

SPECIAL REPORT

9

THE LICHENS OF BRITISH COLUMBIA

Illustrated Keys

Part 2 — Fruticose Species

by Trevor Goward

1999

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(Illustrations by Trevor Goward)



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INTRODUCTION

Our knowledge of lichen floristics in British Columbia has advanced rapidly in recent years. Only three decades ago, the known British Columbia lichen flora stood at 569 species (Otto and Ahti 1967). Today, by contrast, it stands at approximately 1300 species (Noble et al. 1987; Goward, unpublished). Notwithstanding this impressive figure, a comprehensive inventory of the province's lichen flora is still a long way off. In support of this claim, consider that more than 20 lichen species, on average, are added to the provincial lichen flora each year!

A significant number of lichen species warrant formal designation as "rare" or "infrequent" in British Columbia. To date, four such species carry official endangerment status in Canada (Goward et al. 1998), while one species appears on the International Union for Conservation

of Nature and Natural Resources (IUCN) "global redlist of lichens" (Thor 1996: www.dha.slu.se/guest/global.htm). Several other species may already be at risk of extirpation in the province (Goward 1996). Reflecting these concerns, the British Columbia Conservation Data Centre has recently initiated a preliminary tracking list of the province's "red-listed" and "blue-listed" lichens.

Few portions of the province have received serious attention from lichenologists. To date, comprehensive lichen studies have been carried out only on southeast Vancouver Island (Noble 1982) and the Queen Charlotte Islands (Brodo 1995; Brodo and Ahti 1996; Brodo and Santesson 1997; Brodo and Wirth 1998). The lichen flora of Wells Gray Park is also relatively well documented (Goward and Ahti 1992; Goward, unpublished).

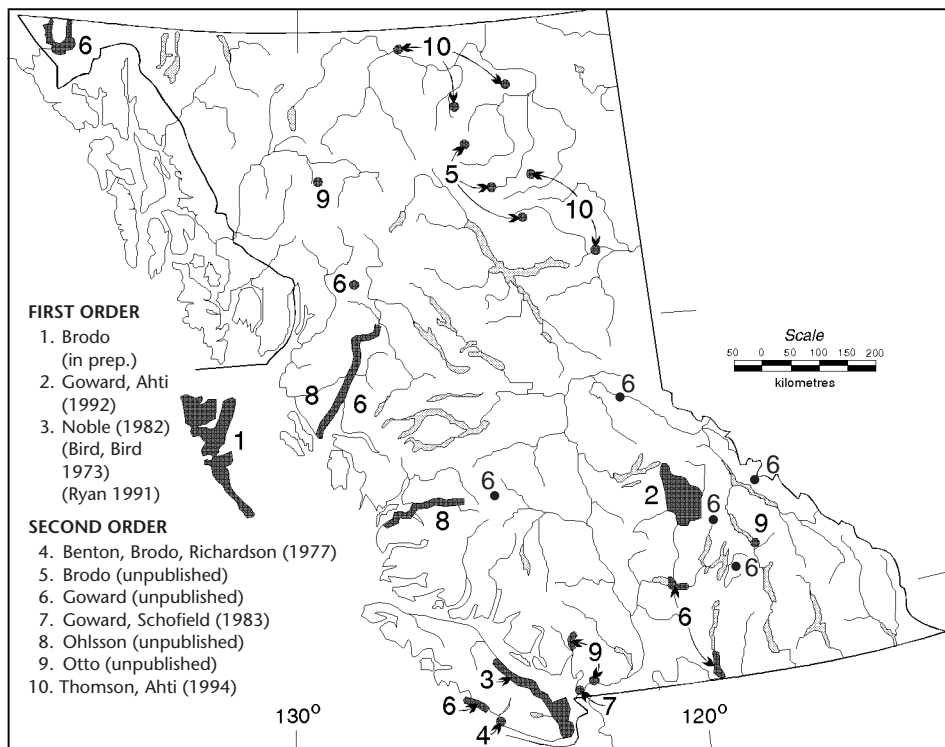


FIGURE 1 First- and second-order lichen floristic studies in British Columbia to 1998.

Important collections from other regions do exist (Figure 1), but have not been published, and are widely scattered.

Lichen study in British Columbia has traditionally been hampered by a lack of comprehensive keys to the species. Recently, however, Goward et al. (1994) published illustrated keys to 327 species of foliose and squamulose lichens. The present manual is a companion volume to that work; it provides illustrated keys to 309 species of fruticose lichens (and allied fungi) that are known from or expected to occur in British Columbia.

This manual adopts a broad interpretation of the fruticose life form. Included here are all lichen genera—both macrolichens and microlichens—in which a majority of species bear stalks or branches that are roughly circular in cross-section. Although fruticose microlichens are traditionally regarded as crustose, they are included here owing to their dominant stalked sexual or asexual reproductive structures. Examples of fruticose microlichens include *Calicium*, *Chaenotheca*, *Gyalideopsis*, and *Microlychnus*.

Two primary objectives have guided the preparation of this manual:

1. to briefly summarize the ecology, distribution, and frequency status of all fruticose lichens known to occur in British Columbia.
2. to stimulate lichenological research by making these lichens accessible to a broad audience.

In keeping with the presumed needs and resources of ecologists, biologists, naturalists, teachers, and other beginning students of lichens, this manual emphasizes morphological characters over chemical and spore characters; it also avoids technical terms as far as possible.¹ It must be acknowledged, however, that some species cannot be reliably identified without recourse to thin-layer chromatography or

examination under a light microscope; fortunately, most such species are small and inconspicuous, and are unlikely to be encountered by the beginner.

The genus and species concepts adopted here are often pragmatic. As a rule, they give priority to “intuitive” morphological groupings that do not always accord with the latest findings of anatomical and molecular research. This approach proceeds from the assumption that laboratory research will continue to uncover evolutionary relationships not readily perceived in the field. Looking ahead, two parallel approaches to lichen taxonomy can be expected to evolve: one that emphasizes taxonomic stability, and is suited to the requirements of lichen floristics and field ecology; and one that emphasizes phylogenetic relatedness, and is suited to continuing molecular, chemical, and ultrastructural studies. Although this manual follows the first of these approaches, alternative genus and species concepts are given in the synonymy under the accepted species.

Accompanying the keys are 320 line drawings intended to convey species concepts based on typical material. The drawings emphasize specific characters expressed in the adjacent key, and are not intended to depict the entire lichen. Illustrations of whole lichens can be found in various popular and semi-popular references, including Hale (1979), Kershaw et al. (1998), McCune and Geiser (1997), McCune and Goward (1995), MacKinnon et al. (1992), Parish et al. (1996), Pojar and MacKinnon (1994), Thomson (1984, 1997), and Vitt et al. (1988).

It is beyond the scope of this manual to provide a comprehensive summary of lichen biology (see instead: Hale 1983; Hawksworth and Hill 1984; Lawrey 1984; Nash 1996). Effective identification does, however, require a basic understanding of lichen morphology and chemistry.

¹ Technical terms are discussed in “Identifying Lichens” (page 10) and appear there in bold type. Additional terms are defined in the keys, as well as in the Glossary (page 295).

Interpreting the Genus and Species Accounts

Accordingly, the reader is invited to consult “Identifying Lichens” (page 10) prior to using the keys.

This manual represents a first attempt to provide comprehensive keys to the fruticose lichens of British Columbia. Though

For convenience, lichens can be arranged in several different growth forms, including crustose, squamulose, foliose, and fruticose (see “Identifying Lichens,” page 10). Because, however, these growth forms are units of convenience, not biology, they do not always offer a perfect “fit” with the genera they are supposed to circumscribe. For example, while all species of *Bryoria* are fruticose, the genus *Cladonia* contains both squamulose species and fruticose species. For convenience, this manual incorporates all lichen genera known to occur in British Columbia in which a majority of species can be described as fruticose. In a few instances, fruticose species belonging to essentially nonfruticose genera are also included (in parentheses) in the keys, but are not discussed in the species accounts. Species appearing in square brackets [...] are expected to occur in British Columbia, but have yet to be reliably recorded.

The body of the manual is arranged alphabetically, first by genus and then by species within each genus.

The genus accounts include:

1. the scientific name,
2. a common name,
3. a short description of the genus, with diagnostic characters placed in bold italic type,
4. pertinent references,
5. the derivation of the common name,
6. notes on global status, distribution, taxonomy, chemistry, and points of distinction with similar genera.

The species accounts are more complex, and are organized under the following headings:

every effort has been made to make the keys as usable as possible, numerous errors and oversights doubtless remain. The reader is invited to bring these to the author’s attention for the benefit of future students of British Columbia’s lichens.²

Species and Author Citation: Except in cases of recent taxonomic or nomenclatural revision, species names and author citations follow Esslinger and Egan (1995).

Synonyms: As a rule, only synonyms in recent or widespread use are given.

Distribution Maps: The map number appearing to the right of some species is keyed to Appendix 1, in which distribution maps are provided for species judged to be rare or infrequent in the province.

Common Names: Common names are adopted, adapted, or introduced for all lichen species included in this manual. Alternative common names are given in parentheses (...). See also “A Note on Common Names,” page 21.

Habitat/Range: Information is provided on lichen frequency status, common substrates, site characteristics, provincial “life zone” distribution, distribution in the northern hemisphere, and cordilleran distribution.

1. **Frequency status** is given using the following terms: rare, infrequent, frequent, common.
2. **Substrates** include acid/base-rich/mossy/seasonally inundated rock, coniferous/deciduous trees or shrubs, and soil, moss, duff, bark, or wood.
3. **Site characteristics** are expressed as: exposed/open/ sheltered/shady/old-growth forests, steppe, depressions, or outcrops, at lower/middle/upper/alpine elevations.
4. **Provincial “life zone” distributions** are given according to the terms listed in columns I and II of Table 1; see also Figure 2. Biogeoclimatic units (column III of Table 1) are occasionally used,

² Please direct comments to Trevor Goward, Edgewood Blue, Box 131, Clearwater, BC V0E 1N0.

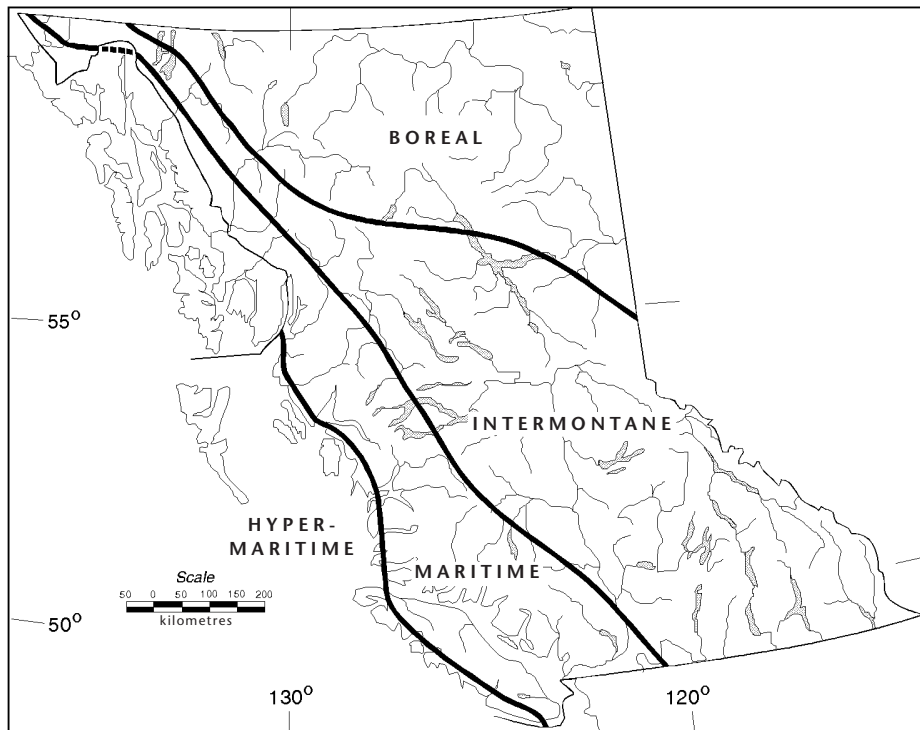


FIGURE 2 "Life zones" of British Columbia.

TABLE 1 *Distributional units and their definition*

General Range (I)	Life Zone (II)	Biogeoclimatic Equivalent ^a (III)	Conrad's Index of Continentality (IV)
COAST	Hypermaritime	CWH wh and vh ^b	< 8
	Maritime		9 - 29
	-dry	CDF	
	-wet	CWH (not wh and vh)	
INLAND	-subalpine	MH	
	Intermontane		30 - 39
	-semi-arid	BG, PP	
	-dry (lowland)	IDF	
	-dry (upland)	SBPS	
	-moist (lowland)	SBS	
	-moist (upland)	MS	
	-humid (lowland)	ICH	
SUBALPINE	-subalpine	ESSF	
	Boreal	BWBS, SWB	> 40
ALPINE	Throughout	MH, ESSF	various
WIDESPREAD	Throughout	AT	various
	Throughout	"throughout"	various

a See Table 2 or the Glossary for definitions of these biogeoclimatic zone codes.

b Only the Wet Hypermaritime (wh) and Very Wet Hypermaritime (vh) subzones of the Coastal Western Hemlock Zone (CWH) are included here.

and are mapped in Figure 3; see also “Understanding Biogeoclimatic Zonation” (below). The continentality units in column IV are based on Conrad’s Index of Continentality (Conrad 1946), and are included to enable ecoclimatic comparisons with other regions of the world (for further details, see Goward and Ahti 1992).

5. *Distribution in the northern hemisphere* is expressed relative to western North America. The following distributional units are used:

- western N Am
- western N Am - eastern N Am
- western N Am - western Eurasia
- western N Am - eastern Eurasia
- incompletely circumpolar (= any three of the above distributional units)
- circumpolar

6. *Cordilleran distribution* is summarized using the following geographic units: N to sAK (Alaska: Pacific coast only), AK (Alaska: boreal and arctic regions only), YU (Yukon), or wNT (Northwest Territories: west of the Mackenzie River only); and S to AZ (Arizona), CA (California), CO (Colorado), ID (Idaho), MT (Montana), MX (Mexico), NM (New Mexico), NV (Nevada), OR (Oregon),

UT (Utah), WA (Washington), or WY (Wyoming); and AB (Alberta). While most state records appearing in this manual are based on published reports, a few unpublished records are also given; these appear in parentheses.

Reactions: In most cases, only positive reactions are given, based on commonly used chemical reagents and ultraviolet light; negative reactions are generally omitted. For further details see “Making Use of Lichen Chemistry,” page 20.

Contents: In most cases, only dominant lichen substances are listed. Substances given in parentheses are “accessory,” that is, they do not occur in all specimens.

Variability: Some lichen species vary greatly with habitat, whereas others are more uniform. To assist in identification, each species has been assigned a variability rating of “low,” “medium,” or “high.” Species rated as “high” do not necessarily conform with all characters given in the keys.

Notes: Included here are comments on taxonomic problems, points of distinction with similar species, chemistry, and keys to subspecies and varieties. In general, detailed notes are reserved for taxonomically difficult genera.

Understanding Biogeoclimatic Zonation

British Columbia is a highly diverse province in which hundreds of ecosystems can be recognized. Maintaining these in the face of increasing pressure for resource development represents an enormous challenge—and involves, as a first step, classifying the province’s ecosystems in detail.

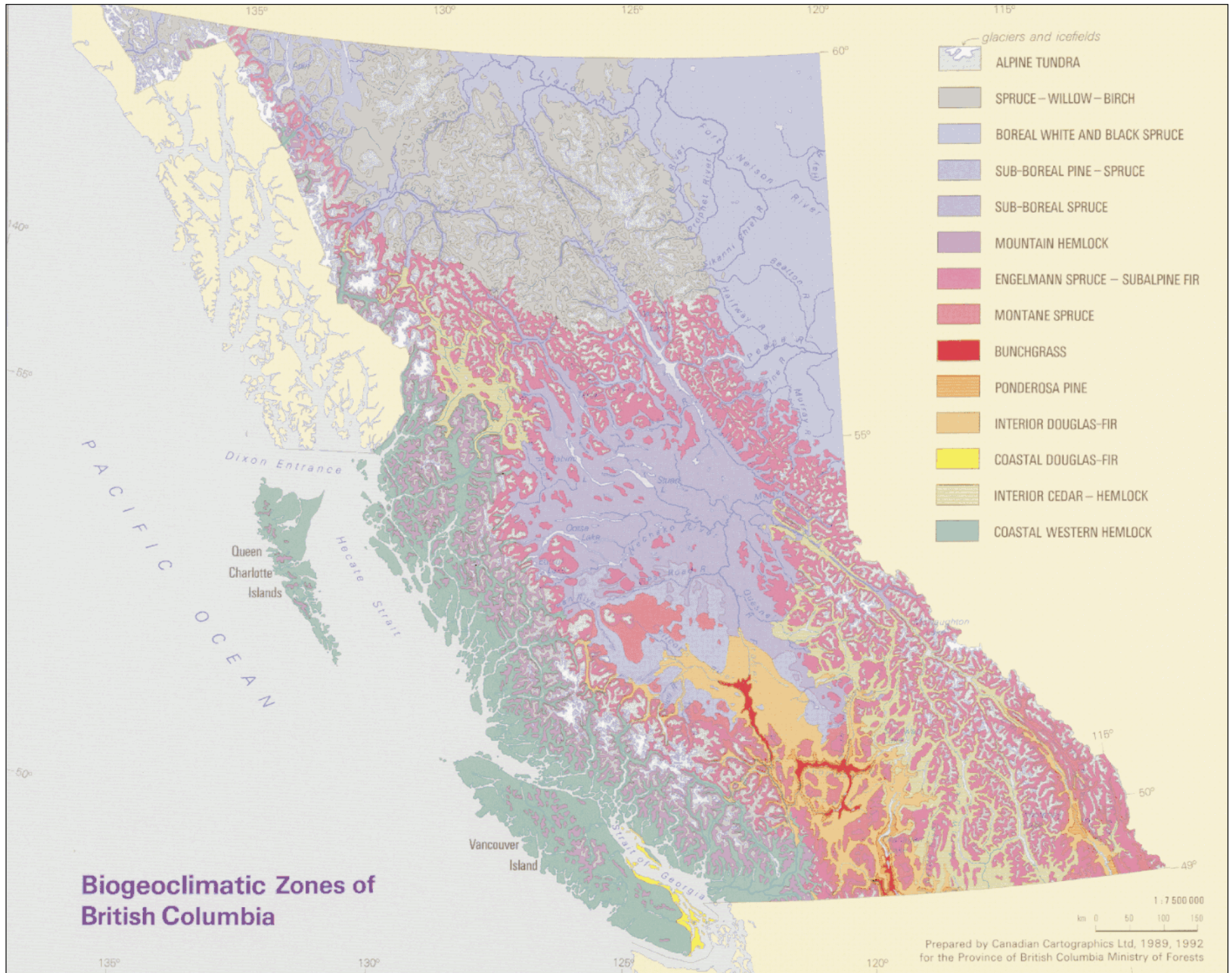
In recent years, researchers with the B.C. Ministry of Forests have described medium-scale ecosystems according to the principles of biogeoclimatic ecosystem classification (Pojar et al. 1987). They have also arranged these ecosystems into a hierarchical system of biogeoclimatic zones, subzones, and variants.

Collectively, the zones, subzones, and

variants of the biogeoclimatic system are referred to as biogeoclimatic units. Each unit is characterized by a unique set of climatic variables, and supports—and is for practical purposes defined by—a unique vegetation. In biogeoclimatic ecosystem classification, the defining vegetation for each unit occurs on moderately well-drained sites. Such sites are said to be “zonal.”

The most encompassing of the biogeoclimatic units is the biogeoclimatic zone. Fourteen biogeoclimatic zones are recognized for British Columbia and many of these are used here to describe lichen distribution. They are briefly characterized in Table 2 and mapped in Figure 3. For a

FIGURE 3 Biogeoclimatic zones of British Columbia.



more detailed summary, see *Ecosystems of British Columbia* (Meidinger and Pojar 1991).

Lichen distribution may also be expressed using more generalized classification systems such as the “life zone system” (see Figure 2) and “general range system” adopted here. These systems are compared with their biogeoclimatic counterparts in Table 1. The comparison is

made mostly at the zonal level, though two biogeoclimatic subzones have also been used: the Wet Hypermaritime (wh) and Very Wet Hypermaritime (vh) subzones of the Coastal Western Hemlock Zone (CWH). These subzones occur in the hypermaritime or outer coastal areas of British Columbia (see Figure 2). See Table 2 for the full names of other biogeoclimatic zones.

TABLE 2 Summary information on the biogeoclimatic zones of British Columbia (Source: Lavender et al. 1990)

Zone	Code	Zonal vegetation	Zonal soils	Selected climatic characteristics ^a				
				Monthly temp. range	°days >5°C	°days <0°C	May–Sept. ppt (mm)	Oct.–April ppt (mm)
Alpine Tundra	AT	<i>Cassiope</i> spp., <i>Phyllodoce</i> spp., <i>Luetkea pectinata</i> , <i>Loiseleuria procumbens</i> , <i>Dryas</i> spp., <i>Salix</i> spp., <i>Silene acaulis</i> , <i>Poa</i> spp., <i>Festuca</i> spp., <i>Carex</i> spp., <i>Cetraria</i> spp., <i>Stereocaulon</i> spp., <i>Polytrichum piliferum</i>	Regosols, Humic Regosols, Brunisols, Humo-Ferric Podzols	-11.1–9.5	427	1763	287	469
Boreal White and Black Spruce	BWBS	White spruce, lodgepole pine, black spruce, <i>Rosa acicularis</i> , <i>Viburnum edule</i> , <i>Mertensia paniculata</i> , <i>Pyrola asarifolia</i> , <i>Cornus canadensis</i> , <i>Vaccinium vitis-idaea</i> , <i>Ptilium crista-castrensis</i> , <i>Pleurozium schreberi</i>	Gray Luvisols, Dystric and Eutric Brunisols	-24.5–16.6	709–1268	1692–2742	145–305	182–198
Bunch-grass	BG	<i>Agropyron spicatum</i> , <i>Artemisia tridentata</i> , <i>Artemisia frigida</i> , <i>Poa sandbergii</i> , <i>Koeleria macrantha</i> , <i>Festuca scabrella</i> , <i>Festuca idahoensis</i> , <i>Chrysothamnus nauseosus</i>	Brown and Dark Brown Chernozems	-10.8–22.4	1771–2516	230–878	98–175	108–208
Coastal Douglas-fir	CDF	Douglas-fir, grand fir, bigleaf maple, western flowering dogwood, <i>Holodiscus discolor</i> , <i>Gaultheria shallon</i> , <i>Mahonia nervosa</i> , <i>Rosa gymnocarpa</i> , <i>Symphoricarpos albus</i> , <i>Trientalis latifolia</i> , <i>Rubus ursinus</i> , <i>Pteridium aquilinum</i> , <i>Kindbergia oregana</i> , <i>Rhytidia-delphus triquetrus</i>	Dystric Brunisols	1.8–18.0	1794–2121	9–43	107–238	540–1107

TABLE 2 Continued

Zone	Code	Zonal vegetation	Zonal soils	Selected climatic characteristics ^a				
				Monthly temp. range	°days >5°C	°days <0°C	May–Sept. ppt (mm)	Oct.–April ppt (mm)
Coastal Western Hemlock	CWH	Western hemlock, amabilis fir, Sitka spruce, yellow-cedar, <i>Vaccinium alaskaense</i> , <i>Vaccinium parvifolium</i> , <i>Menziesia ferruginea</i> , <i>Gaultheria shallon</i> , <i>Polystichum munitum</i> , <i>Pteridium aquilinum</i> , <i>Blechnum spicant</i> , <i>Clintonia uniflora</i> , <i>Rhytidiadelphus loreus</i> , <i>Hylocomium splendens</i>	Ferro-Humic and Humo-Ferric Podzols	-6.6–18.7	1059–2205	5–493	159–1162	695–3225
Engelmann Spruce–Subalpine Fir	ESSF	Subalpine fir, Engelmann spruce, <i>Rhododendron albiflorum</i> , <i>Menziesia ferruginea</i> , <i>Vaccinium (membranaceum, ovalifolium, scoparium)</i> , <i>Rubus pedatus</i> , <i>Gymnocarpium dryopteris</i> , <i>Tiarella unifoliata</i> , <i>Valeriana sitchensis</i> , <i>Orthilia secunda</i> , <i>Streptopus roseus</i> , <i>Veratrum viride</i> , <i>Barbilophozia lycopodioides</i> , <i>Pleurozium schreberi</i> , <i>Rhytidiopsis robusta</i>	Humo-Ferric Podzols	-10.9–13.3	629–801	879–1189	205–425	271–1597
Interior Cedar–Hemlock	ICH	Western hemlock, western red-cedar, hybrid white spruce, Douglas-fir, subalpine fir, <i>Vaccinium ovalifolium</i> , <i>Oplopanax horridus</i> , <i>Vaccinium membranaceum</i> , <i>Rubus parviflorous</i> , <i>Paxistima myrsinites</i> , <i>Smilacina racemosa</i> , <i>Streptopus (amplexifolius, roseus)</i> , <i>Chimaphila umbellata</i> , <i>Goodyera oblongifolia</i> , <i>Gymnocarpium dryopteris</i> , <i>Ptilium crista-castrensis</i> , <i>Pleurozium schreberi</i> , <i>Hylocomium splendens</i> , <i>Rhytidiadelphus triquetrus</i>	Humo-Ferric Podzols, Gray Luvisols, and Dystric Brunisols	-10.7–20.8	1267–2140	238–820	200–439	294–1098
Interior Douglas-fir	IDF	Douglas-fir, lodgepole pine, ponderosa pine, <i>Spiraea betulifolia</i> , <i>Amelanchier alnifolia</i> , <i>Juniperus communis</i> , <i>Symphoricarpos albus</i> , <i>Mahonia aquifolium</i> , <i>Paxistima myrsinites</i> , <i>Calamagrostis rubescens</i> , <i>Arctostaphylos uva-ursi</i> , <i>Agropyron spicatum</i> , <i>Pleurozium schreberi</i>	Gray Luvisols, Eutric and Dystric Brunisols	-13.1–21.3	903–2366	235–1260	107–291	149–1022

TABLE 2 Continued

Zone	Code	Zonal vegetation	Zonal soils	Selected climatic characteristics ^a				
				Monthly temp. range	°days >5°C	°days <0°C	May–Sept. ppt (mm)	Oct.–April ppt (mm)
Montane Spruce	MS	Hybrid white spruce, sub-alpine fir, lodgepole pine, Douglas-fir, <i>Vaccinium scoparium</i> , <i>Lonicera utahensis</i> , <i>Shepherdia canadensis</i> , <i>Paxistima myrsinites</i> , <i>Vaccinium membranaceum</i> , <i>Alnus viridis</i> , <i>Linnaea borealis</i> , <i>Empetrum nigrum</i> , <i>Calamagrostis rubescens</i> , <i>Pleurozium schreberi</i>	Dystric Brunisols and Humo-Ferric Podzols	-12.5–17.4	891–1310	847–890	158–252	223–469
Mountain Hemlock	MH	Mountain hemlock, amabilis fir, yellow-cedar, <i>Vaccinium (ovalifolium, membranaceum, alaskaense)</i> , <i>Menziesia ferruginea</i> , <i>Rhododendron albiflorum</i> , <i>Rubus pedatus</i> , <i>Phyllodoce empetriformis</i> , <i>Rhytidiopsis robusta</i> , <i>Rhytidiadelphus loreus</i> , <i>Hylocomium splendens</i>	Ferro-Humic Podzols and Folisols	-2.3–13.2	919–933	307–352	694–707	1857–2260
Ponderosa Pine	PP	Ponderosa pine, <i>Agropyron spicatum</i> , <i>Balsamorhiza sagittata</i> , <i>Festuca (saximontana, idahoensis)</i> , <i>Koeleria macrantha</i> , <i>Lithospermum ruderale</i> , <i>Achillea millefolium</i>	Eutric and Dystric Brunisols	-8.6–21.6	1505–2442	258–861	86–270	170–334
Spruce–Willow–Birch	SWB	White spruce, subalpine fir, <i>Salix glauca</i> , <i>Betula glandulosa</i> , <i>Potentilla fruticosa</i> , <i>Shepherdia canadensis</i> , <i>Festuca altaica</i> , <i>Lupinus arcticus</i> , <i>Pedicularis labradorica</i> , <i>Epilobium angustifolium</i> , <i>Empetrum nigrum</i> , <i>Vaccinium (vitis-idaea, caespitosum)</i> , <i>Hylocomium splendens</i> , <i>Cladina</i> spp., <i>Nephroma arcticum</i>	Eutric or Dystric Brunisols, Humo-Ferric Podzols	-19.2–14.0	534–933	2036–2298	275–280	179–424
Sub-Boreal Pine–Spruce	SBPS	Lodgepole pine, white spruce, <i>Shepherdia canadensis</i> , <i>Spiraea betulifolia</i> , <i>Rosa acicularis</i> , <i>Calamagrostis rubescens</i> , <i>Arctostaphylos uva-ursi</i> , <i>Vaccinium caespitosum</i> , <i>Linnaea borealis</i> , <i>Pleurozium schreberi</i> , <i>Peltigera</i> spp., <i>Cladina</i> spp.	Gray Luvisols and Dystric Brunisols	-13.8–14.3	697–1044	1140–1405	243–300	218–222

TABLE 2 *Concluded*

Zone	Code	Zonal vegetation	Zonal soils	Selected climatic characteristics ^a				
				Monthly temp. range	°days >5°C	°days <0°C	May–Sept. ppt (mm)	Oct.–April ppt (mm)
Sub-Boreal Spruce	SBS	Hybrid white spruce, sub-alpine fir, lodgepole pine, <i>Vaccinium membranaceum</i> , <i>Rubus parviflorus</i> , <i>Viburnum edule</i> , <i>Lonicera involucrata</i> , <i>Spiraea betulifolia</i> , <i>Rosa acicularis</i> , <i>Aralia nudicaulis</i> , <i>Cornus canadensis</i> , <i>Linnaea borealis</i> , <i>Arnica cordifolia</i> , <i>Clintonia uniflora</i> , <i>Aster conspicuus</i> , <i>Osmorhiza chilensis</i> , <i>Oryzopsis asperifolia</i> , <i>Smilacina racemosa</i> , <i>Gymnocarpium dryopteris</i> , <i>Pleurozium schreberi</i> , <i>Ptilium crista-castrensis</i> , <i>Hylocomium splendens</i> , <i>Dicranum polysetum</i> , <i>Rhytidiadelphus triquetrus</i> , <i>Peltigera</i> spp.	Gray Luvisols and Dystric Brunisols, Humo-Ferric Podzols	-14.6–16.9	884–1510	792–1369	189–353	250–1383

a Selected climatic characteristics summarized from Atmospheric Environment Service (AES) long-term stations. Prepared by D. Meidinger.

Identifying Lichens

The vast majority of lichens are classified as *Ascomycetes* (cup fungi), and hence are related to morels and elf saddles. While most fungi, however, draw their nourishment from sources external to themselves (e.g., decaying leaves or logs), lichen fungi “cultivate” their foodstuff among the fungal threads of which they themselves are composed. This foodstuff consists of tiny, photosynthesizing algal or cyanobacterial cells, or both. Lichens can therefore be viewed as living greenhouses supported largely by carbohydrates derived from the photosynthetic “crops” growing within them. This in part accounts for the exposed lifestyle adopted by most lichens: whereas a majority of fungi pass their lives (except when fruiting) within the things they feed on, lichens colonize the surfaces of rocks, trees, logs, duff, and soil.

When a fungus enters into a stable, enduring relationship with a microscopic alga or cyanobacterium, both partners are said to be **lichenized**. In general appearance, most lichenized fungi, algae, and cyanobacteria do not closely resemble

their **unlichenized** relatives. Rather, they form a composite “plant,” or **thallus** (Figures 4–5). Under the microscope, a typical lichen thallus resembles a kind of sandwich in which the fungal partner (**mycobiont**) and the “algal” partner (**photobiont**) are **stratified** in distinct layers (Figure 4). In many conspicuous lichen species, four such layers can be discerned: a protective rind or **upper cortex** (Figure 4a); an “algal” or **photobiont layer** (Figure 4b); a pale, usually whitish region of loosely interwoven fungal threads, called the **medulla** (Figure 4c); and another protective covering or **lower cortex** (Figure 4d).

As already mentioned, the photobionts in nearly all lichens consist of **green algae** or **cyanobacteria**. When exposed by a razor blade and viewed under a dissecting microscope, most algae are easily recognized by their characteristic single-celled habit, as well as by their bright grass-green colour (but yellowish green in *Trentepohlia*). Cyanobacteria are much more variable in form—single-celled, cluster-

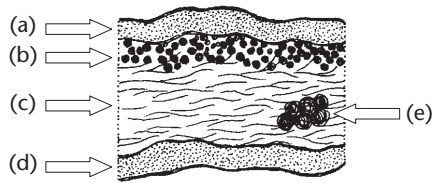


FIGURE 4 *Thallus stratified/heteromerous* (cross-section): (a) upper cortex; (b) algal or cyanobacterial layer / photobiont layer; (c) medulla; (d) lower cortex; and (e) a cephalodium.

celled, or strandlike—but they are never grass-green, although at least one genus can be yellowish green. In some species dominated by a green algal photobiont, cyanobacteria are also present as scattered, localized colonies called **cephalodia** (Figure 4e). These can occur internally or over the upper or lower surface (Figures 10d, 11l).

In some groups having a cyanobacterial photobiont, the photobiont cells are intermingled throughout with fungal threads, and the thallus is uniformly dark both inside and out. Such lichens are said to be **nonstratified** (Figure 5); viewed from the outside, they are typically brownish, blackish, or bluish grey. They can assume a **gelatinous** consistency when wet, and are then popularly referred to as “gel lichens.” Most nonstratified lichens lack a cortex (Figure 5a), though a primitive cellular cortex is present in *Leptogium* and

Polychidium (Figure 5b). Strandlike **rhizoids** (Figure 5c) can also occur in some cyanobacterial species.

Many different groups of algae and cyanobacteria have entered into association with lichen fungi. Common cyanobacterial groups include the Chroococcales (Figure 6a), *Nostoc* (Figure 6b), the Rivulariaceae (Figure 6c), *Scytonema* (Figure 6d), and *Stigonema* (Figure 6e). The most common algal groups include *Stichococcus* (Figure 6f), *Trebouxia* and related genera (Figure 6g), and *Trentepohlia* (Figure 6h). For keys to these and other photobiont genera, see page 23.

Specialized **holdfasts**, or **rhizines** (Figure 7a–e), occur in many species having a lower cortex. Rhizines anchor the lichen to the colonized surface or substrate, and can be **simple** (Figure 7a), **forking** (Figure 7b), **squarrose** (Figure 7c), **tufted** (Figure 7d), or **flocculent**

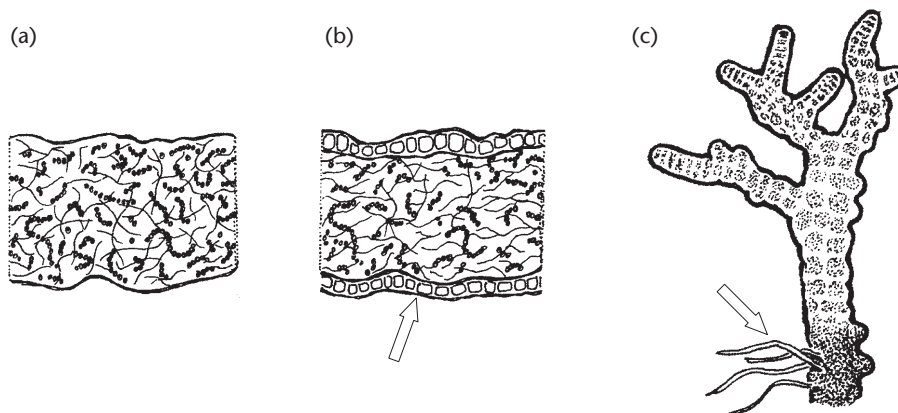


FIGURE 5 *Thallus nonstratified/homoiomerous* (cross-section, in part): (a) noncorticate, (b) corticate(←), (c) bearing rhizoids(←).

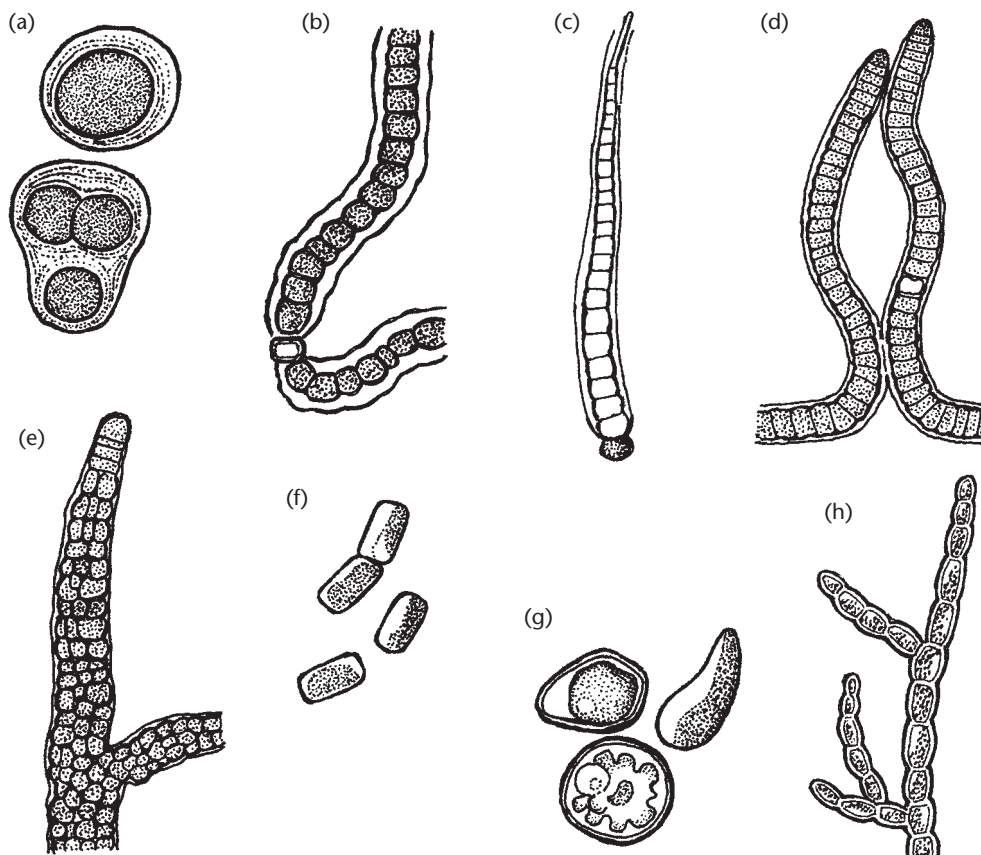


FIGURE 6 Common photobionts (free-growing/unlichenized forms; for lichenized forms, see the key on page 23), a–e = cyanobacteria; f–h = algae: (a) Chroococcales; (b) Nostoc; (c) Rivulariaceae; (d) Scytonema; (e) Stigonema; (f) Stichococcus; (g) trebouxioid; and (h) Trentepohlia.

(Figure 7e). In some foliose species (see below), rhizines are replaced by a single thickened point of attachment, or **umbilicus** (Figure 7f). In others, the rhizines are replaced by a dark, woolly **hypothallus** (Figure 7g) that can sometimes extend beyond the margins of the lichen. Rhizine-like structures that occur along the margins of leaflike lobes are called **cilia** (Figure 10i).

Two broad categories of branching are recognized in this manual. Branching is said to be **even** when the arms of each branch pair are predominantly equal (Figure 8a), and **uneven** when they are not equal (Figure 8b). Similarly, five degrees of attachment can be distinguished: **appressed** (Figure 8c), **decumbent**

(Figure 8d), **semi-erect** (Figure 8e), **erect** (Figure 8f), and **pendent** (Figure 8g).

Lichens have traditionally been divided into three growth forms (**crustose**, **foliose**, and **fruticose**: see below), though other classifications are possible. The one adopted here recognizes seven growth forms:

1. **Dust/leprose** lichens (Figure 9a) lack both an upper and lower cortex, the lower surface being attached directly to the substrate, and the upper surface bearing a continuous covering of powdery or granular soredia.
2. **Crust/crustose** lichens (Figure 9b) are also attached directly to the substrate, but have a hard, protective upper cortex; viewed from above, they often resemble paint stains. Some crust

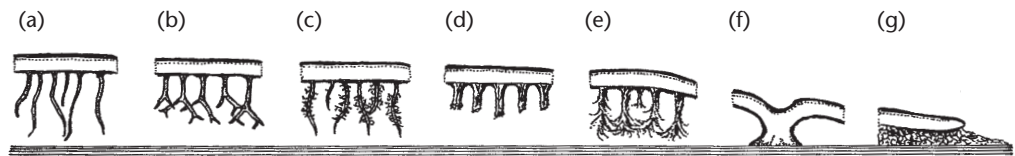


FIGURE 7 *Organs of attachment (cross-section): (a) rhizines (simple); (b) rhizines (forking); (c) rhizines (squarrose); (d) rhizines (tufted); (e) rhizines (flocculent, confluent); (f) holdfast (umbilicus); and (g) hypothallus.*

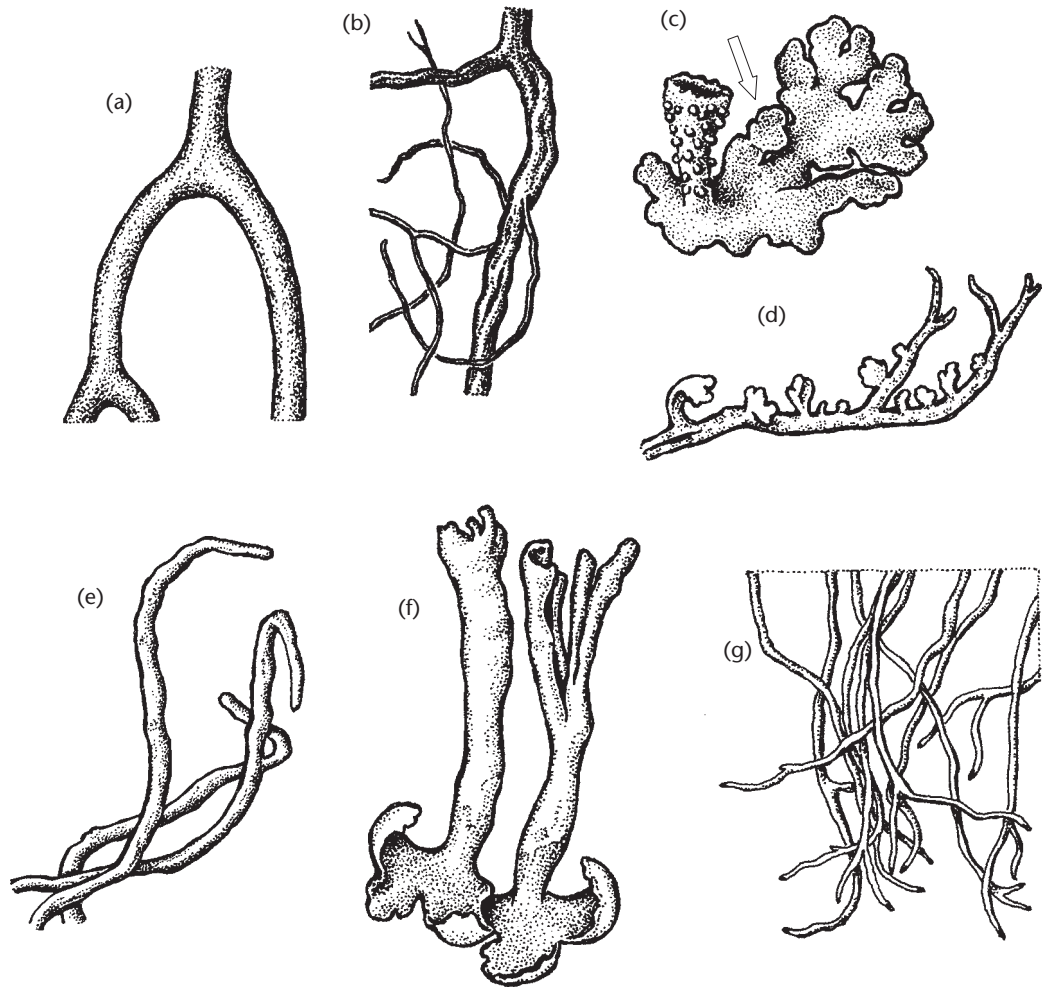


FIGURE 8 *Branching and degrees of attachment: (a) even/isotomic branching; (b) uneven/anisotomic branching; (c) appressed(←); (d) decumbent; (e) semi-erect; (f) erect; and (g) pendent.*

lichens give rise to elongate **isidia** (see below), while others bear stalked fruiting structures termed **podetia** and **pseudopodetia**; such species can be classified as **club lichens** or **shrub lichens** (see below). Other crust lichens intergrade with scale and leaf lichens (see below).

3. **Scale/squamulose** lichens (Figure 9c) are similar to dust and crust lichens in lacking a lower cortex (and rhizines). The thallus, however, consists of small, often partly raised, and usually overlapping/**imbricate** scales/**squamules** (Figure 9c), the lower surface of which is often white and cottony (check under hand lens). In *Cladonia*, the squamules often give rise to hollow, stalked fruiting structures called **podetia**; see also club and shrub lichens, below.
4. **Leaf/foliose** lichens (Figure 9d) more or less resemble leaves—at least in the sense that their thalli consist of flattened **lobes** that typically have an upper and lower cortex. The lobes can be narrow or broad, and short or elongate. The degree of attachment to the substrate varies from appressed through semi-erect or even unattached. This is the only growth form in which well-developed **rhizines** occur.
5. **Club/fruticose** lichens (Figure 9e) are at least partly round in cross-section; they have no “true” lower surface and therefore no lower cortex and rhizines. Most club lichens consist of thickened, up-

right, unbranched, or sometimes sparsely branched stems; when hollow, they are usually referred to as **podetia**; when solid, they are called **pseudopodetia**.

6. **Shrub/fruticose** lichens (Figure 9f) resemble club lichens in having somewhat thickened stems that are more or less circular in cross-section. Here, however, the stems are strongly branched. Occasionally the stems arise from a basal crust or basal scales. When hollow, they are generally termed **podetia**; whereas, when solid, they are again called **pseudopodetia**. Shrub lichens vary from decumbent to semi-erect or erect.
7. **Hair/fruticose** lichens (Figure 9g) differ from shrub lichens in having much finer, and proportionately much longer, branches. In habit, hair lichens are semi-erect or pendent.

The upper cortex of most lichens is smooth and naked. However, in some species it can be minutely roughened (i.e., **scabrid**), or covered in **pustules** (Figure 10a) or a fine network of ridges (a **reticulum**: Figure 10b). Other species bear a thin whitish frosting (or **pruina**), while others still have a fine nap of tiny, erect, or appressed glasslike hairs (or **tomentum**: Figure 10c). A woolly tomentum is also sometimes present over the lower surface.

The lower surface of most lichens is also smooth, though raised **veins** (Figure 10h) occur in some foliose species. In others, the lower surface can be sparsely

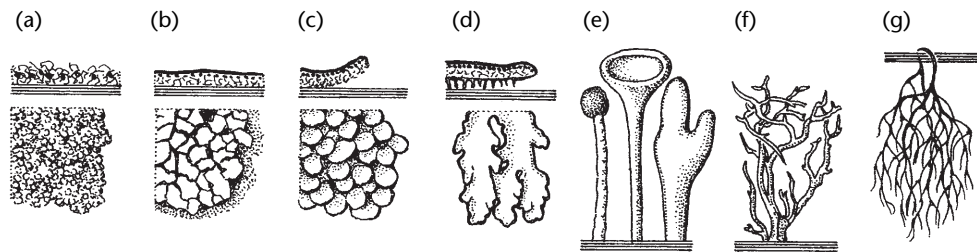


FIGURE 9 Growth forms (cross-section and surface view, in part): (a) dust/leprose; (b) crust/crustose; (c) scale/squamulose (with squamules); (d) leaf/foliose (with lobes); (e) club/fruticose; (f) shrub/fruticose; and (g) hair/fruticose.

speckled with tiny pits through which the medulla is exposed. When rimmed and craterlike, these pits are termed **cyphellae** (Figure 10f); otherwise they are called **pseudocyphellae** (Figure 10g). In some lichens, pseudocyphellae occur over the upper cortex, and must then be carefully distinguished from **maculae** (Figure 10e): pale areas of the upper surface in which the cortex is unbroken. Fruticose lichens can also produce pseudocyphellae.

Surface details can provide important

clues to identification. In some species, for example, the cortex is pocked by broad depressions (or **foveoles**: Figure 11a), while in others it bears conspicuous **longitudinal striations** (Figure 11b). Yet other species carry numerous tile-like **areoles** (Figure 11c) which may or may not be **peltate** (i.e., attached by a short central stalk: Figure 11d). The presence of tiny, scale-like **microsquamules** (Figure 11f) is diagnostic for some *Cladonia* species, whereas some species of *Usnea* bear

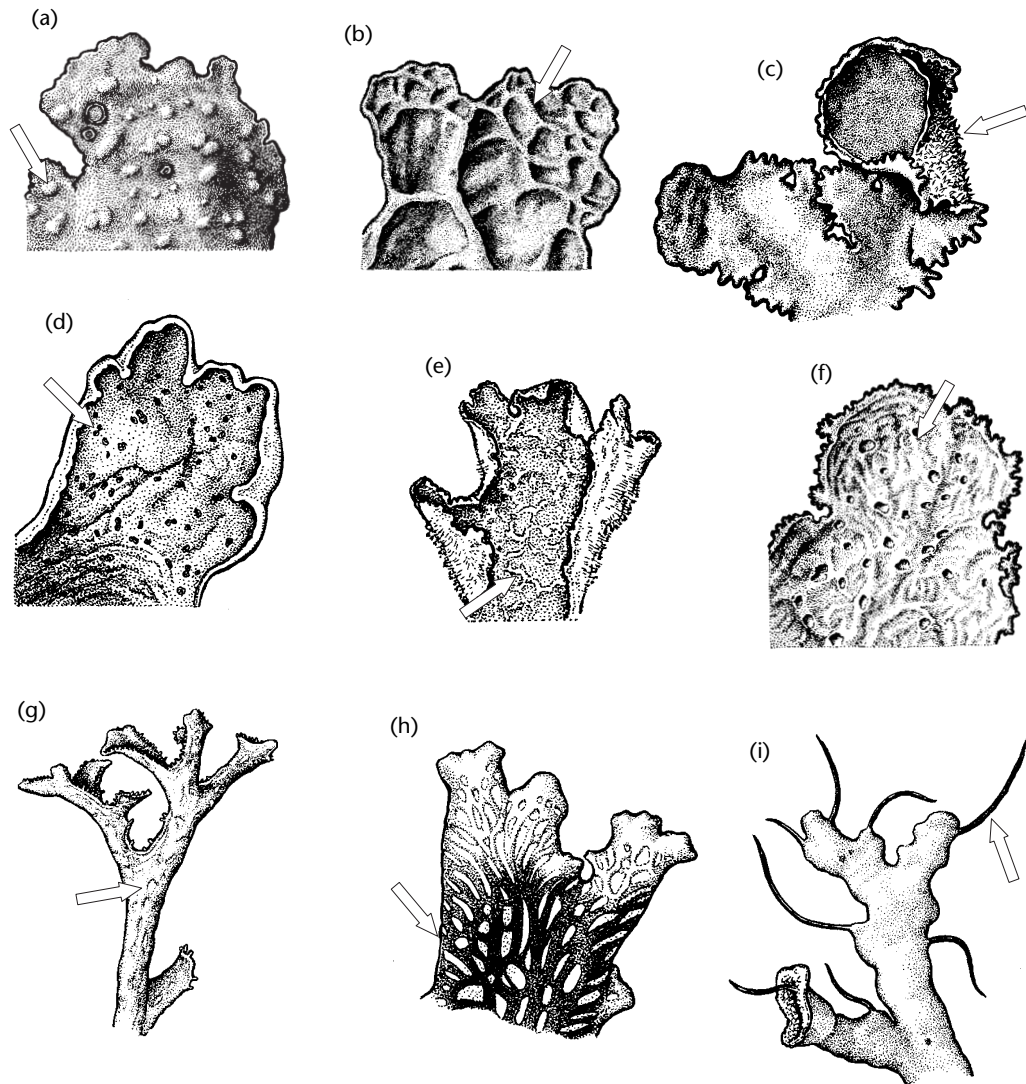


FIGURE 10 Surface (and other) details: foliose: (a) pustules(←); (b) reticulum(←); (c) tomentum(←); (d) cephalodia(←); (e) maculae(←); (f) cyphellae(←) (lower); (g) pseudocyphellae(←); (h) veins(←) (lower); and (i) cilia(←).

numerous goosefleshlike **papillae** (Figure 11g), or copious short side branches (or **fibrils**: Figure 11h). Similarly, most *Stereocaulon* species support a dense “foliage” of **phyllocladia** (Figure 11j), while small spine-like **spinules** (Figure 11i) occur in some species of *Bryoria*.

As a group, lichens reproduce both

vegetatively (in which case the fungus and alga/cyanobacterium are dispersed together, as a functional unit), and by sexual means (in which case only the spores of the fungus are dispersed: see below).

Vegetative reproduction sometimes occurs as a result of mechanical fragmentation (wear and tear), but more often it involves

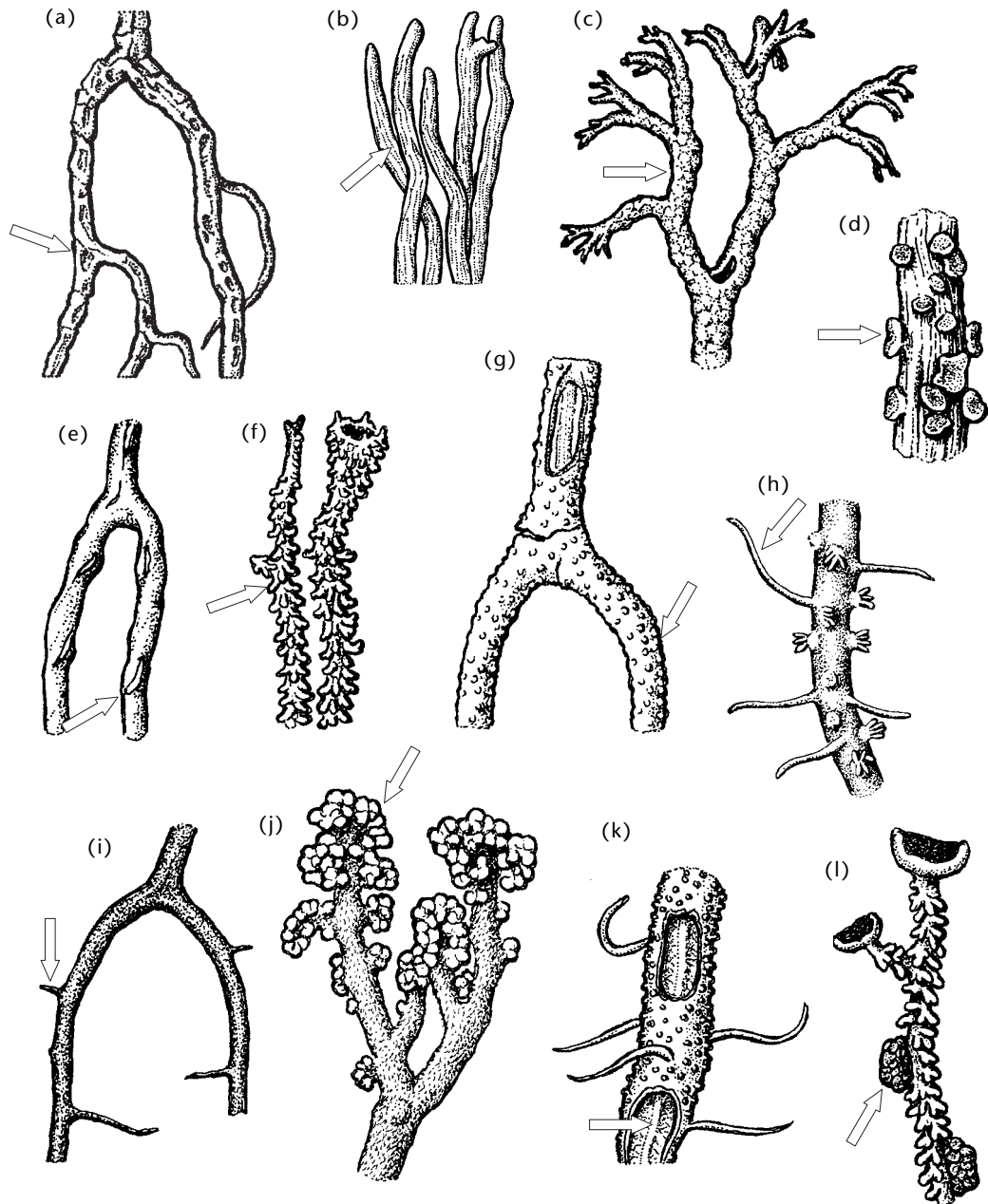


FIGURE 11 Surface (and other) details: fruticose: (a) foveoles(←); (b) striations(←); (c) plates/areoles(←); (d) peltate areoles(←); (e) pseudocyphellae(←); (f) microsquamules(←); (g) papillae(←); (h) fibrils(←); (i) spinules(←); (j) phyllocladia(←); (k) central cord(←); and (l) cephalodia(←).

transport (as by birds) of specialized outgrowths called soredia and isidia. **Soredia** (Figure 14a–d) are masses of soft, powdery granules that have erupted through cracks and other areas of weakness in the cortex. When very fine (i.e., resembling talcum powder), they are said to be powdery/farinose (Figure 14b); otherwise they can be described as more or less granular (Figure 14c). Though commonly borne in well-delimited **soralia** (Figure 14a), soredia can also be broadcast over the surface; they are then said to be **diffuse** (Figure 14d). By contrast, **isidia** (Figure 14e–i) are tiny outgrowths of the upper cortex; their hardened outer surface is usually readily distinguished from the powdery appearance of soredia. Similar to soredia, isidia

contain both a fungus and an alga/cyanobacterium. They can be **granular/globose** (Figure 14e), **barrel-shaped** (Figure 14f), **fingerlike/cylindrical** (Figure 14g), **coralloid** (Figure 14h), or **scale-like** (Figure 14i).

The primary function of sexual fruiting bodies is to produce sexual **spores** (Figure 12a–l). Sexual spores come in many shapes, and can be **threadlike/filiform** (Figure 12a), **spindle-shaped/fusiform** (Figure 12b), **ellipsoid** (Figure 12c), **clublike/clavate** (Figure 12d), **globose** (Figure 12e), or **peanut-shell-like** (Figure 12f). They can also be **1-celled** (Figure 12g), or divided by a narrow cross-wall or **septum** (Figure 12h, i) into **2-celled** (Figure 12h) or **multi-celled** spores (Figure 12i). When the septum is very broad, the spores are

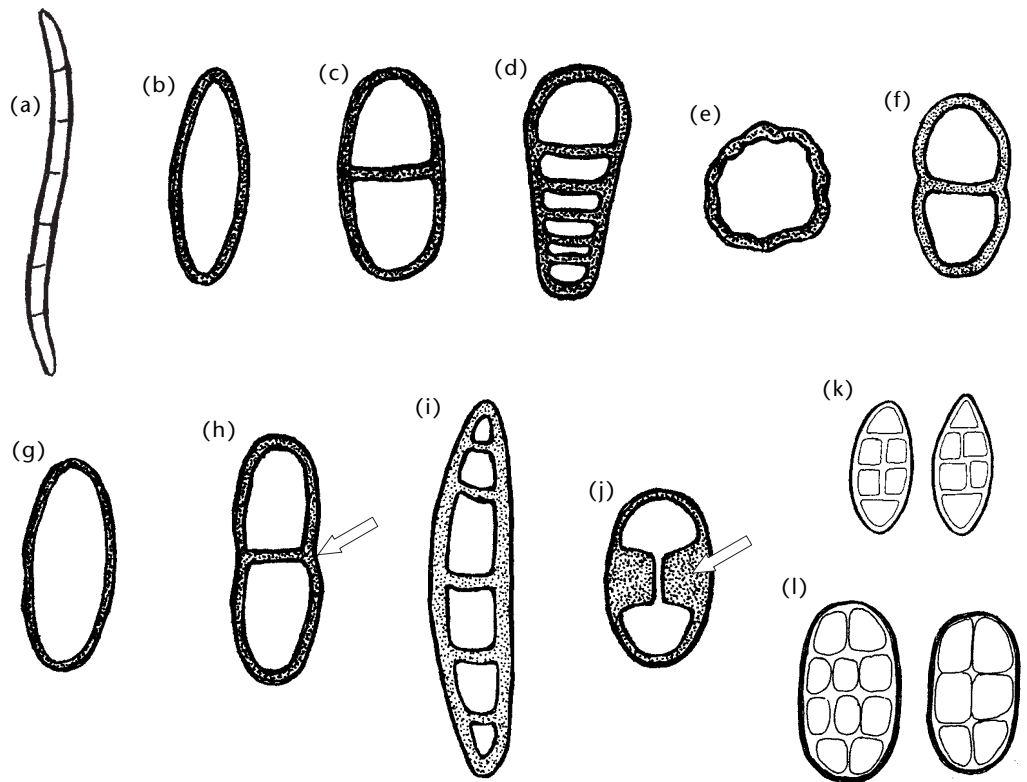


FIGURE 12 Spores and conidia: (a) threadlike/filiform; (b) spindle-shaped/fusiform; (c) ellipsoid; (d) clublike/clavate; (e) globose; (f) peanut-shell-shaped; (g) 1-celled/simple; (h) 2-celled (with narrow septum(←)); (i) many-celled/multi-septate; (j) polarilocular (with broad septum(←)); (k) submuriform; and (l) muriform.

termed **polarilocular** (Figure 12j). Spores having both crosswise and lengthwise septa are called **submuriform** (Figure 12k) or, when well developed, **muriform** (Figure 12l).

For most species covered in this manual, sexual fruiting bodies take the form of **apothecia** (Figure 13a–g). These are small saucerlike, buttonlike, or hemispherical structures usually readily observed over the thallus surface. Apothecia are gen-

erally **unstaked** (Figure 13a–e), but in a few genera they are borne at the ends of long, brittle stalks as expanded “heads,” or **capitula** (Figure 13f, g).

Apothecia contain both fertile and sterile tissues. The former comprise the **central disc**: a compact cluster of tiny vial-like **asci**, each bearing its complement of one to several spores (Figure 13a–e). Surrounding the disc is a sterile rim, or **excipulum** (Figure 13a, d, e). When photobiont cells

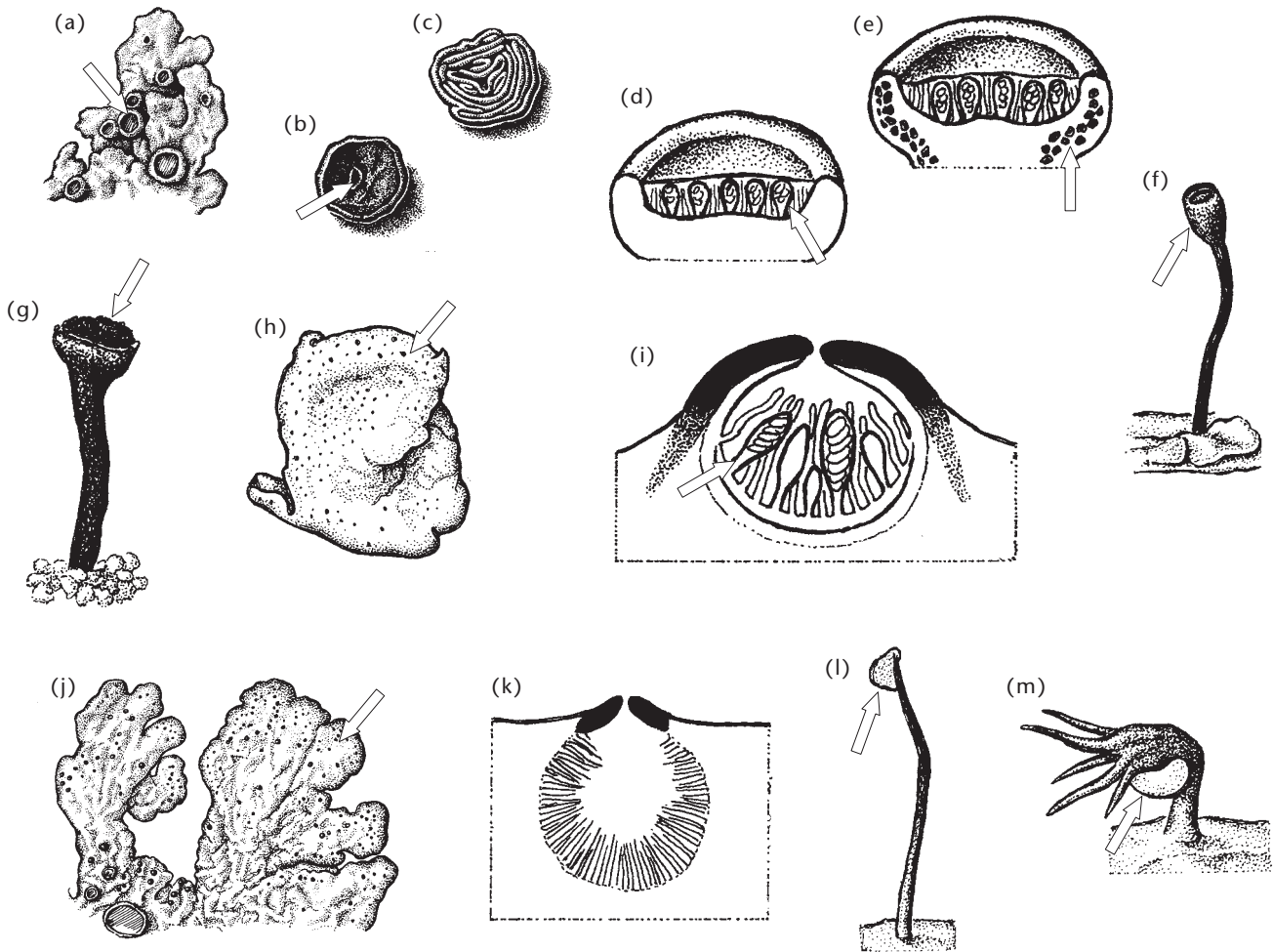


FIGURE 13 Sexual and asexual reproductive structures (surface view unless indicated): (a) unstalked apothecia (showing discs and well-developed apothecial rims/excipula(←)); (b) unstalked apothecium (with a buttoned disc/omphalodisc(←)); (c) unstalked apothecium (with fissured disc/gyrodisc); (d) unstalked apothecium (cross-section: with nonthalline rim/excipulum and spore-containing asci(←)); (e) unstalked apothecium (cross-section: with thalline rim/excipulum: note presence of algae(←)); (f) stalked apothecium (with excipulum and disc [i.e., capitulum(←)]); (g) stalked apothecium (showing mazaedium(←)); (h) perithecia; (i) perithecia (cross-section: note spore-containing asci); (j) pycnidia; (k) pycnidia (cross-section): note absence of asci; (l and m) hyphophores (showing stalks and conidial heads(←)).

are present in the excipulum, it is said to be **thalline** (Figure 13e); when they are lacking, it is **nonthalline** (Figure 13d). In *Calicium*, *Sphaerophorus*, and related genera, the disc is replaced by a distinctly powdery **mazaedium** (Figure 13g) that readily smudges when rubbed. In other lichens, sexual fruiting bodies take the form of **perithecia** (Figure 13h, i): minute flask-like, ascus-bearing structures that are immersed in the thallus, and are visible from above as blackish or brownish dots.

Perithecia must be carefully distinguished from some forms of **pycnidia**

(Figure 13j, k) which, though also dotlike, bear reproductive cells called **conidia**. Conidia come in many shapes but, unlike sexual spores, they never develop in vial-like asci. They are also usually much smaller than sexual spores, often measuring less than 4–5 μm long. In some genera, conidia are produced at the tips of stalked fruiting bodies called **hyphophores** (Figure 13l, m), while in others they are borne directly over the cortex in well-demarcated, black, sooty patches; these are termed **thalloconidia**.

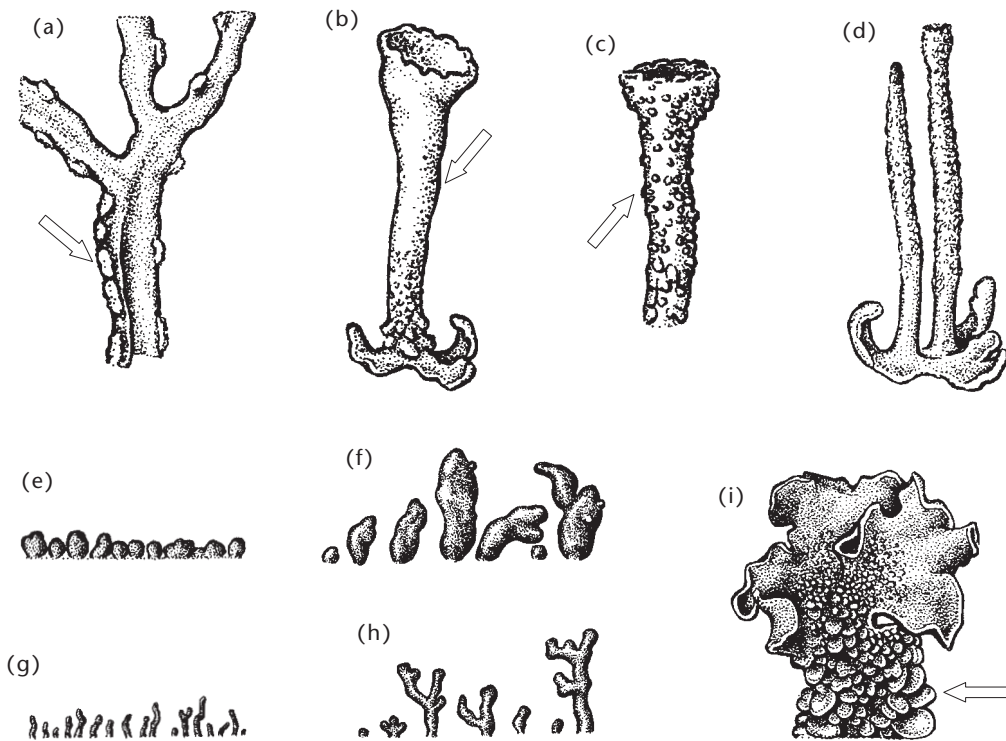


FIGURE 14 Vegetative reproductive structures: (a) soredia in a soralium(←); (b) soredia (powdery/farinose(←)); (c) soredia (granular(←)); (d) soredia (diffuse); (e) isidia (granular/globose); (f) isidia (barrel-shaped); (g) isidia (fingerlike/cylindrical); (h) isidia (coralloid); and (i) isidia (scale-like(←)).

Making Use of Lichen Chemistry

Lichens produce a diverse array of chemical substances. Reflecting this, lichen chemistry provides a useful tool for the identification of many species. The presence of specific chemical substances can be established through the use of spot tests, ultraviolet lamps, and thin-layer chromatography.

1. Spot Tests A spot test is performed when a small quantity of liquid reagent is applied to one or more lichen tissues. This can be done using a fine brush or capillary pipette that has been drawn to a point over a flame. The resulting colour change (or lack of it) is often diagnostic for one or more of several chemical substances present in the lichen. Five reagents are called for in this manual: calcium hypochlorite (C),³ nitric acid (H), potassium iodide (I), potassium hydroxide (K), and paraphenyldiamine (PD). Of these, only C, K, and PD are used routinely. All of the reagents are toxic and should be carefully stored in small, tightly sealed glass bottles. Chemical reactions can be observed using a hand lens (10x or stronger), but a dissecting microscope allows more detailed observation. Work the lichen using a stiff, single-edged razor blade and a pair of fine forceps or tweezers. Never apply a reagent directly to an herbarium specimen; instead, break off a tiny fragment that can later be discarded. Carefully record all colour changes, taking care to record both positive and negative reactions (e.g., Cortex K+ yellow, C-, PD-; medulla K-, C-, PD+ yellow becoming orange).

Calcium hypochlorite (C): This reagent, chlorine bleach (e.g., Javex), can be purchased from most grocery outlets. The reaction (a reddish or pinkish coloration) is often fleeting, and must be observed carefully. In some cases, a more vivid reaction can be obtained by using a “KC” test, in which K is followed by C. Calcium hypochlorite is unstable and

should be discarded (usually after two or three months) when it no longer smells strongly of chlorine.

Nitric acid (H): This reagent is rarely used, but is helpful in distinguishing between the foliose genera *Neofuscelia* and *Melanelia*. The expected reaction (in *Neofuscelia*) is a rapid darkening of the upper cortex, with a blue-green tinge. It is also used to discriminate among certain species of *Chaenothecopsis*. Use at 50% concentration.

Potassium iodide (I): Iodine solutions react with a variety of starches. For example, when applied to the spore-producing apothecial layer (or hymenium) in the foliose genera *Fuscopannaria* and *Pannaria*, the tissues become blue, violet, or even bluish black (check under a light microscope). This reagent also gives a bluish or purplish reaction when applied to the medulla of some *Sphaerophorus* species. The preferred formula is Lugol's iodine solution: 0.5 g iodine, 1.5 g potassium iodide, and 100 ml distilled water.

Potassium hydroxide (K): This is a 10–35% solution of potassium hydroxide in water. The reagent can be purchased (in pellet form) from most drugstores. The usual colour reactions are: yellow, yellow changing to orange or red, and red. If tightly stoppered, a solution of K will often remain active for up to six months.

Potassium hydroxide / calcium hypochlorite (KC): In this test, K is applied first, and then C. A positive reaction yields instantaneous pinks or reds that often fade quickly. Useful in the identification of a wide range of lichens.

Calcium hypochlorite / potassium hydroxide (CK): This is a seldom-used test, in which C is applied first, followed by K. A positive reaction gives a deep yellow or orangish colour, and is useful primarily in the recognition of barbatic acid (diagnostic, for example, in *Usnea ceratina*), although salazinic acid also yields a

³ The abbreviations used here for calcium hypochlorite (C), nitric acid (H), potassium iodide (I), and potassium hydroxide (K) should not be confused with the standard symbols for the chemical elements carbon, hydrogen, iodine, and potassium. Alternative abbreviations include HNO₃ for H, and KOH for K.

CK+ yellowish to orangish reaction.

Paraphenylenediamine (PD): This reagent is most safely used as Steiner's Stable PD Solution: 1 g PD crystals, 10 g sodium sulphite, 5 ml detergent (e.g., Photo-flo), 100 ml distilled water. An alternative solution (preferred for *Stereocaulon*) can also be prepared by dissolving a few crystals of PD in two or three drops of 70% ethyl alcohol (note: rubbing alcohol works well, but avoid the use of isopropyl alcohol). The resulting solution is highly unstable, and deteriorates after only a few minutes. By contrast, Steiner's Solution lasts a month or more, especially if stored in a dark bottle; it should be discarded when it turns a dark pink. PD is suspected of being carcinogenic; it must be handled carefully, as it is absorbed through the skin, and stains cloth, books, and specimens. Reactions often develop slowly (e.g., 30–60 seconds), and result in a yellow, orange, or red coloration. The crystals can be difficult to obtain.

2. Ultraviolet (UV) Lamps Ultraviolet fluorescence provides an effective means

of detecting many lichen substances. Long-wave UV is preferred (i.e., 365 µm). The technique involves exposing the medulla of the specimen with a razor blade, and then examining it with a UV lamp in a darkened room. A positive UV reaction yields a distinct bluish, yellowish, or whitish incandescence. Because UV light is damaging to the eyes, protective goggles should be worn when conducting these tests. Avoid using UV lamps for extended periods, and never look directly into the lamp. Ultraviolet lamps can be obtained from scientific and geological supply outlets.

3. Thin-layer Chromatography (TLC)

Thin-layer chromatography is more expensive and time consuming than spot tests or UV tests, but is also more discriminating. In fact, many chemical substances can be detected in no other way (i.e., without the use of even more sophisticated techniques). The technique is not difficult to learn, but instruction in the method is beyond the scope of this manual. White and James (1985) provide a good introduction.

A Note on Common Names

In this manual, common names are proposed for all fruticose macrolichens and microlichens known to occur in British Columbia.

Some of these names have been adopted from *Lichens of North America* (Brodo et al. [2001]), though most are original with this publication. Names in parentheses have been used by earlier authors—for example, Alvin (1977), Benton and Underhill (1977), Bland (1971), Bolton (1960), Brodo (1988), Casselman (1993), Hawksworth et al. (1995), Johnson et al. (1995), Kershaw et al. (1998), McCune and Geiser (1997), McGrath (1977), MacKinnon et al. (1992), Nearing (1947), Parish et al. (1996), Perez-Llano (1944), Pojar and MacKinnon (1994), Richardson (1975), Smith (1921), and Vitt et al. (1988)—but for various reasons are not accepted here.

Most of the accepted common names

record observable attributes of the species and genera to which they apply, though other names are intentionally fanciful. In most cases, the same “root” name applies to all members of a given genus (e.g., all species of *Bryoria* bear the name “horsehair”), but in some cases this name is applied also to the species of other similar genera.

Common names are perhaps most satisfactorily viewed as vehicles of communication for those who are unwilling to use scientific names. Scientific names are intended to be universal and stable; common names are by nature regional and highly plastic. The common names introduced here are intended primarily for use by the naturalist community of British Columbia. While some may gain currency elsewhere in North America, alternative names will probably be coined for many species.