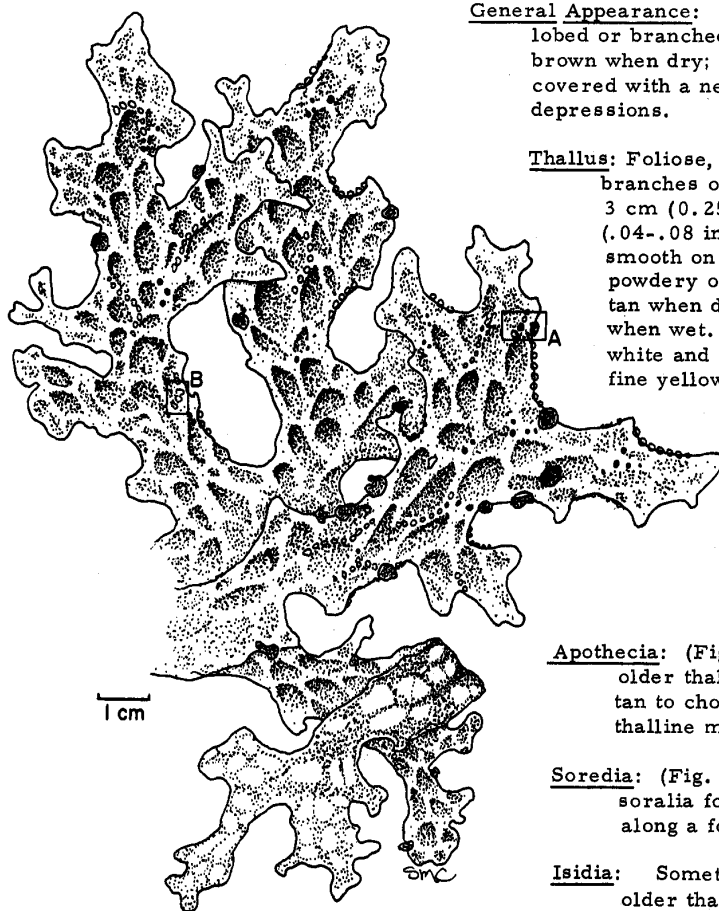
Soredia: Lacking.

Isidia: Lacking.

Comments: Lepraria membranacea is common on twigs but is often hidden by more conspicuous fruticose species. A related species, Lepraria candelaris, is bright yellow, orange-yellow, or greenish-yellow. It has a similar powdery, superficial thallus and lacks apothecia, soredia and isidia. The only other common yellow lichen or fungus on twigs is Xanthoria polycarpa which has a foliose thallus and apothecia.

Lobaria pulmonaria (L.) Hoffm.

LUNGWORT Fig. 10



General Appearance: Large, 5-25 cm (2-10 in), lobed or branched sheets; light greenish-brown when dry; bright green when wet; covered with a network of raised folds and depressions.

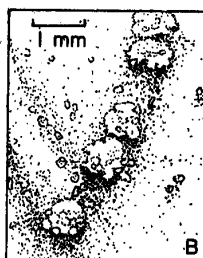
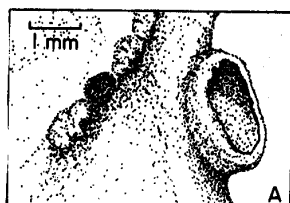
Thallus: Foliose, composed of broad, thin branches or lobes; the branches 0.5-3 cm (0.25-1.5 in) wide and 1-2 mm (.04-.08 in) thick. Upper surface smooth on young branches becoming powdery on old ones; pale greenish-tan when dry, becoming bright green when wet. Lower surface mottled white and tan; tan areas covered by fine yellowish hairs (use a hand lens). The thallus is attached at a central point and the branches are easily lifted from the bark.

Apothecia: (Fig. A) Sometimes present on older thalli, 1-4 mm (.04-.15 in) across, tan to chocolate brown with a thin, pale thalline margin.

Soredia: (Fig. B) Present, usually in lines of soralia following the margin of a lobe or along a fold.

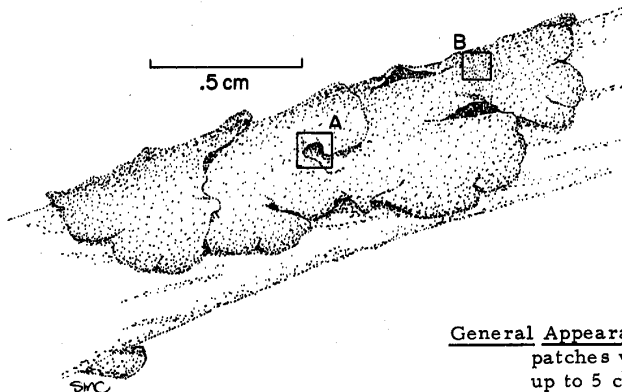
Isidia: Sometimes developing in soralia of older thalli.

Comments: This large green lettuce-like lichen with its puckered thallus is easily recognized. It contains, in addition to the green algae which make its food, packets of blue-green algae which fix nitrogen in the same way that bacteria in the roots of legumes do.



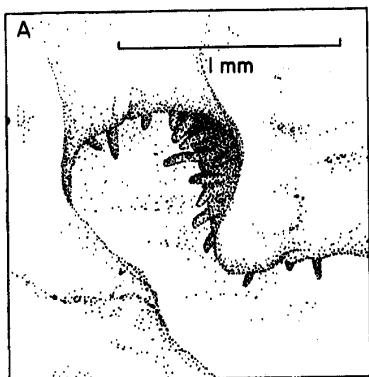
Parmelia subaurifera Nyl.

PAPERY BRONZE PARMELIA Fig. 11



General Appearance: Flat, smooth, brown patches with lobed margins; the patches up to 5 cm (2 in) across, but often smaller.

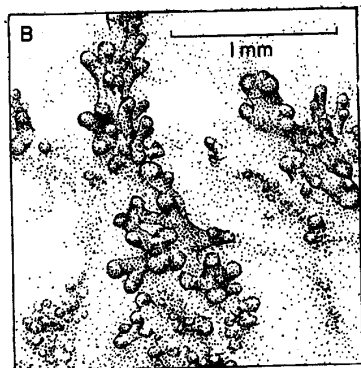
Thallus: Foliose, consisting of paper-thin flat or slightly concave, unbranched scales with lobed margins, tightly attached to the bark except at the margin. Young thalli shiny; older ones roughened. Upper surface brown, bronze, olive-brown, or dark brown when dry, becoming paler and greenish when wet. Lower surface olive at the margin but darker elsewhere, brown to blackish, because covered by dark brown rhizines (Fig. A).



Apothecia: Rare

Soredia: Sometimes present. Usually developing at the tips of the isidia.

Isidia: (Fig. B) Consisting of minute, brown, finger-like projections from the upper surface of older thalli. (Use a hand lens.)



Comments: The brown color; small, foliose thallus; and minute isidia distinguish this species. Parmelia subaurifera is common and widespread, and because it is relatively tolerant of pollution, it is found in all but the dirtiest areas.

Parmelia sulcata Tayl.

NET-MARKED PARMELIA Fig. 12

General Appearance: Pale gray to greenish-gray patches composed of flat, overlapping branches and lobes; the patches commonly 2-7 cm (1-3 in) across, but often smaller on twigs.

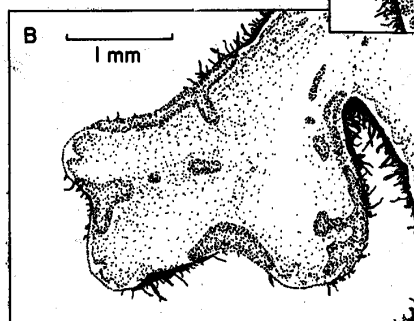
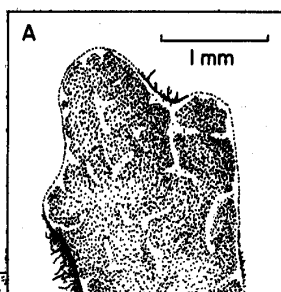
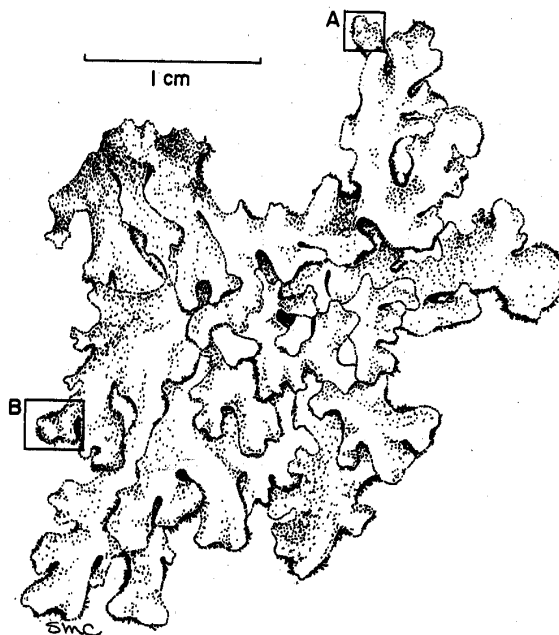
Thallus: Foliose, consisting of flat, overlapping branches which are tightly attached to the bark; the branches 2-5 mm (1/8-1/4 in) wide. Upper surface pale gray or greenish gray when dry; greenish-gray when wet; smooth with raised whitish ridge-like folds (Fig. A) (use a hand lens.) Lower surface dark brown to blackish, covered with blackish rhizines over the entire lower side.

Apothecia: Rare.

Soredia: Developing at margins and on raised folds on upper surface (Fig. B) (Use a hand lens.)

Isidia: Lacking.

Comments: The broken network of white ridges on the upper surface of the lobes distinguishes this species from other species of gray, foliose lichens. Parmelia sulcata is common and widespread. It is relatively tolerant of pollution, so it is found in all but the dirtiest areas. Nevertheless, studies by LeBlanc and Rao (1973) indicate that amounts of sulfur dioxide ranging from 0.01 to 0.03 parts per million in the atmosphere result in serious damage or death in this species.



Parmelia sulcata Tayl.

NET-MARKED PARMELIA Fig. 12

General Appearance: Pale gray to greenish-gray patches composed of flat, overlapping branches and lobes; the patches commonly 2-7 cm (1-3 in) across, but often smaller on twigs.

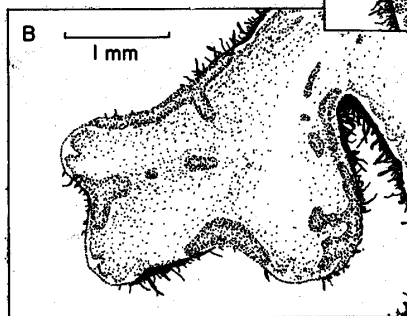
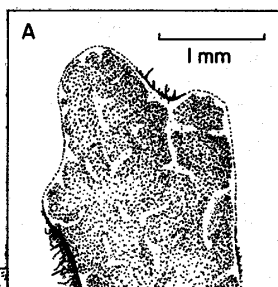
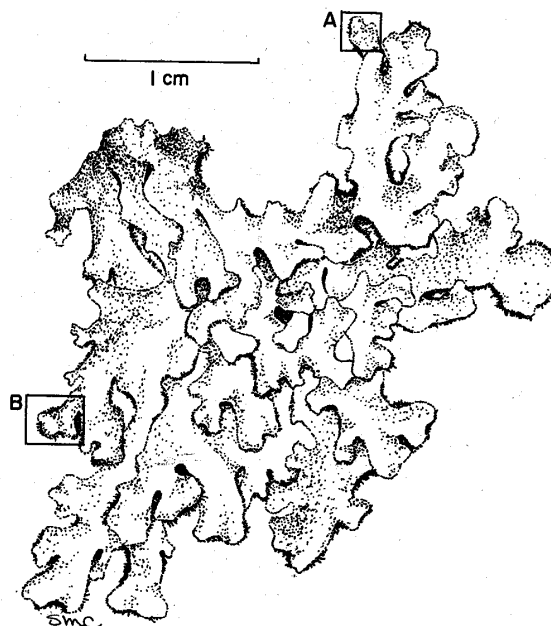
Thallus: Foliose, consisting of flat, overlapping branches which are tightly attached to the bark; the branches 2-5 mm (1/8-1/4 in) wide. Upper surface pale gray or greenish gray when dry; greenish-gray when wet; smooth with raised whitish ridge-like folds (Fig. A) (use a hand lens.) Lower surface dark brown to blackish, covered with blackish rhizines over the entire lower side.

Apothecia: Rare.

Soredia: Developing at margins and on raised folds on upper surface (Fig. B) (Use a hand lens.)

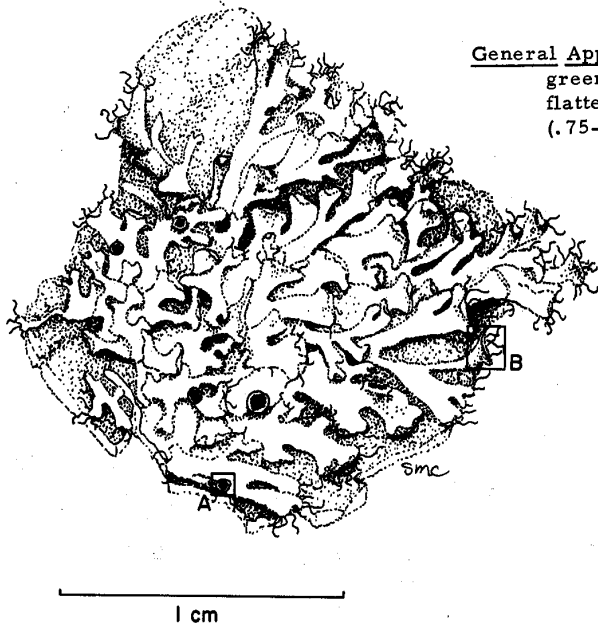
Isidia: Lacking.

Comments: The broken network of white ridges on the upper surface of the lobes distinguishes this species from other species of gray, foliose lichens. Parmelia sulcata is common and widespread. It is relatively tolerant of pollution, so it is found in all but the dirtiest areas. Nevertheless, studies by LeBlanc and Rao (1973) indicate that amounts of sulfur dioxide ranging from 0.01 to 0.03 parts per million in the atmosphere result in serious damage or death in this species.



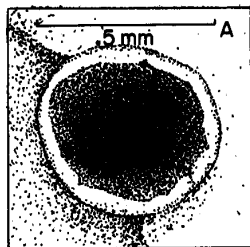
Physcia adscendens (Fr.) Oliv.

HAIR-TIPPED PHYSICIA Fig. 13



General Appearance: Small, rough, pale gray to greenish-gray patches composed of narrow, flattened branches; the patches 2-4 cm (.75-1.75 in) across.

Thallus: Foliose, consisting of narrow flattened branches; the branches 0.5-2.0 mm (.02-.08 in) across, tightly attached to the bark. Upper surface of branches smooth, dull, greenish-gray to whitish when dry; similarly colored when wet. Lower surface similar in color to the top. The tips of the branches are sometimes bulged upward like the back of a fist and have conspicuous curved, branched hairs (Fig. B). The hairs are light colored when young, but may become dark.

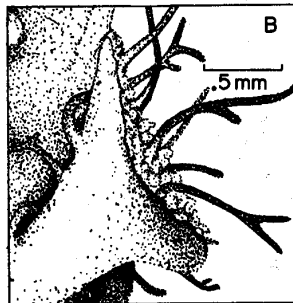


Apothecia: (Fig. A) Uncommon, except on older thalli; small, 0.5-1.0 mm (.02-.04 in) across; brown, with a whitish thalline margin.

Soredia: Usually present on older branches, located on the underside of the tips of branches (Fig. B).

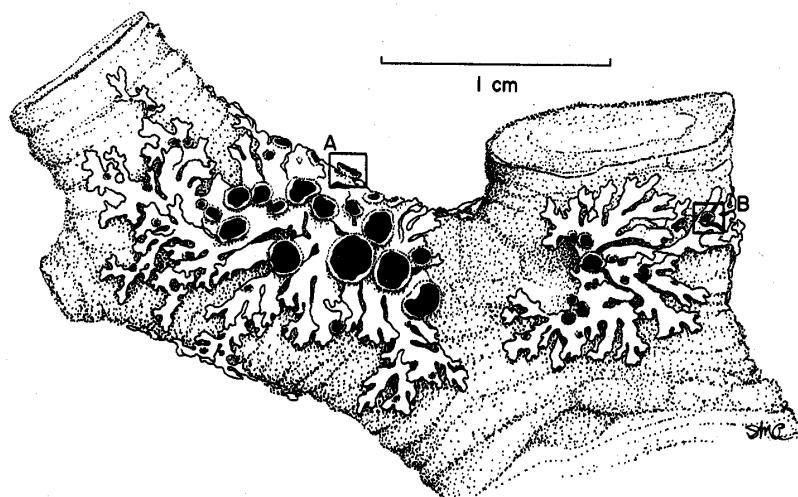
Isidia: Lacking.

Comments: This is a small foliose lichen with slender branches. It is distinguished by the curved, branched hairs projecting from the tips of the branches and by the soredia on the underside of the tips of branches.



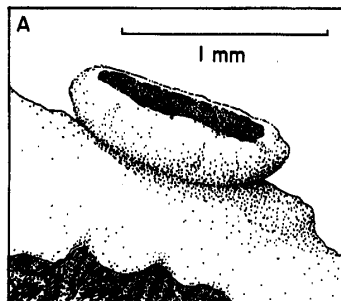
Physcia aipolia (Ehrn.) Hampe.

HOARY PHYSCIA Fig. 14



General Appearance: Rough, gray to brownish-gray patches with broad, flat branches or a lobed margin; the patches commonly 3-6 cm (1.25-2.25 in) broad. Black apothecia with light-colored thalline margins are usually abundant.

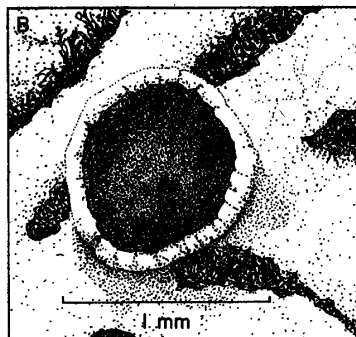
Thallus: Foliose, consisting of flat branches which are tightly attached to the bark and which may grow so closely side by side that they seem to form a continuous sheet; the branches 0.5-4.0 mm (.02-.15 in) wide. Upper surface of branches smooth, dull, pale ashen gray to pale tannish gray when dry; similarly colored when wet. Lower surface light colored, gray to buff, with blackish rhizines. Margin lacking hairs.



Apothecia: (Figs. A & B) Common, 1-3 mm (.04-.12 in) wide, black or very dark brown with a whitish thalline margin.

Soredia: Lacking.

Isidia: Lacking.



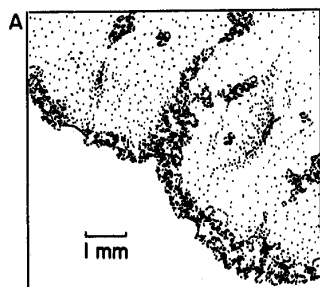
Comments: This species is distinguished from other gray, foliose species by its abundant apothecia.

Platismatia glauca (L.) Culb. & Culb.

RAGGED PLATISMATIA Fig. 15



General Appearance: Medium-sized thallus with numerous thin, irregular lobes which stand up from the bark. The color varies from tan to gray to green but is most often pale greenish-tan when dry and pale green when wet. Individual thalli 3-10 cm (1-4 in) broad.

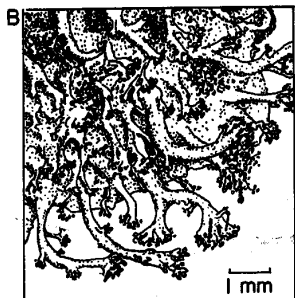


Thallus: Foliose, composed of broad branching sheets with numerous upcurved lobes; the individual lobes 2-5 mm (.08-.20 in) broad; thin, papery, less than 1 mm thick; often with ragged margins. Upper surface smooth, dull, sometimes with inconspicuous wrinkles; pale, greenish-gray to tan when dry, becoming green to olive or greenish-gray or tan when wet. Lower surface smooth, shiny, irregularly mottled brown and white; lacking rhizines.

Apothecia: Lacking.

Soredia: (Fig. A) Often present, usually at the margins of the lobes.

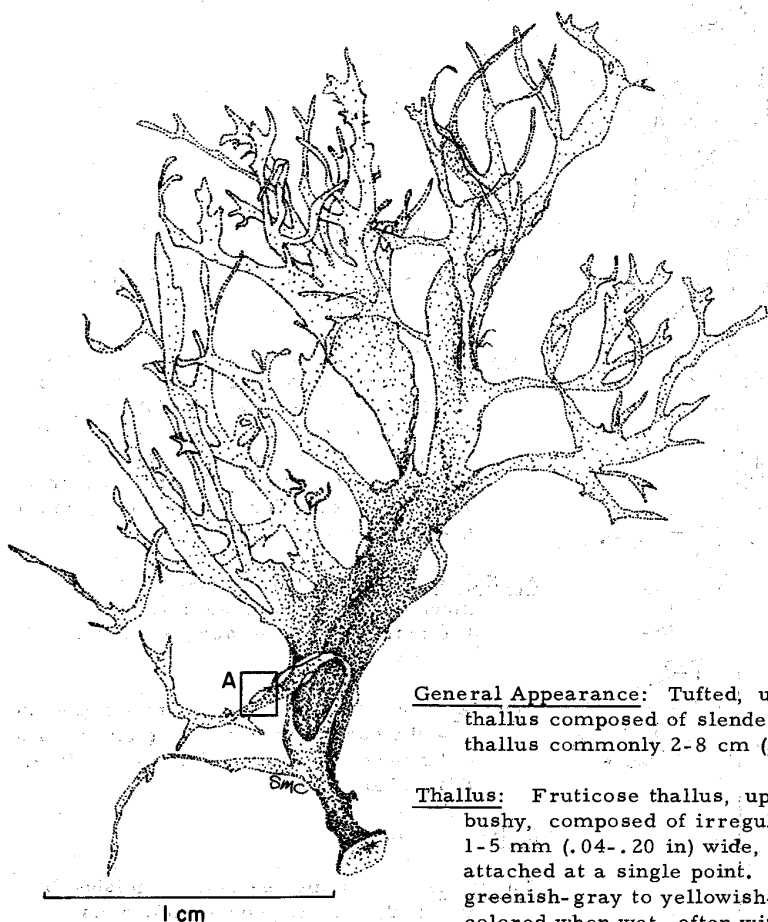
Isidia: (Fig. B) Sometimes present, usually developing from soralia.



Comments: This is one of the most variable and non-descript of foliose lichens. It is quite common. The color is highly variable. The distinguishing features include abundant, irregular paper-thin upright lobes with ragged margins and a hairless, mottled undersurface.

Ramalina farinacea (L.) Ach.

MEALY RAMALINA Fig. 16



General Appearance: Tufted, upright, pale greenish-gray thallus composed of slender, irregular branches; the thallus commonly 2-8 cm (3/4-3 in) tall.

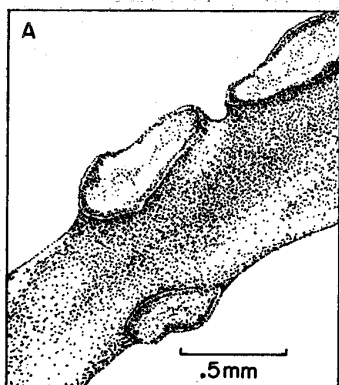
Thallus: Fruticose thallus, upright, rarely hanging, bushy, composed of irregular, flattened branches, 1-5 mm (.04-.20 in) wide, 0.5-1.5 mm thick and attached at a single point. Exterior smooth, pale greenish-gray to yellowish-green when dry, similarly colored when wet, often with a whitish superficial "bloom".

Apothecia: Lacking.

Soredia: Present, formed on circular raised soralia (Fig. A). (Use a hand lens.)

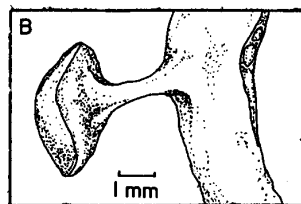
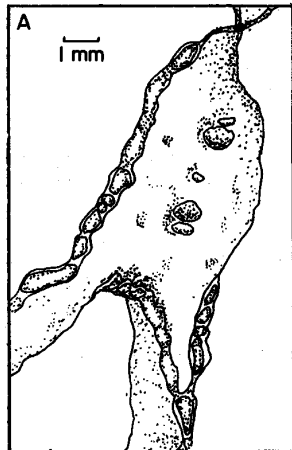
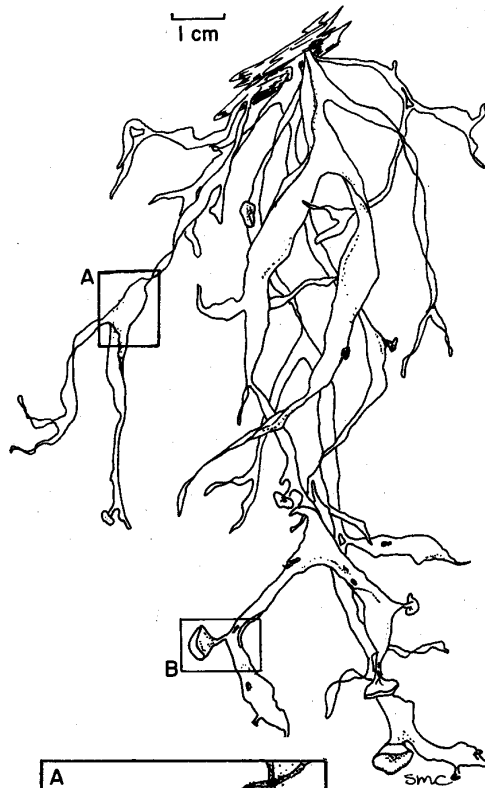
Isidia: Lacking.

Comments: Ramalina farinacea is distinguished from Ramalina leptocarpha by its well-developed, disk-like soralia, and by its lack of apothecia.



Ramalina leptocarpha Tuck.

MOOSE ANTLER RAMALINA Fig. 17



General Appearance: Small to medium-sized bushy tufts with smooth, flattened, greenish-gray branches; the tufts 2-10 cm (3/4-4 in) tall.

Thallus: Fruticose, usually upright but older thalli sometimes hanging; attached at a single point; composed of flattened, irregular branches 1-8 mm (.04-.3 in) wide, 0.5-1.5 mm thick. Exterior smooth or wrinkled, pale greenish-gray when dry, becoming pale yellow-green to gray-green when wet.

Apothecia: (Fig. B) Often present but inconspicuous, color similar to thallus, 1-6 mm (.04-.24 in) across; attached by a short stalk.

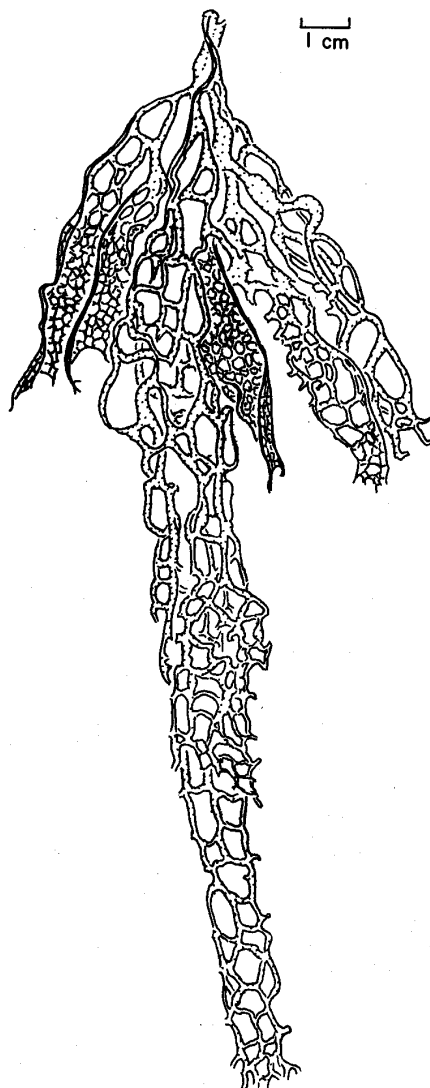
Soredia: (Fig. A) Usually present, formed in pit-like soralia in lines along the margins of branches or scattered on the surface. (Use a hand lens.)

Isidia: Uncommon.

Comments: This species is distinguished by its apothecia and poorly-differentiated pit-like soredia. Individual branches of Ramalina leptocarpha are usually broader than those of a thallus of Ramalina farinacea of comparable size.

Ramalina menziesii Tuck.

FISHNET LICHEN Fig. 18



General Appearance: Long, hanging, greenish-gray thallus pierced by many large, angular holes so that it resembles a net. Individual thalli are often 25-40 cm (10-16 in) long.

Thallus: Fruticose, composed of hanging, flattened, netlike branches; attached at a single point. Individual strands highly variable in width, 0.5-5.0 mm (.02-.20 in) wide, 0.5-1.5 mm thick. Exterior smooth or longitudinally wrinkled, dull; yellowish-gray or greenish-gray when dry, becoming yellowish-green when wet.

Apothecia: Rare.

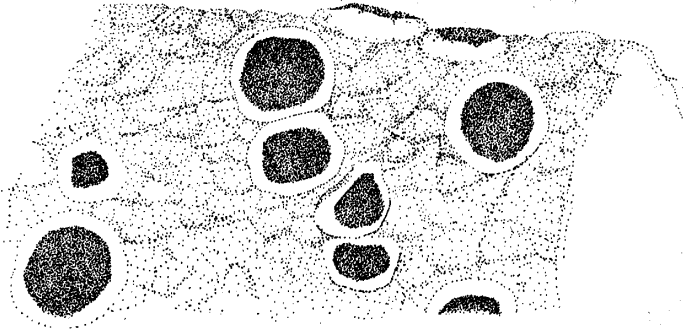
Soredia: Lacking.

Isidia: Lacking.

Comments: This large, easily-recognized lichen frequently drapes the trees along streams. It is the only common lichen with a net-like thallus. Ramalina menziesii is frequently called "spanish moss" because of its resemblance to the flowering plant called Spanish moss which drapes the trees of southeastern coastal regions in a similar fashion.

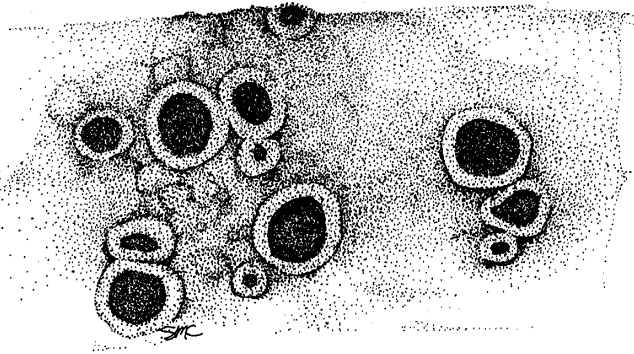
Rinodina marysvillensis H. Magn.

MARYSVILLE RINODINA Fig. 19



Rinodina archaea (Ach.) Arn.

OLD RINODINA Fig. 20



Two species of Rinodina: R. marysvillensis and R. archaea, occur commonly on twigs in our area. Because they are very similar in general appearance, they are shown on the same page.

General Appearance: (both species) Dark gray-brown to black patches which cannot be separated from the bark; the patches mostly 1 - 2 cm (3/8 - 3/4 in) or less across.

Thallus: (both species) Thallus crustose, dull blackish, dark gray or gray-brown when dry, similarly colored when wet; smooth or divided into irregular polygons.

Apothecia: (both species) Apothecia always present, disk-shaped with a thalline margin, minute, less than 1 mm across. (Use a hand lens)

Rinodina marysvillensis: Thalline margin whitish, distinct.

Rinodina archaeae: Thalline margin dark gray, often indistinct.

Soredia: (both species) Lacking.

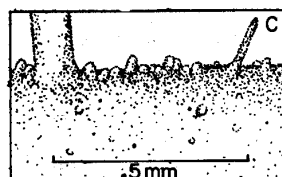
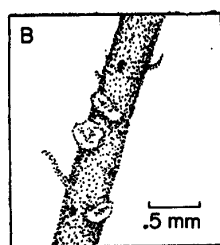
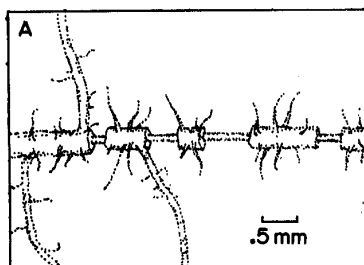
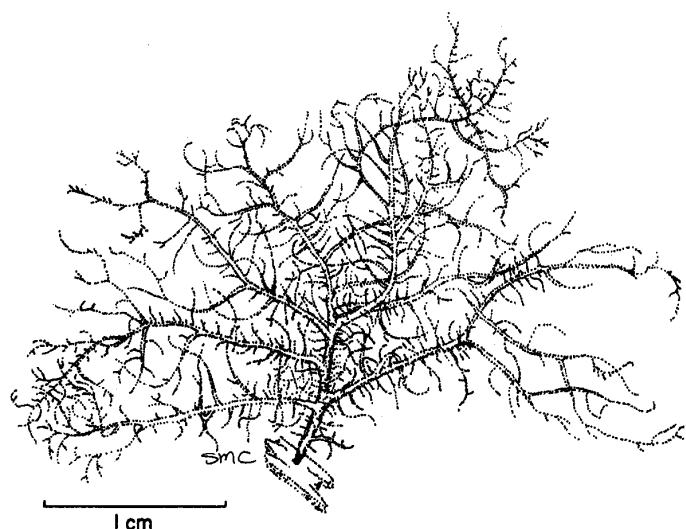
Isidia: (both species) Lacking.

Comments: Rinodina species resemble those of Lecanora species, but differ in having a blackish thallus.

Usnea subfloridana Stirt.

BUSHY CORD LICHEN

Fig. 21



General Appearance: Pale greenish-yellow tufts of slender, fuzzy, cylindrical branches. The tufts 1-10 cm (3/8-4 in) long; attached at a single point.

Thallus: Fruticose, composed of slender (up to 1 mm wide) cylindrical branches with numerous fine side branches. When stretched (Fig. A), the outer part of the thallus breaks into short segments strung on an elastic inner core. Exterior dull greenish-yellow, covered with minute warts. (Fig. C) (Use a hand lens). Attached to the bark by a black constricted base.

Apothecia: Rare.

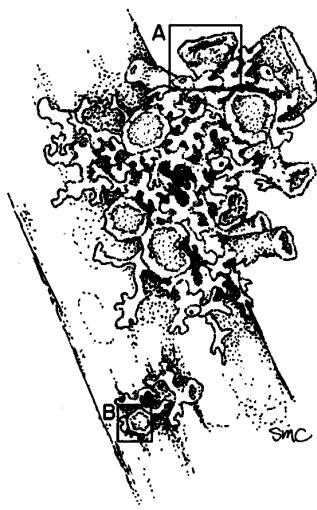
Soredia: Often present; formed in circular soralia on the major branches (Fig. B) (Use a hand lens).

Isidia: Present.

Comments: The cylindrical thallus with an elastic inner core and a black base distinguishes this species from other common fruticose lichens on twigs.

Xanthoria polycarpa (Ehrh.) Oliv.

GOLDEN XANTHORIA Fig. 22



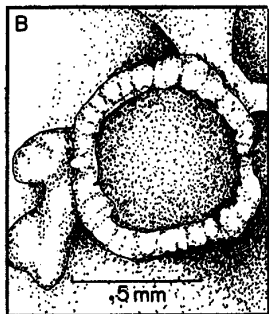
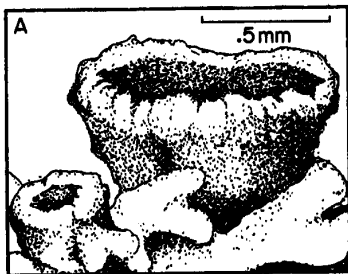
General Appearance: Small, rough, yellow to orange, cushion-like patches, up to 3 cm (1.25 in) across, but often smaller.

Thallus: Minutely foliose, composed of tiny, closely-packed, flattened, irregularly-lobed branches. (Use a hand lens!) The individual branches are 0.1-0.5 mm wide; mustard-yellow when dry, greenish-yellow when wet; similarly colored on both upper and lower sides; turn purple or purple-brown when wet with dilute (ca. 10% w/v) potassium hydroxide (lye).

Apothecia: (Fig. A & B) Disk-shaped or saucer-shaped; up to 3 mm (3/32 in) across; bright orange with a yellow margin when fresh, becoming orange-brown when dry; present on almost all older thalli.

Soredia: Lacking.

Isidia: Lacking.



Comments: The bright yellow to orange color distinguishes this species from most other lichens growing on oak or ash twigs in our area. Lepraria candelaris is similarly colored, but it is crustose and lacks apothecia. Xanthoria polycarpa will tolerate more pollution than most species. Thus, it is often found in suburban or lightly industrialized areas. In areas with cleaner air it may be crowded out by less tolerant species.

HOW TO USE THE GUIDE

EQUIPMENT

Before going out to select a site, you will need some equipment:

1. Hand lens or magnifier: A good lens which magnifies 8 to 20 times life size is essential for seeing the fine detail used in recognizing lichen species.
2. Map: A detailed map, preferably a U.S. Geological Survey map, is a necessity if you are going to report your findings.
3. Knife or pruning shears: If you plan to cut branches in order to examine them you will need a sharp knife, pruning shears, or a saw.
4. Compass: A compass may be needed to determine the direction of the sampling site from known sources of pollution or map reference points.
5. Tape or ruler: A tape measure may be used to measure the diameter of the tree.

SELECTING THE TREE

Find an oak or ash. The drawings on pages 3 and 5 will show you what they look like. If you cannot find an oak or ash, some other kinds of trees may do. Old apple trees (not in a sprayed orchard!) work very well. Alder trees and most conifers, including Douglas fir, have totally different lichens and therefore cannot be used with this GUIDE.

If possible, select a tree standing in the open or, if you can only find trees standing in groups, select one on the side of the group which faces the wind.

SELECTING BRANCHES

Select five branches well up in the tree. When in doubt, select those branches which seem to have the most lichens. Cut the branches down, bend them down, or climb up to them. In any event, you will need to be able to examine them very closely.

FINDING FIVE AND TEN-YEAR-OLD TWIGS

On each of five branches find a segment that is five years old and a segment that is ten years old. Do this by starting at the terminal bud

at the end of the branch and counting each year's growth back toward the trunk. (See drawing and explanation on page 7).

IDENTIFYING THE LICHENS

Compare the lichens you find on the twigs with the pictures and descriptions you find on pages 10 through 26 of this GUIDE. Start with the oldest twigs and the largest lichens. The drawings were made from mature specimens and show some features, such as apothecia, which are important for identification but which may not be present on young thalli. Once you have learned to recognize the mature form of a lichen you will find it easier to identify the young ones.

Note that in most cases the drawing is much larger than the lichen which it depicts and that the amount of enlargement differs from one drawing to the next. The amount of enlargement is indicated by a line with an accompanying measurement. (1 cm). If, for example, the measurement says "1 cm", but the line is actually five centimeters long, then the drawing is five times as large as the corresponding lichen.

WHICH FORM SHOULD YOU USE?

Two different data sheets are included in the GUIDE. The one labeled Air Quality Evaluation Form #2 is designed to make it as easy as possible for you to evaluate air quality in your neighborhood. The other one, which is labeled Air Quality Evaluation Form #1 and consists of two pages, is to be used if you wish to report your findings and have us include them in a master map of your area.

ESTIMATING LICHEN COVER

Once you have identified a lichen, you need a rough measure of its abundance. Examine the entire surface of each five-year-old or ten-year-old segment of twig and estimate how much of the total surface of each segment is covered by each species. If you use Form #2, record a zero ("0") if the lichen is absent or covers less than 5% of the total area; record a checkmark (✓) if it covers 5% to 25% of the surface; and record a plus (+) if it covers more than 25% of the surface. If you use Form #1, record a zero (0) if the lichen is absent; record a 5 if it is barely present or covers up to 5% of the surface; record a 25 if it covers 5% to 25%; record a 50 if it covers 25% to 50%; a 75 if it covers 50% to 75%; a 95 if it covers 75% to 95%; and a 100 if it covers 95% to 100% of the twig surface.

USING FORM #1

Form #1 consists of two sides. Side A is used to record the presence and abundance (% cover), or the absence, of each species of lichen. Side B is used to describe the locality where the lichens were found. If your sample is to be of use to others you must fill out both sides as completely as possible.

Side A:

Number the ten segments (five five-year-old segments and five ten-year-old segments) one through ten. Beginning with segment number one, record its age. Then record the percent cover of each of the lichens on the list. Use the code at the bottom of the Form. If you do not find a particular lichen, leave the space blank. Few segments will have more than five or six lichens. When you have finished recording the first segment, continue to the second, and so on through all ten segments.

Side B:

Fill in your name, address, and the date you collected the sample.

Location of Sample Site: Fill in as much of the information called for as possible. It is important to be able to locate the site accurately and since street names or place names are often changed, it is helpful to have more than one point of reference. Most of the information required is easily found and self-explanatory, but the most useful information, the Universal Transverse Mercator (UTM) coordinates, require explanation. The UTM coordinates of a site are given by two numbers: 1) the distance east of a line which runs north and south; and 2) the distance north of a line which runs east and west. Both distances are measured in kilometers (km). The coordinates are found in the following manner:

- 1) Obtain a 15 minute (15') USGS (U.S. Geological Survey) map of the area where you collected the lichens. Many bookstores and sporting goods stores have these maps and can help you find the one that includes your site.
- 2) Mark the exact location of the site on the map.
- 3) Find the UTM east value. These are printed in blue along the bottom edge of the map next to the blue tick marks. UTM values for the Willamette Valley range from 480000 to 558000. Because your site will probably fall between two of the tick marks, try to estimate its east value. For example, if your site is halfway between 497000 m and 498000 m, record 497.5 km (that is, 497500 m) as the east coordinate.

- 4) Find the UTM north value. These are printed in blue along the right edge of the map. Note that for the Willamette Valley, the north coordinates are about ten times larger than the east coordinates, because we are further north from the UTM reference point than we are east. A typical UTM north value for the Willamette Valley is 4673000, which you would record as 4673.0 km.
- 5) If you are uncertain whether you have recorded the UTM coordinates correctly, make a photocopy of the USGS map with your site clearly marked, and send it to us. Label the photocopy with the name of the map: for example, "Hillsboro Quadrangle."

Note that the UTM coordinates are not always printed on the map in exactly the same way. For example, they may be printed in black instead of blue, or may be found only beside selected tick marks. However, tick marks are always in blue and are always one kilometer (1 km) apart.

Description of Sample Site: Fill in as much information as possible. It is particularly important to identify the kind (species) of tree and tell whether it stands alone or with others. The height and diameter may be estimated. The altitude and slope are important because they influence the movement of wind at low elevations; that is, at the heights at which wind strikes a tree.

When you have completed both Side A and Side B of Form #1, mail it to: LICHEN TECHNOLOGY, INC. Box 369. Corvallis, Oregon 97330. A new, blank copy of Form #1 will be sent to you.

USING FORM #2

Instructions for using and interpreting Form #2 are printed on the form.

LICHEN TECHNOLOGY, INC. AIR QUALITY EVALUATION FORM #1
SIDE A

Twig number	1	2	3	4	5	6	7	8	9	10
Twig age										
<i>Evernia prunastri</i>										
<i>Hypogymnia physodes</i>										
<i>Hypogymnia tubulosa</i>										
<i>Lecanora carpinea</i>										
<i>Lecanora confusa</i>										
<i>Lecanora pacifica</i>										
<i>Lepraria candelaris</i>										
<i>Lepraria membranacea</i>										
<i>Lobaria pulmonaria</i>										
<i>Parmelia subaurifera</i>										
<i>Parmelia sulcata</i>										
<i>Physcia adscendens</i>										
<i>Physcia aipolia</i>										
<i>Platismatia glauca</i>										
<i>Ramalina farinacea</i>										
<i>Ramalina leptocarpha</i>										
<i>Ramalina menziesii</i>										
<i>Rinodina archaea</i>										
<i>Rinodina marysvillensis</i>										
<i>Usnea subfloridana</i>										
<i>Xanthoria polycarpa</i>										

Use the following code
to record % cover:

5 = barely present to 5%
25 = 5% to 25%
50 = 25% to 50%
75 = 50% to 75%
95 = 75% to 95%
100 = 95% to 100%

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Lichen Technology, Inc.
Box 369, Corvallis, Ore. 97330

Date

Person or group taking sample: Name

Address

I. Location of Sample Site: A. State B. County

C. UTM Military Grid Coordinates: East km North km

D. Urban Sites: street address

E. Rural Sites: 1. Nearest city or town: a. Name

b. Distance c. Direction

2. Nearest Road: a. Name

b. Distance c. Direction

F. Landmarks

.

G. Specific Directions

.

II. Description of Sample Site: A. Sample Tree:

1. Species of tree 2. Height of tree

3. Diameter of trunk 4.5 ft. above ground

4. Position (check one) ☐ a. standing alone ☐ b. at the edge of a woods☐ c. one of a small clump of trees in the open☐ d. in a line of trees along a road, stream, etc.☐ e. other (describe)

.

B. Land Use Pattern in Sample Area: (check one or more)

☐ 1. residential ☐ 2. industrial ☐ 3. agricultural ☐ 4. other

Describe area

.

C. Altitude: (check one) ☐ 1. 0 - 500 ft. ☐ 2. 500 - 1,000 ft.☐ 3. above 1,000 ft.D. Slope: 1. Degree: (check one) ☐ a. level (less than 10° from horizontal)☐ b. moderate (10° - 40°) ☐ c. steep (more than 40°)

2. Direction downslope from sample tree

LICHEN TECHNOLOGY, INC. AIR QUALITY EVALUATION FORM #1
SIDE A

Twig number	1	2	3	4	5	6	7	8	9	10
Twig age										
<i>Evernia prunastri</i>										
<i>Hypogymnia physodes</i>										
<i>Hypogymnia tubulosa</i>										
<i>Lecanora carpinea</i>										
<i>Lecanora confusa</i>										
<i>Lecanora pacifica</i>										
<i>Lepraria candelaris</i>										
<i>Lepraria membranacea</i>										
<i>Lobaria pulmonaria</i>										
<i>Parmelia subaurifera</i>										
<i>Parmelia sulcata</i>										
<i>Physcia adscendens</i>										
<i>Physcia aipolia</i>										
<i>Platismatia glauca</i>										
<i>Ramalina farinacea</i>										
<i>Ramalina leptocarpha</i>										
<i>Ramalina menziesii</i>										
<i>Rinodina archaea</i>										
<i>Rinodina marysvillensis</i>										
<i>Usnea subfloridana</i>										
<i>Xanthoria polycarpa</i>										

Use the following code
to record % cover:

5 = barely present to 5%
25 = 5% to 25%
50 = 25% to 50%
75 = 50% to 75%
95 = 75% to 95%
100 = 95% to 100%

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Date

Person or group taking sample: Name

Address

I. Location of Sample Site: A. State B. County

C. UTM Military Grid Coordinates: East km North km

D. Urban Sites: street address

E. Rural Sites: 1. Nearest city or town: a. Name

b. Distance c. Direction

2. Nearest Road: a. Name

b. Distance c. Direction

F. Landmarks

G. Specific Directions

II. Description of Sample Site: A. Sample Tree:

1. Species of tree 2. Height of tree

3. Diameter of trunk 4.5 ft. above ground

4. Position (check one) ☐ a. standing alone ☐ b. at the edge of a woods☐ c. one of a small clump of trees in the open☐ d. in a line of trees along a road, stream, etc.☐ e. other (describe)

B. Land Use Pattern in Sample Area: (check one or more)

☐ 1. residential ☐ 2. industrial ☐ 3. agricultural ☐ 4. other

Describe area

C. Altitude: (check one) ☐ 1. 0 - 500 ft. ☐ 2. 500 - 1,000 ft.☐ 3. above 1,000 ft.D. Slope: 1. Degree: (check one) ☐ a. level (less than 10° from horizontal)☐ b. moderate (10° - 40°) ☐ c. steep (more than 40°)

2. Direction downslope from sample tree

LICHEN TECHNOLOGY, INC. AIR QUALITY EVALUATION FORM #2

36

Lichen species	Record cover for five 5-year and five 10-year twigs										Is the lichen abundant?	If so, scale value is:
	1	2	3	4	5	6	7	8	9	10		
<i>Physcia aiopolia</i>												Class 4
<i>Lobaria pulmonaria</i>												Class 4
<i>Evernia prunastri</i>												Class 3
<i>Lepraria membranacea</i>												Class 3
<i>Usnea subfloridana</i>												Class 2
<i>Ramalina farinacea</i>												Class 2
<i>Parmelia subaurifera</i>												Class 2
<i>Parmelia sulcata</i>												Class 1
<i>Xanthoria polycarpa</i>												Class 1

- 1) Starting with the first lichen species, *Physcia aiopolia*, record the amount of each twig that the lichen covers, for ten twigs. Record a 0 for less than 5% cover, a ✓ for 5% to 25% cover, and a + for greater than 25% cover.
- 2) Decide whether the lichen is abundant. The lichen is considered abundant if it has either two checks or one plus.
- 3) If the lichen is abundant, read the scale value from the right hand column, and record it below. If it is not abundant, repeat steps one through three for the next lichen species. Continue until you find a lichen which is abundant. If none of the above lichens are abundant, record a scale value of "Class 0." If no lichens at all are present, the scale value is "Class 00."

The scale value for this site is Class

- Class 4 = very clean air
- Class 3 = typical rural air
- Class 2 = typical urban air
- Class 1 = polluted air
- Class 0 = more polluted air
- Class 00 = most polluted air

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LICHEN TECHNOLOGY, INC. AIR QUALITY EVALUATION FORM #2

Lichen species	Record cover for five 5-year and five 10-year twigs										Is the lichen abundant?	If so, scale value is:
	1	2	3	4	5	6	7	8	9	10		
<i>Physcia aipolia</i>												Class 4
<i>Lobaria pulmonaria</i>												Class 4
<i>Evernia prunastri</i>												Class 3
<i>Lepraria membranacea</i>												Class 3
<i>Usnea subfloridana</i>												Class 2
<i>Ramalina farinacea</i>												Class 2
<i>Parmelia subaurifera</i>												Class 2
<i>Parmelia sulcata</i>												Class 1
<i>Xanthoria polycarpa</i>												Class 1

- 1) Starting with the first lichen species, *Physcia aipolia*, record the amount of each twig that the lichen covers, for ten twigs. Record a 0 for less than 5% cover, a ✓ for 5% to 25% cover, and a + for greater than 25% cover.
- 2) Decide whether the lichen is abundant. The lichen is considered abundant if it has either two checks or one plus.
- 3) If the lichen is abundant, read the scale value from the right hand column, and record it below. If it is not abundant, repeat steps one through three for the next lichen species. Continue until you find a lichen which is abundant. If none of the above lichens are abundant, record a scale value of "Class 0." If no lichens at all are present, the scale value is "Class 00."

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Class 4 = very clean air
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 Class 00 = most polluted air

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GLOSSARY

Apothecium (pl. apothecia) a spore producing organ which is open and more or less concave or convex; may be disk-like, saucer-shaped, or irregular. see Fig. 22(A & B), p. 26.

Crustose a lichen growth form; thalli crust-like, growing in direct contact or buried within the substrate; lacking a lower surface layer and rhizines. see Fig. 9, p. 14.

Foliose a lichen growth form; thalli leaf-like, flattened, with both an upper and a lower surface; usually attached to the twig by rhizines which grow from the lower surface. see Figs. 10 & 12, pp. 15 & 17.

Fruticose a lichen growth form; thalli shrubby or hairy; standing upright from the twig or dangling from it; usually attached at a single point. see Figs. 17 & 18, pp. 22 & 23.

Hyphae the thread-like elements of a fungal body.

Isidium (pl. isidia) fragile, finger-like or irregular outgrowths from the surface of the thallus. The isidia break easily and their fragments can produce a new lichen. see Fig. 11B, p. 16.

Rhizines strands of hyphae extending from the lower surface of a thallus; found on many foliose lichens. see Fig. 11A, p. 16.

Soralium (pl. soralia) a group of soredia on the surface or margins of the thallus; conspicuous clumps of soredia occurring in definite patterns on the thallus. see Fig. 7(A & B), p. 12; Fig. 10B, p. 15.

Soredium (pl. soredia) erupt from the surface of the thallus in patches, mounds, or piles called soralia. Individual soredia are so small that they are almost invisible even with a hand lens, but in groups they give the surface of the soralia a powdery appearance. see Fig. 15A, p. 20; Fig. 16A, p. 21.

Substrate the surface on which the lichen grows. In the case of the lichens in this guide, normally the substrate is the surface of a twig.

Thalline margin a rim around an apothecium which contains algae and which resembles the surrounding thallus in color and texture. A thalline margin usually differs in color from the disk of the apothecium. see Fig. 14(A & B), p. 19.

Thallus (pl. thalli) the plant body of a lichen.

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air quality map.....	9
ash, Oregon.....	5
bushy cord lichen.....	25
<u>Evernia prunastri</u>	4, 10
fishnet lichen.....	23
<u>Fraxinus latifolia</u>	5
golden Xanthoria.....	26
hair-tipped Physcia.....	18
hoary Physcia.....	19
<u>Hypogymnia physodes</u>	11, 12
<u>Hypogymnia tubulosa</u>	12
inflated Hypogymnia.....	11
<u>Lecanora carpinea</u>	13, 24
<u>Lecanora confusa</u>	13, 24
<u>Lecanora pacifica</u>	13, 24
<u>Lepraria candelaris</u>	14, 26
<u>Lepraria membranacea</u>	4, 13, 14
<u>Lobaria pulmonaria</u>	4, 10, 15
lungwort.....	15
marysville Rinodina.....	24
mealy Ramalina.....	21
moose antler Ramalina.....	22
mosses.....	1
net-marked Parmelia.....	17
Nylander, William.....	2
oak, Oregon white.....	3
old Rinodina.....	24
papery bronze Parmelia.....	16
<u>Parmelia subaurifera</u>	4, 16
<u>Parmelia sulcata</u>	4, 17
<u>Physcia adscendens</u>	18
<u>Physcia aiopolia</u>	4, 19
<u>Platismatia glauca</u>	20
powdery paint lichen.....	14
<u>Quercus garryana</u>	3
ragged Platismatia.....	20
<u>Ramalina farinacea</u>	4, 21, 22
<u>Ramalina leptocarpha</u>	21, 22
<u>Ramalina menziesii</u>	23
<u>Rinodina archaea</u>	13, 24
<u>Rinodina marysvillensis</u>	13, 24
Spanish moss.....	23
tick marks.....	29, 30
tubular Hypogymnia.....	12
<u>Usnea subfloridana</u>	4, 25
UTM coordinates.....	29, 30
<u>Xanthoria polycarpa</u>	4, 26
wrinkled Evernia.....	10