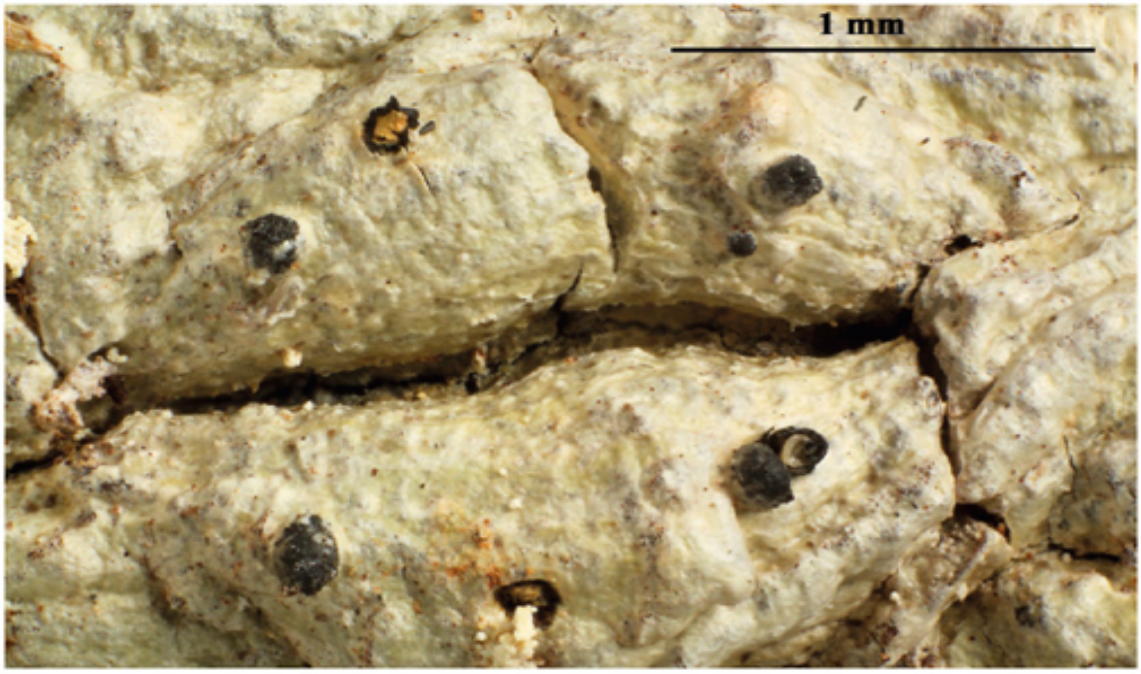
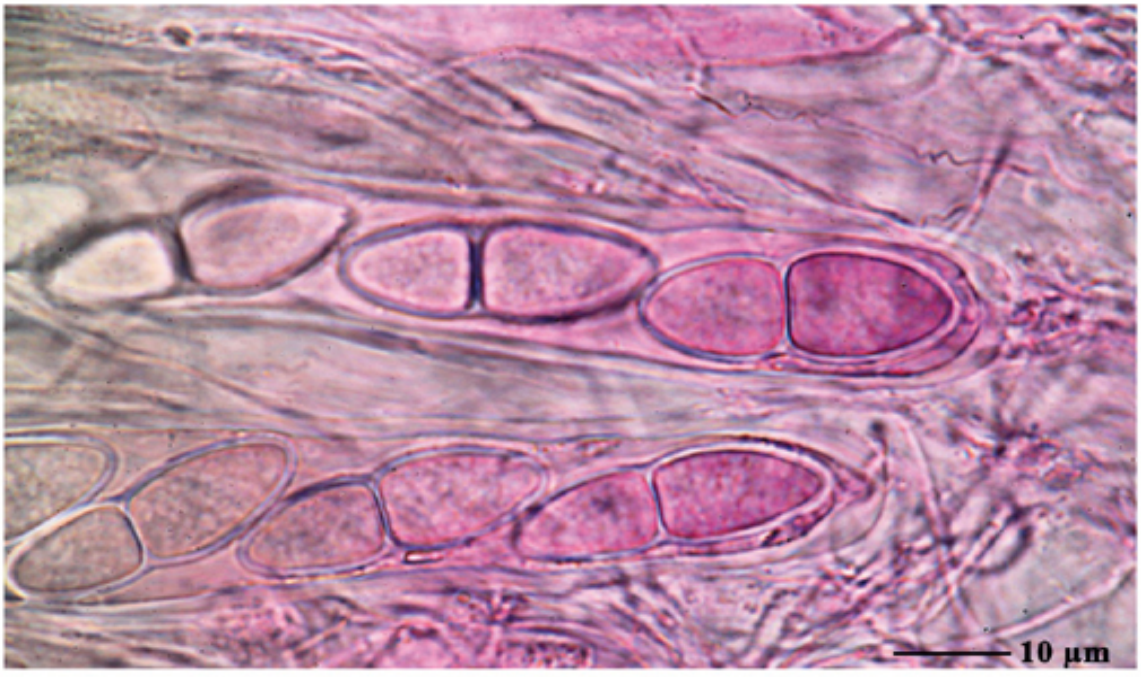


Felix Schumm & André Aptroot

Atlas of Pyrenulaceae and Trypetheliaceae

Volume 1



Content

new combinations

Astrothelium himalayense (Upreti & Aptroot) Aptroot & Schumm
Bogoriella oleosa (Aptroot) Aptroot & Schumm
Pseudopyreniila kantvilasii (P.M. McCarthy) Aptroot

Atlas of Pyrenulaceae and Trypetheliaceae

The Pyrenulaceae and the Trypetheliaceae are the most speciose groups of pyrenocarpous lichens. They are mainly tropical and corticolous. While taxonomical work on most other groups of lichens has been continuous, these family got more attention in the initial century of lichenology than in the past century, with even three monographs of *Trypethelium* published before 1900. In the present century however, more attention was paid to these families, leading to the description of many new species and world keys for e.g. *Lithothelium* (Aptroot 2006), *Pyrenula* (Aptroot 2012) and Trypetheliaceae (Aptroot & Lucking 2016, and their contributions to Hongsanan et al. 2020). The families are differing in morphological characters which correlate well with phylogeny. The species concept in these groups was changed considerably this century. Future, detailed phylogenetic studies may necessitate more changes, but they are not anticipated here. Recently, *Arthopyrenia* and a similar group have been shown to

belong to the Trypetheliaceae, but they are not treated here as they are no lichens (and not tropical).

Taxonomic work on these families continues, and keys become soon outdated. Some changes to these keys were already published, e.g. on internet by Aptroot & Sipman, and when a new species in these families is described, it is usually indicated where it would key out in a published key. Here, we present fully updated keys to these families, in which all published changes are incorporated, as well as some other changes, most importantly a more precise wording of the first couplet in each *Astrothelium* part key. The keys will gradually become outdated when new species are being continuously described, but we intend to indicate where newly described species would key out in these keys. To facilitate this purpose, each key has an identifying letter.

More importantly, we provide detailed illustrations of the majority of the accepted species. Published illustrations of species in these family are scarce, and mainly restricted to recently described species, and for Pyrenulaceae ascospore drawings, but for Trypetheliaceae mainly habitus photographs. Here we illustrate mostly recently collected material, mostly from ABL herbarium. It does include many type specimens of recently described species. Some are holotypes, but most are officially isotypes, because the counries they were collected demand that the holotype is preserved in a herbarium in the original country. However, the illustrated isotype is often the part of the type collection that was mostly used for the description of the new species. We did not illustrate many old types, because the characters are often much better seen in recent material. An example of an exception is *Blastodesmia nitida*, which has not been found this century and for which

we illustrated the most recent specimen we could find; its spores are howver much degenerated.

The selection of the species treated is based on ready availability. Still, it covers the majority of the species in these two families. In addition, some representatievs of other, mainly tropical, mainly corticolous groups are illustrated, especially, but not restricted to, Monoblastiaceae, Porinaceae, Strigulaceae, Thelenellaceae, and genera of uncertain position like *Melanophloea, Mycoporum* and *Topelia*. For these groups, keys are not provided. For *Thelopsis* and *Topelia*, one is referred to Aptroot et al. 2014, for the Strigulaceae and some Monoblastiaceae to contributions of Lücking and Aptroot in Hongsanan et al. 2020.

For all treated species, full synonymy is cited, and a description, which is usually taken from published descriptions, but checked against our own observations. No major effort is made to strictly homogenize them, which means e.g. that the ascomata are sometimes called perithecia, an extending wall involucrellum or clypeus, and the hamathecium filaments either paraphyses, pseudoparaphyses or paraphysoids. Such different terminology should not be taken as too meaningful.

Keys like this are meant to narrow down the possible choices while identifying. Following them is however no guarantee for a succesful identification. That depends on many things. For of all, and we cannot stress that too often, the majority of wrong identifications results from starting with a wrong key. Quite often, somebody thinks to know that the specimen belongs to a certain family or genus, and starts with a key to the species, while in fact, the specimen does not belong to that group at all. Clearly, no satisfactory

identification will be reached, and it has even led to the new description of already described species in wrong genera.

The chemistry of Pyrenulaceae and Trypetheliaceae is not very diverse, with only a few xanthones and anthraquinones. However, the detection of these, and also the exact location of them (e.g. in thallus, ostiole, inside pseudostroma, in ascoma wall, inside hamathecium gel, outside on ascoma, outside on pseudostroma) is important. Take care with UV reactions. Many *Pyrenula* species reflect somewhat greenish. This is not a positive reaction. The best is to approach the lamp gradually with the lichen. If it gradually brightens, this is no reaction. It will suddenly brighten yellow when comong close if it contains lichexanthone. Best seen in the dark.

Hamathecium gel inspersion and gelatinous sheaths. Inspersion is a key character, which often is not mentioned in old descriptions. Inspersion is oil droplets in the hymenial gel between paraphyses. Droplets inside the paraphyses are not constant and should not be noted. Often there are pre-formed gelatinous sheaths or tails on the spores (or on larger conidia), in fresh specimens. They are not mentioned in keys, because they are not visible in historical specimens.

Material and methods

The pictures are made in Wangen with a Canon Eos 600D, Canon MP-E 65 mm and Olympus BX51 microskope. In many cases we stained the spores for better contrasting with red Phloxine in water or more rarely with Lactophenol-Cottonblue. Most sections through apothecia and thalli are made with a freezing microtome (Kryostat Micron HM 560) and are 5-20 µm thick. Sometimes the lichens have been pre-treated with acetone or alcohol in order to solve lichen substances before the section was made. Sometimes we made also pictures from the IKI+ reaction of the ascus tholus if it has diagnostic value. But there exists no standard method and we tried to apply for each species various methods so as to find an optimum that best shows the important details.

In front of the collecting location we mention the code number of the source of the examined specimen, so that it always can be located in our herbaria [number], in Herbarium Felix Schumm, Wangen; [ABLnumber] in ABL-Herbarium André Aptroot, partly stored also in Wangen, and so on.

General key to the families and some genera of tropical pyrenocarpous lichens

(specimens without ascospores or with only conidia can rarely been identified and are not keyed out; it is important to distinguish septation with thickened cell walls, called distosepta, from simple eusepta; also it is important to observe whether or not the hamathecium filaments = paraphyses are branched; in case one of these characters is not ascertained, try both alternatives)

Please note that **keys A** to **E** mainly contain Pyrenulaceae, and **keys F** to **Ω** are all Trypetheliaceae. The keys look similar to previously published keys, but differ in numerous points, notably additional species and the corrections of mistakes. Each key alternative is given a separate code (like K2b) for easy future reference. Updated known world distributions are indicated for each species.

1a Hamathecium filaments absent or slimy; algae dark green, verrucarioid; thallus usually microsquamulose. Verrucariaceae (corticolous: *Agonimia, Endocarpon, Placidium, Psoroglaena*)
1b Hamathecium filaments present; algae trentepohlioid, or sometimes absent. 2

2a Ascospores simple. 3
2b Ascospores septate. 5

3a Ascospores globose, >50 per ascus; pantropical (Brazil, Papua New Guinea, Solomon Islands). *Melanophloea pacifica* P. James & Vìzda

3b Ascospores 1 to 8 per ascus. 4

4a Ascospores ornamented with warts or spines. *Monoblastia*
4b Ascospores not ornamented, with wide, shaped gelatinous sheath: pantropical, but rarely reported (Brazil, Papua New Guinea). *Papilionovela athallina* Aptroot

5a Hamathecium with unbranched paraphyses or hamathecium unclear. 6
5b Hamathecium with branched to anastomosing paraphysoids. 19

6a Ascospores brown. 7
6b Ascospores hyaline. 12

7a Ascospores remaining stuck in mass on top of the ascoma, mazaedioid. Pyrenulaceae (*Mazaediothecium, Pyrgillus*). **Key E**
7b Ascospores discharged. 8

8a Ascospores 1-septate. 9
8b Ascospores more than 1-septate. Pyrenulaceae. 11

9a Ascospores not ornamented, often thick-walled, distoseptate. Pyrenulaceae (*Clypeopyrenis, Distopyrenis, Granulopyrenis, Parapyrenis*). **Key D**
9b Ascospores ornamented, thin-walled. 10

10a Ascospores up to 20 × 8 µm, only in one species larger (up to 30 × 10 µm). *Pseudobogoriella*. **Key X**
10b Ascospores 20–50 × 8–15 µm. *Bogoriella*. **Key Q**

11a Ascospores transversely septate. Pyrenulaceae (mostly *Eopyrenula*, *Lithothelium, Pyrenula*). **Key B**
11b Ascospores (sub)muriform. Pyrenulaceae (mostly *Anthracothecium, Pyrenula*). **Key A**

12a Ascospores >10 per ascus. *Thelopsis*
12b Ascospores 1 to 8 per ascus. 13

13a Hamathecium a pseudoparenchymatous tissue; ascomata usually in dense groups with common black cover. *Mycoporum*
13b Hamathecium consisting of filaments. 14

14a Ascospores thick-walled, distoseptate, either with rather unclear septation or with filiform ascopores). Pyrenulaceae (*Celothelium, Lithothelium*). **Key C**
14b Ascospores thin-walled, euseptate. 15

15a Ascomata in thalline warts with black pulveraceous mass. *Phyllobathelium*
15b Ascomata not in thalline warts with black pulveraceous mass. 16

16a Thallus medulla bright yellow or orange. *Myeloconis*
16b Thallus medualla not bright yellow or orange. 17

17a Ascomata with periphyses in addition to paraphyses. *Topelia*
17b Ascomata without periphyses. 18

18a Ascomata adorned with setae formed of conglutinated hairs. *Trichothelium*
18b Ascomata usually not adorned, but if with setate, these not made of conglutinated hairs. *Porina*

19a Ascospores distoseptate, mostly thick-walled; when realtively thinwalled, either hyaline and with constrictions or brown and ornamented. Trypetheliaceae. 23
19b Ascospores thin-walled, euseptate. 20

20a Hamathecium filaments unbranched between the asci. 21
20b Hamathecium filaments branched. 22

21a Ascospores 1 to 3-septate. Monoblastiaceae (*Acrocordia, Anisomeridium, Megalotremis, Trypetheliopsis*)
22b Ascospores muriform. *Julella*

22a Ascospores hyaline, usually uniseriate in the ascus; conidia with gelatinous appendages. Strigulaceae (*Dichoporis, Flagellostrigula, Strigula, Swinscowia*)
22b Ascospores biseriate; conidia without appendages. Thelenellaceae (*Aspidothecium, Thelenella*)

23a Ascospores remaining hyaline. 24
23b Ascospores becoming brown. 50

24a Ascospores 1-septate. 25
24b Ascospores 3-septate to muriform. 26

25a Ascospores smooth-walled. *Constrictolumina*. **Key R**
25b Ascospores granular ornamented. *Macroconstrictolumina*. **Key T**

26a Thallus ecorticate, usually whitish or greyish. 27
26b Thallus distinctly corticate, olive-green to yellowish brown. 31

27a Hamathecium filaments basally thickened, branched but usually not anastomosing. 28
27b Hamathecium filaments thin, straight, branched and anastomosing to form a net-like structure. 29

28a Ascospores smooth-walled. *Constrictolumina*. **Key R**
28b Ascospores granular ornamented. *Macroconstrictolumina*. **Key T**

29a Ascospores with diamond-shaped lumina. *Pseudopyrenula*. **Key Y**
29b Ascospores with almost rectangular lumina. 30

30a Ascospores transversely septate, or when muriform, ostiole apical. *Polymeridium*. **Key W**
30b Ascospores muriform; ostioles lateral. *Dictyomeridium*. **Key S**

31a Ascospores transversely septate. 32
31b Ascospores muriform. 41

32a Ascospores very large with few (3–5) septa, typically over 100 × 30 µm and up to 190 × 60 µm; septa and walls somewhat thickened but lumina not astrothelioid. *Architrypethelium*. **Key G**

32b Ascospores when 3–5-septate very rarely exceeding 100 × 30 µm and if so, ascospores distinctly astrothelioid, with diamond-shaped lumina. 33

33a Ascospores with diamond-shaped lumina. 34

33b Ascospores with ellipsoid to lentiform or almost rectangular lumina. 38

34a Ascomata strongly prominent to sessile, completely exposed, pure black, somewhat egg-shaped. *Nigrovothelium*. **Key V**

34b Ascomata immersed to erumpent or aggregate in erumpent to sessile pseudostromata. *Astrothelium*. 35

35a Ascomata each with a separate, consistently apical ostiole. 36

35b Ascomata either with a separate, eccentric to lateral ostiole or several ascomata with afus ed ostiole which is then positioned apically relative to the ascomatal cluster but with individual channels originating eccentric or lateral from each individual ascoma or chamber. 37

36a Thallus and/or ascomata with external or internal, yellow to red pigment(s) (usually K+ red to purple) and/or with lichexanthone (then UV+ yellow). **Key H**

36b Pigments and lichexanthone absent. **Key I**

37a Thallus and/or ascomata with external or internal, yellow to red pigment(s) (usually K+ red to purple) and/or with lichexanthone (then UV+ yellow). **Key J**
37b Pigments and lichexanthone absent. **Key K**

38a Ascomata aggregate in prominent to sessile, brownish black pseudostromata; ascospores with thin septa and walls. *Bathelium*. **Key P**
38b Ascomata solitary to pseudostromatic but pseudostromata not as above; ascospores with slightly thickened septa. 39

39a Ascomata immersed to erumpent or rarely indistinctly pseudostromatic; pigments mostly absent. 40
39b Ascomata aggregate in distinct, prominent to sessile pseudostromata; internal and/or external pigments usually present. *Trypethelium*. **Key Z**

40a Thallus UV-negative. *Viridothelium*. **Key Ω**
40b Thallus UV+ yellow; Brazil. *Exiliseptum ocellatum* (Müll. Arg.) R.C. Harris

41a Ascospores with ellipsoid to lentiform or almost rectangular lumina. 42
41b Ascospores with diamond-shaped lumina. 45

42a Ascomata single. *Architrypethelium submuriforme* Aptroot
42b Ascomata aggregate. 43

43a Ascomata aggregate in prominent to sessile, brownish black pseudostromata. *Bathelium*. **Key P**

43b Ascomata in erumpent, whitish pseudostromata. 44

44a Thallus UV-negative: Panama. *Viridothelium tricolor* Lücking, M.P. Nelsen & N. Salazar

44b Thallus UV+ yellow; Brazil. *Trypethelium muriforme* Aptroot & M.F. Souza

45a Ascomata in prominent to sessile warts covered by a thick layer of yellow-orange or red pigment. *Marcelaria*. **Key U**

45b Ascomata immersed to erumpent, rarely prominent, usually covered by thallus, rarely with a thin layer of pigment pruina. 46

46a Ascomata aggregate in irregular, blackish pseudostromata; ascospores about 50 × 15 µm; Thailand. *Architrypethelium murisporum* Luangsuph., Lumbsch & Sangvichien

46b Ascomata and ascospores not with the above combination of characters. *Astrothelium*. 47

47a Ascomata each with a separate, consistently apical ostiole. 48

47b Ascomata either with a separate, eccentric to lateral ostiole or several ascomata with afus ed ostiole which is then positioned apically relative to the ascomatal cluster but with individual channels originating eccentric or lateral from each individual ascoma or chamber. 49

48a Thallus and/or ascomata with external or internal, yellow to red pigment(s) (usually K+ red to purple)

and/or with lichexanthone (then UV+ yellow). **Key L**
48b Pigments and lichexanthone absent. **Key M**

49a Thallus and/or ascomata with external or internal, yellow to red pigment(s) (usually K+ red to purple) and/or with lichexanthone (then UV+ yellow). **Key N**
49b Pigments and lichexanthone absent. **Key O**

50a Ascospores transversely septate. 51
50b Ascospores (sub-)muriform. 56

51a Ascospores with a basal euseptum and the basal cell pale, otherwise distoseptate and brown; neotropical. *Polypyrenula sexlocularis* (Müll. Arg.) D. Hawksw.
51a Ascospores septa all similar. 52

52a Ascospores large, usually over 100 µm long. 53
52b Ascospores small, under 50 µm long. 54

53a Ascospores 3-septate, 25–50 µm broad, about 3–4 times as long as broad. *Architrypethelium*. **Key G**
53b Ascospores 11–15-septate, 25–30 µm broad, about 4–5 times as long as broad; Colombia. *Astrothelium fuscosporum* Soto-Medino, Aptroot & Lücking

54a Ascospores drop-shaped, macrocephalic, with strongly thickened terminal walls and two narrow, rectangular lumina near the center; Azores. *Schummia angulata* (Aptroot & Schumm) Lücking, R. Miranda & Aptroot
54b Ascospores ellipsoid, not macrocephalic. 55

55a Ascospores up to 20 × 8 µm, only in one species larger (up to 30 × 10 µm). *Pseudobogoriella*. **Key X**
55b Ascospores 20–50 × 8–15 µm. *Bogoriella*. **Key Q**

56a Ascospores small, under 50 × 20 µm, often with irregularly thickened endospore and halter-shaped lumina. *Bogoriella*. **Key Q**
56b Ascospores very large, 150–400 × 50–140 µm, with outer wall often breaking under pressure. *Aptrootia*. **Key F**

Key A. Mostly tropical corticolous pyrenocarpous lichens with simple paraphyses and brown, submuriform to muriform, distoseptate ascospores (mostly Pyrenulaceae: *Anthracothecium, Lithothelium* and *Pyrenula*)

A1a Young ascospores with eusepta only; mature ascospores with scarce endospore and edgy corners. *Anthracothecium*. 2
A1b Septation only or mostly distoseptate, with notably thick endospore layers, in particularly in the corners, and causing the locules to appear rounded. 6

A2a Ascomata simple. 3
A2b Ascomata mostly compound with a joint ostiole. 5

A3a Ostiole apical. 4
A3b Ostiole lateral; pantropical. *Anthracothecium australiense* (Müll. Arg.) Aptroot

A4a Ascospores 2–4/ascus; pantropical. *Anthracothecium macrosporum* (Hepp) Müll. Arg.
A4b Ascospores 6–8/ascus; pantropical. *Anthracothecium prasinum* (Eschw.) R.C. Harris

A5a Ascospores 1–2/ascus; pantropical. *Anthracothecium interlatens* (Nyl.) Aptroot
A5b Ascospores 6–8/ascus; australasian, possibly also african.
Anthracothecium gregale (C. Knight) Aptroot

A6a Ascospores strongly flattened (lozenge-shaped), with two rows of locules. *Sulcopyrenula*. 7
A6b Ascospores not flattened, circular in transverse section. 11

A7a Thallus UV-negative. 8
A7b Thallus UV+ yellow. 9

A8a Hamathecium inspersed; neotropical. *Sulcopyrenula canellae-albae* (Fée) H. Harada
A8b Hamathecium not inspersed; pantropical. *Sulcopyrenula staurospora* (Tuck.) H. Harada

A9a Ascospores with 4 locules. 10
A9b Ascospores with 8 locules; Guyana. *Sulcopyrenula biseriata* Aptroot & Sipman

A10a Ascospores ellipsoidal, c. 2 times as long as wide; Brazil.
Sulcopyrenula cruciata Aptroot

A10b Ascospores nearly globose; neotropical. *Sulcopyrenula subglobosa* (Riddle) Aptroot

A11a Ascospores submuriform, only one or a few of the median locules with longitudinal septa. 12
A11b Ascospores muriform (when ascospores small, logically only few longitudinal septa can be present; when in doubt, start with the first alternative). 25

A12a Ascomata usually fused or compound, when separate, ostioles lateral; ostioles apical or lateral. 13
A12b Ascomata separate and simple; ostioles apical. 18

A13a Ascomata fused, in black, exposed groups with several ostioles; ascospores 15–22 µm long; australasian. *Lithothelium hieroglyphicum* Aptroot
A13b Ascomata compound, with several, usually flask-shaped chambers usually immersed in the thallus and with a joint ostiole. 14

A14a Ascospores mostly less than 25 µm long. 15
A14b Ascospores mostly over 25 µm long. 17

A15a Thallus with pseudocyphellae; ascospores 15–19 µm long; Guyana. *Pyrenula infrastroidea* Aptroot & Sipman
A15b Thallus without pseudocyphellae. 16

A16a Ascospores red-brown, 14–23 µm long; eastern palaeotropical (Australia to Japan). *Lithothelium nanosporum* (C. Knight) Aptroot

A16b Ascospores grey-brown, 17–20(−25) µm long; neotropical. *Pyrenula subvariabilis* Aptroot & Sipman

A17a Ascospores up to 32 µm long; australasian. *Pyrenula subumbilicata* (C. Knight) Aptroot
A17b Ascospores 45–65 µm long; neotropical. *Pyrenula erumpens* R.C. Harris

A18a Ascospores 13-35(-40) µm long. 19
A18b Ascospores 34–72 µm long. 24

A19a Ascospores 13-17 µm long. 20
A19b Ascospores 22–35(-40) µm long. 21

A20a Ascospores with little endospore formation, lumina almost angular; on wood, pacific. *Pyrenographa irregularis* (Wehmeyer) R.C. Harris
A20b Ascospores much thickened, with rounded lumina; Florida. *Distopyrenis submuriformis* R.C. Harris

A21a Thallus probably without algae; temperate. *Requienella seminuda* (Pers.) Boise
A21b Thallus superficial, with copious algae. 22

A22a Ascospores 22–40 µm long; overmature ascospores with reddish content before shiveling; pantropical. *Pyrenula seminuda* (Müll. Arg.) Sipman & Aptroot
A22b Ascospores 23–35 µm long; overmature spores all shrivelled. 23

A23a Ascospores 23–35 µm long; hamathecium not inspersed; eastern palaeotropical. *Pyrenula gibberulosa* (Vain.) Aptroot

A23b Ascospores 23–33 µm long; hamathecium inspersed; eastern palaeotropical (India). *Pyrenula darjeelingensis* Jagadeesh Ram & G.P. Sinha

A24a Ascospores with pointed ends; hamathecium not inspersed; eastern palaeotropical (Australia to Japan). *Pyrenula subvariolosa* (C. Knight) Aptroot

A24b Ascospores with rounded ends; hamathecium inspersed; neotropical. *Pyrenula novemseptata* Vain.

A25a Ascomata and/or thallus or medulla with yellow, orange or red anthraquinone pigments; pigments K+ pink to purplish. 26

A25b Anthraquinones absent; thallus K- or yellowish. 32

A26a Thallus warts internally with soft orange medulla; Philippines. *Pyrenula endocrocea* Aptroot

A26b Yellow, orange or red pigment on outside. 27

A27a Ascomata and/or thallus red. 28

A27b Ascomata and/or thallus yellow to orange. 30

A28a Ostiole apical; hamathecium inspersed; neotropical. *Pyrenula cruentata* (Mull. Arg.) R.C. Harris

A28b Ostiole lateral; hamathecium not inspersed. 29

A29a Ascomata partly fused with joint ostioles; ascospores with up to 6 locules per segment; caribbean. *Pyrenula kermesina* R.C. Harris

A29b Ascomata solitary; ascospores with up to 2 locules per segment; pacific. *Pyrenula palmarum* (Krempelh.) R.C. Harris

A30a Ascospores 10–23 µm long, with 3 primary septa. 31
A30b Ascospores 23–35 µm long, with 5–7 primary septa; neotropical. *Pyrenula ochraceoflavens* (Nyl.) R.C. Harris

A31a Thallus red-orange; ascospores 9–18 µm long; Brazil. *Pyrenula aurantiacorubra* Aptroot & M. Câceres
A31b Thallus yellow to orange; ascospores 10–23 µm long; pantropical. *Pyrenula ochraceoflava* (Nyl.) R.C. Harris (with small ascospores with two layers of locules; pacific: *Pyrenula ochraceoflava* var. *pacifica* P.M. McCarthy)

A32a Ostioles lateral. 33
A32b Ostioles apical. 41

A33a Ascospores <70 µm long. 34
A33b Ascospores >70 µm long. 36

A34a Ascomata at least partly with more than one chamber and with joint ostiole. 35
A34b Ascomata all simple and single, with separate ostioles; ascospores 15–33 µm long; pantropical (El Salvador, India). *Pyrenula microspora* (Nagarkar & Patw.) Upreti

A35a Ascospores 25–45 µm long; pantropical. *Pyrenula astroidea* (Fée) R.C. Harris

A35b Ascospores 45–70 µm long; pantropical. *Pyrenula ravenelii* (Tuck.) R.C. Harris

A36a Ascospores 2/ascus, 135–200 µm long; pantropical. *Pyrenulalyoni* (Zahlbr.) Aptroot
A36b Ascospores 4–8/ascus. 37

A37a Ascospores 25–110 µm long. 38
A37b Ascospores 85–135 µm long. 40

A38a Ascospores 25–31 µm long; Guyana. *Pyrenula triangularis* Aptroot & Sipman
A38b Ascospores 50–110(–135) µm long. 39

A39a Ascospores 50–90 µm long; pantropical (El Salvador, India). *Pyrenula ceylonensis* (Ajay Singh & Upreti) Aptroot
A39b Ascospores 70–135 µm long; W. Europe, Madagascar & Macaronesia). *Pyrenula hibernica* (Nyl.) Aptroot

A40a Ascomata mostly with several chambers; pantropical. *Pyrenula schiffneri* (Zahlbr.) Aptroot
A40b Ascomata often with single chamber; neotropical. *Pyrenula chilensis* (Fée) R.C. Harris

A41a Ascospores <25 µm long. 42
A41b Ascospores >25 µm long. 46

A42a Hamathecium inspersed. 43
A42b Hamathecium not inspersed. 44

A43a Ascospores 13–18 µm long, with basal cilium; Mauritius. *Pyrenula muriciliata* Diederich & Ertz
A43b Ascospores 20–25 µm long, without cilium; Borneo. *Pyrenula borneensis* Aptroot

A44a Thallus UV+yellow; pantropical. *Pyrenula confinis* (Nyl.) R.C. Harris
A44b Thallus UV-negative. 45

A45a Ascospores 15–22 µm long; pantropical. *Pyrenula parvinuclea* (Meyen & Flot.) Aptroot
A45b Ascospores 7–10 µm long; India. *Pyrenula nanospora* (Ajay Singh) Upreti

A46a Old ascospores containing orange oil before shriveling; pantropical. *Pyrenula breutelii* (Müll. Arg.) Aptroot
A46b Old ascospores without orange oil, directly shriveling. 47

A47a Ascospores >80 µm long, mostly 2/ascus. 48
A47b Ascospores <80 µm long, mostly 4–8/ascus. 53

A48a Hamathecium inspersed, ascospores 90–200 µm long. 49
A48b Hamathecium not inspersed. 50

A49a Thallus UV+ yellow, with lichexanthone; neotropical. *Pyrenula xanthoglobulifera* Aptroot, Lücking & M. Cáceres
A49b Thallus UV-negative, without lichexanthone; pantropical. *Pyrenula globifera* (Eschw.) Aptroot

A50a Thallus without pseudocyphellae, ascospores 80–140(–155) µm long; pantropical. *Pyrenula platystoma* (Müll. Arg.) Aptroot
A50b Thallus with pseudocyphellae. 51

A51a Ascospores 80–180 µm long, 2-8/ascus. 52
A51b Ascospores 205–350 µm long, 1/ascus; Guyana. *Pyrenula monospora* Aptroot & Sipman

A52a Ascospores 80–110 µm long, 2-8/ascus; Hawaii. *Pyrenula neo-sandwicensis* Aptroot
A52b Ascospores 115–180 µm long, 2/ascus; pantropical. *Pyrenula duplicans* (Nyl.) Aptroot

A53a Hamathecium inspersed. 54
A53b Hamathecium not inspersed. 55

A54a Ascospores 2/ascus, 55–75 µm long; Brazil. *Pyrenula bispora* Aptroot & M. Cáceres
A54b Ascospores 8/ascus, 30–45 µm long; pantropical (India, Brazil). *Pyrenula sublaevigata* (Patw. & Makhija) Upreti

A55a Locules relatively large and angular, with up to 6 between 2 primary septa; pantropical. *Pyrenula leucostoma* Ach.
A55b Locules mostly round, at least in the central part of the ascospore with more than 6 between 2 primary septa. 56

A56a Ascospores <50 µm long. 57
A56b Ascospores >50 µm long. 60

A57a Ascospores 25–35 µm long; palaeotropical. *Pyrenula welwitschii* (Upreti & Ajay Singh) Aptroot
A57b Ascospores >35 µm long. 58

A58a Ascospores 11–15 µm wide; pantropical. *Pyrenula thelomorpha* Tuck.
A58b Ascomata 14–22 µm wide. 59

A59a Old ascospores containing colourless oil before shriveling; neotropical. *Pyrenula oleosa* R.C. Harris
A59b Old ascospores without oil, directly shriveling when old; neotropical. *Pyrenula dissimulans* (Müll. Arg.) R.C. Harris

A60a Ascomata deeply immersed in bark below the thallus, not visible, only ostioles visible; Brazil. *Pyrenula abditicarpa* Aptroot & M. Cáceres
A60b Ascomata more-or-less exposed. 61

A61a Ascospores with rounded ends; pantropical. *Pyrenula pyrenuloides* (Mont.) R.C. Harris
A61b Ascospores with pointed ends; pantropical. *Pyrenula papillifera* (Nyl.) Aptroot

Key B. Corticolous pyrenocarpous lichens with simple paraphyses and brown, transversely 3- or more septate distoseptate ascospores (mostly Pyrenulaceae: *Eopyrenula, Lithothelium* and *Pyrenula*)

B1a Ascospores 3-loculate. 2
B1b Ascospores 4- or more-loculate. 4

B2a Ascospore septation strongly asymmetrical; Madagascar. *Lacrymospora parasitica* Aptroot
B2b Ascospore septation symmetrical. 3

B3a Ascomata aggregated in grey to black pseudostromata; pantropical. *Pyrenula lineatostroma* Aptroot
B3b Ascomata dispersed, not stromatoid; Brazil. *Pyrenula biseptata* Aptroot & M. Cáceres

B4a Ascospores nearly only euseptate, locules rectangular, at most a bit rounded in the corners, end cells often paler than middle cells. 5
B4b Ascospores clearly distoseptate, locules more or less rounded or diamond-shaped. 17

B5a Ascospores more than 5 times as long as wide; South Africa. *Pyrenowilmsia wilmsiana* (Zahlbr.) Aptroot
B5b Ascospores less than 4times as long as wide. 6

B6a Ascospores only 4-loculate; macroconidia 3-septate or unknown.
B6b Ascospores 4–8-loculate; macroconidia either 1–7-septate or unknown. 12

B7a Ascoma wall dense. 8
B7b Ascoma wall cellular. *Eopyrenula*. 10

B8a Ascospores smooth, 14–17 µm long; neotropical. *Pyrenula tenuisepta* R.C. Harris
B8b Ascospores verrucose, 30–47 µm long. *Bogoriella*. 9

B9a Ascomata at least partly fused with a more or less joint ostiole; Japan; pantropical. *Bogoriella collospora* (Vain.) Aptroot & Lücking

B9b Ascomata all single; Australasian; pantropical. *Bogoriella queenslandica* (Müll. Arg.) Aptroot & Lücking

B10a Ascospores 4–5 µm wide; New world temperate. *Eopyrenula parvispora* R.C. Harris & Aptroot

B10b Ascospores 5.5–7.5 µm wide. 11

B11a Ascospores mostly <15 µm long; Atlantic (W. Europe). *Eopyrenula avellanae* Coppins

B11b Ascospores mostly >15 µm long; Atlantic (W. Europe). *Eopyrenula grandicula* Coppins

B12a Ascospores 4(–6)-loculate, macroconidia 1-septate; Old world temperate. *Eopyrenula leucoplaca* (Wallr.) R.C. Harris

B12b Ascospores (4–)6–8-loculate; macroconidia 3–7-septate or unknown. 13

B13a Ascospores mostly >15 µm long. *Eopyrenula*. 14

B13b Ascospores mostly over 25 µm long. 15

B14a Ascospores >6 µm wide, macroconidia (5–)7-septate; Atlantic Europe. *Eopyrenula septemseptata* Coppins

B14b Ascospores <6 µm wide, macroconidia 3(–4)-septate; New world temperate. *Eopyrenula intermedia* Coppins

B15a Ascospores mostly 37–47 µm long, constricted at the septa; Europe. *Blastodesmia nitida* A. Massai.

B15b Ascospores 25–35 µm long. *Requienella*. 16

B16a Ascospores 5-7-septate, rarely 3-septate; temperate. *Requienella seminuda* (Pers.) Boise
B16b Ascospores mostly 3-septate; temperate. *Requienella fraxini* Jaklitsch & Voglmayr

B17a Ascospores red brown and locules at least becoming rounded when older (species on rock not keyed out here). *Lithothelium*. 18
B17b Ascospores grey to brown, rarely red brown and then locules angular or diamond-shaped. *Pyrenula*. 22

B18a Thallus UV+ yellow; Costa Rica. *Lithothelium fluorescens* Aptroot & Sipman
B18b Thallus UV-negative. 19

B19a Ascospores 4-loculate. 20
B19b Ascospores 8-loculate. 21

B20a Ascospores 15–20 µm long; eastern palaeotropical. *Lithothelium decumbens* (Müll. Arg.) Aptroot
B20b Ascospores 25–40 µm long; northern temperate. *Lithothelium phaeosporum* (R.C. Harris) Aptroot

B21a Ascospores 30–40 µm long; northern temperate. *Lithothelium septemseptatum* (R.C. Harris) Aptroot
B21b Ascospores 55–80 µm long; New world temperate. *Lithothelium macrosporum* (R.C. Harris) Aptroot

B22a Ostioles pointing in various directions, mostly eccentric to lateral; ascomata sometimes with several chambers connected to joint ostioles. 23
B22b Ostioles apical or, when eccentric, all pointing in the same direction; ascomata with one chamber or each chamber with own ostiole. 48

B23a Ascospores 6–16-loculate. 24
B23b Ascospores 4-loculate. 27

B24a Ascospores 6-loculate. 25
B24b Ascospores 10–16-loculate. 26

B25a Ascospores 42–55 µm long, 8/ascus; neotropical (Colombia, Florida). *Pyrenula pleiomera* (Nyl.) Zahlbr.
B25b Ascospores 60–65 µm long, 4/ascus; Venezuela. *Pyrenula tetraspora* Aptroot & Sipman

B26a Ascospores 10–14-loculate, 65–90 × 17–22 µm; ascomata with single chamber; Brazil. *Pyrenula fusispora* (Malme) Aptroot
B26b Ascospores 12–16-loculate, 50–70 × 4.5–6 µm; ascomata with 5–15 stellately fused chambers; Japan. *Pyrenula tokyensis* (Müll. Arg.) H. Harada

B27a Thallus UV+ yellow. 28
B27b Thallus UV-negative. 29

B28a Ascospores 21–23 µm long; Hawaii. *Pyrenula hawaiiensis* Aptroot
B28b Ascospores 32–45 µm long; Brazil. *Pyrenula crassiuscula* (Malme) Aptroot