Non-marine algae of Australia: 2. Some conspicuous tuft-forming Cyanobacteria

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Abstract

Skinner, S. and Entwisle, T.J. (Royal Botanic Gardens Sydney, Mrs Macquaries Road, Sydney NSW 2000, Australia. email: tim.entwisle@rbgsyd.nsw.gov.au) *2001. Non-marine algae of Australia: 2. Some conspicuous tuft-forming Cyanobacteria.* Telopea *9(3): 685–712.* Tuft forming, heterocytic filamentous cyanobacteria in the Microchaetaceae, Scytonemataceae and Stigonemataceae were examined from various localities in Australia, aquatic and terrestrial. Sixteen taxa are documented here: *Coleodesmium wrangelii, Tolypotrix tenius, T. distorta* and *T. conglutinata* (newly recorded for Australia), *Petalonema velutinum* (newly recorded for Australia), *Scytonema mirabile, S. cincinnatum, S. subtile and S. hofmann-bangii*, and *Stigonema hormoides, S. ocellatum, S. informe, S. minutum*, and *S. mamillosum* as well as both *S. multipartitum* and *S. robustum* (the latter two new records for Australia).

Introduction

Various cyanobacteria with filamentous habit and heterocytes may be commonly encountered on damp soil, boggy ground, wet rock faces, the bark of trees, and in transient and permanent flowing water. Many belong to the three families Microchaetaceae, Scytonemataceae and Stigonemataceae, where most macroscopic taxa show tuft-like habits of growth, usually without gelatinous coats. Often they appear as blackish or variously yellow to rusty brown or even maroon mossy tufts either breaking the flow of water over soil or rock or streaming with it. Others form moss-like patches on rock or soil where they are occasionally inundated by rain or water streams over their substrate after storms. As with so many other freshwater algae in Australia, there are quite a number of listed records with Australian localities for various taxa in the three families (Day et al. 1995; Entwisle & Nairn 1999), but few are vouchered or adequately documented. They can be compared to their relatives that form gelatinous, and often slippery or rubbery colonies on water and on soil, described in Skinner & Entwisle (2001), or to those that lack heterocytes, the various tufted or skin-forming non-planktonic members of the Oscillatoriales, as yet awaiting critical examination in Australia.

While most of these algae are easily overlooked in the field, some are highly visible in their habitat. *Coleodesmium* is often visible in the fast-flowing, cold, clear headwaters of many catchments as brown fairy rings on pebbles and cobblestones. Species of *Stigonema* and *Scytonema* form moss-like felts at the margins of seepages and in

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waterfalls and creeks, or crusts on bare ground, rock-faces and bark, contributing to the development of vegetation cover in these habitats. Indeed, when dried at the edge of a waterway, larger growths of *Stigonema* look very like fragments of used steel wool. Hopefully our report will increase awareness of and interest in these plants.

Methods

Specimens from MEL, NSW, and selected material from BRI, including material collected by the authors, were treated in the manner discussed in Skinner & Entwisle (2001a). When necessary, specimens were stained with 1% aniline blue (with 4% molar HCl) before mounting. The comments on typification and the use of Bornet & Flahault (1886–1888) in conjunction with more recent revisions outlined in Skinner and Entwisle (2001) also apply here.

The use of the orthograph **'heterocyte'** in place of heterocyst and **'hormogonium'** for hormogone, in line with practice recommended by the International Association for Cyanophyte Research (IAC) (Mollenhauer et al. 1994), is followed here. The term 'filament' follows the usage of other authors, referring to a sheath and its trichome contents, except that in *Stigonema* we have used the term 'axis' to describe the frequently multiseriate and often corticated cell groupings, with pit connections, inside the sheath. Terms for false branching vary between authors. Bornet & Flahault (1886–1888) use geminate for paired branches, which begin as a hairpin loop, or solitary for false branches that arise laterally, and usually tangentially, to the primary filament, noting that in *Tolypothrix* such branches are marked by the production of a heterocyte as the initial cell; Geitler (1932) describes both forms but does not apply specific terms; Desikachary (1959) uses geminate and single; Komárek & Anagnostidis (1989) use 'Scytonema-type' and 'Tolypothrix-type' respectively. We have retained the term geminate, and use tangential to describe single, lateral branches often beginning with one or more heterocytes.

Taxonomy

Key to the genera

1 Thallus of filaments, single or grouped, in continuous tubular sheaths; visible pit connections between vegetative cells absent; false branching present 2

1* Thallus of axes of cells, sheaths taking outline of axes; pit connections present; true branching ..... **5. Stigonema**

2 False branches usually paired and parallel, perpendicular to parent trichome 3

2* False branching tangential and thus thallus penicillate 4

3 Trichome growth isopolar (both directions at once); mostly with geminate (paired perpendicular branching initially as a hairpin) branch formation ..... **4. Scytonema**

3* Trichome growth heteropolar (away from basal heterocyte); paired parallel branching initiated at pair of basal heterocytes (not as a hairpin) ..... **3. Petalonema**

4 Trichomes 2 or more per sheath; heterocytes globose to broadly ellipsoidal .... **1. Coleodesmium**

4* Single trichomes in sheath; basal heterocyte globose, subsequent ones cylindrical .... **2. Tolypothrix**

Microchaetaceae

Komárek and Anagnostidis (1989) place those genera with heterocytes and evenly terete trichomes that have heteropolar growth both in trichomes and at germination of hormogonia and show tangential (tolypothricoid) rather than geminate (scytonemoid) false branching, in the family Microchaetaceae. These genera were previously included in the Scytonemataceae, which is narrowed to include only those genera which show isopolar growth in both hormogonia and trichomes and geminate false branching at least in part.

1. Coleodesmium Borzi

A genus with one widely recognised species, sometimes with infraspecific taxa. Entwisle (1989) lists *C. wrangelii* for Victoria (as ecophene of *Scytonema hofmannii*).

Coleodesmium wrangelii (C. Agardh) Borzi, *Nuov. Giorn. Bot. Ital.*, 11: 348 (1879).

Thorea wrangelii C. Agardh, *Dispositio Algar. Sueciae*: 40 (1812).

Syn: *Desmonema wrangelii* (C. Agardh) Bornet & Flahault, *Ann. Sci Nat. Bot.*, 7s, 5: 127 (1887).

Tufted, green to blackish brown, to a few mm high, often forming fairy rings on stones in waterways; *thallus* much branched, penicillate, interwoven whip of trichome sheaths sometimes up to 10 mm long; *filaments* heteropolar, with lateral tangential false-branching, frequently initiated with the lateral formation of a heterocyte, and two or more filaments within, (15–)18–30(–45) µm wide; *sheath* hyaline or staining yellow to brown, smooth, with parallel lamellae, moderately thin and occasionally crimped, extending to tips of filaments or beyond; *trichomes* with basal and occasionally intercalary heterocytes, terminal cells [at either or both ends] domed, intercalary cells discoid, quadrate or cylindrical, blue, grey-green or brown L/D 0.2–1.5, 6–12(–15) µm diam.; *heterocytes* single or in pairs, obovoid, spherical or elliptical, single pored, sometimes cylindrical if second in a pair, not always present in every filament in a trichome bundle, (7–)12–15(–20) µm long, 8–12 µm diam. *Hormogonia* at ends of filaments**,**usually short, equivalent to six to ten cells, sometimes much longer, often in series of three or four, occasionally with heterocytes. (Fig. 1 a–e).

Distribution and ecology: cosmopolitan. Recorded in Australia from montane localities from the Lamington National Park in Queensland to the Marysville and Whitehouse Creek areas of the Victorian highlands and the upper reaches of the Yarra Valley. Mostly in oligotrophic, cold, fast-flowing water in well-lighted positions. Very often this taxon can be located in the field as rusty or brownish fairy rings on rocks and cobbles, in rapids or rock-races. Most specimens were heavily epiphytised by *Stichosiphon sansibaricus* (Hieron.) Drouet and Daily, giving the penicillate thalli a spotted to feathery appearance under the microscope.

Notes: Australian populations closely resemble those described by Geitler (1932) and Desikachary (1959). While some specimens show similarities to *Coleodesmiumopsis* of Dutt et al. (1982) we feel that the range of variation in our material indicates one plastic species, not two distinct genera. There is much variability in the presence and number of heterocytes in Australian collections (see Entwisle 1989), and also in the size and frequency of hormogonia. These may all be responses to local environmental factors. Three collections from north Queensland (*Entwisle 2250*, *2293* and *2318*) show a taxon with close resemblance to *Coleodesmium* in general form, but with extremely short or no confluence of trichomes and thus similar to *Tolypothrix*. They also have very short hormogonia, and clear sheaths without epiphytes.

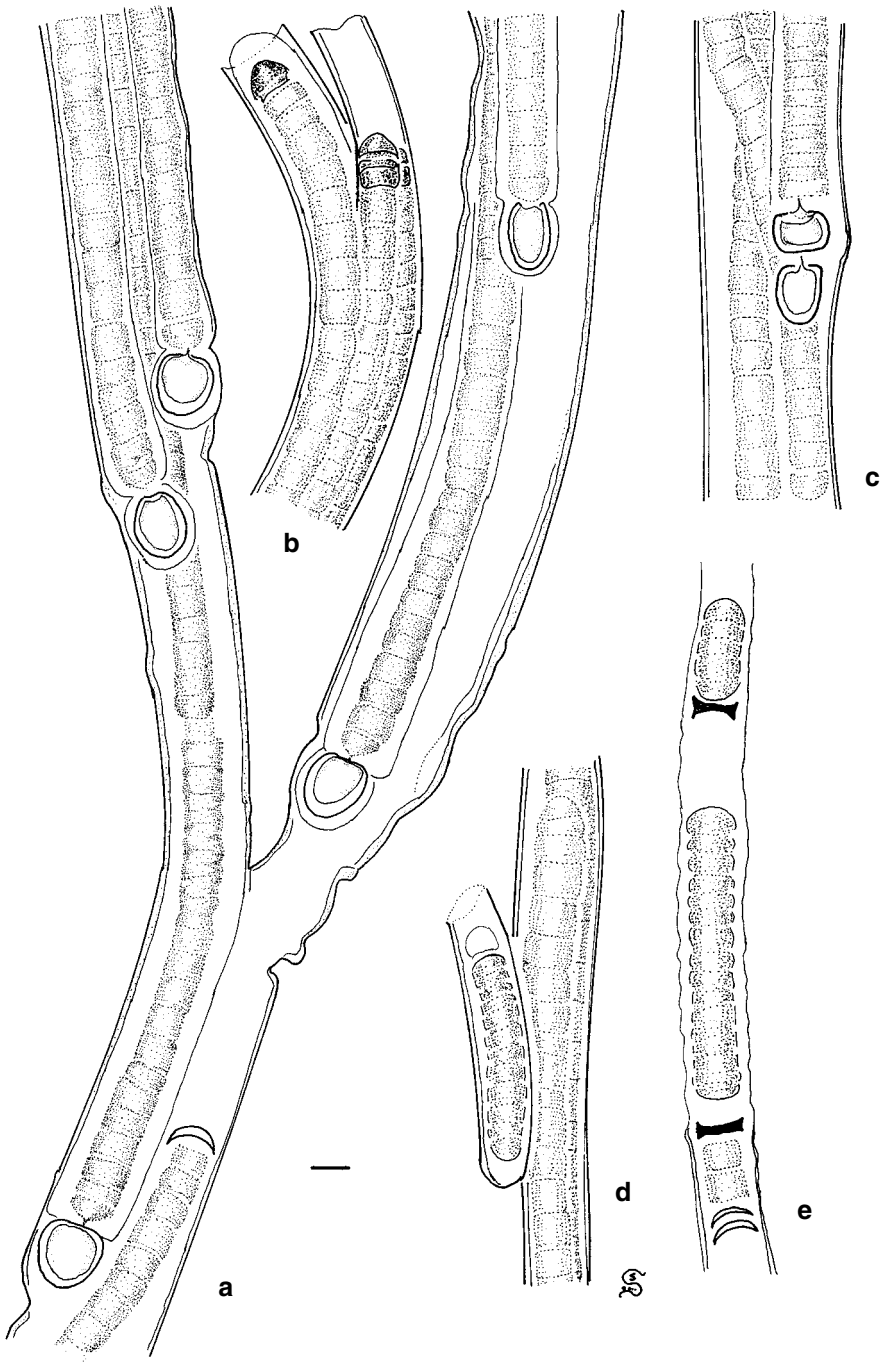

Fig. 1. Coleodesmium wrangelii a, part of filament, showing multiple trichomes and branching; **b,** tip of filament, showing closed and open sheaths, and calypterate terminals on trichomes; **c,** trichome with pair of heterocytes; **d,** hormogonium in short lateral sheath; **e,** hormogonia in sheath end (from *Skinner 0177b*). Scale bar = 10 µm.

The collections from Tullerigumai Falls in the Lamington National Park (*Entwisle 2214* and *2215*) differ from the form described above. Their cellular dimensions (trichomes less than 5 µm diam., heterocytes 12 µm diam. but only 5 µm long) and sheath dimensions (4–5 µm thick and 15–30 µm diam.) are delicate in what is usually a robust taxon. The trichomes taper and end in hairs, while the hormogonia form in series, some of which are carried oblique to the line of growth, and may be bent. These collections may well be referrable to *Sacconema* Borzi in the Rivulariaceae although they are much narrower than the form described by Prescott (1951) and differ in sheath morphology from the description and illustration in Geitler (1932).

Specimens examined: Queensland: Canungra Ck, Picnic Rock, Lamington National Park, Entwisle 2360, 14 Oct 1993 (MEL).

New South Wales: Northern Tablelands: Polblue Ck, near Polblue camping area, Barrington Tops, *Entwisle 2937*, 10 Jan 1999 (NSW); Chichester State Forest, near Barrington Tops, *Entwisle1954*, 9 Feb 1991 (MEL) Chaelundi Ck, at Chaelundi Rest Area, Guy Fawkes National Park, *Skinner 0118 & Cherry*, 23 May 2000 (NSW); Deer Park R., Waterfall Way, *Skinner 0148*, 24 May 2000 (NSW); Bullock Ck, 2 km in from highway on Point Lookout Rd, *Skinner 0175, 0177*, 24 May 2000 (NSW). Southern Tablelands: seepage 500 m from summit of Mt Kosciuszko, *Entwisle 3011*, 17 Jan 2000 (NSW); Merrits Ck, Mt Kosciuszko Walk, *Entwisle 3007B & 3008*, 17 Jan 2000 (NSW); tributary of Thredbo R., Crackenback Ridge, Thredbo, *Entwisle 3005*, 16 Jan 2000 (NSW). South Coast: Geroa R, Rockton, *Entwisle 1844*, 4 Feb 1991 (MEL); Mongarlowe R., 17 km SE of Braidwood, *Entwisle 1873*, 6 Feb 1991(MEL); Yowrie R. at Yowrie R. Crossing, *Skinner 0243*, 13 Jul 2000 (NSW).

Victoria: Steavenson R., Marysville, *Entwisle 2361*, 14 Oct 1993 (MEL) and see Entwisle (1989).

2. Tolypothrix Kützing

A genus with perhaps thirty known species, marine and freshwater, distinguished from *Scytonema* by heteropolar growth and tangential rather than geminate false branching, and from *Coleodesmium* by the obligate single trichome in filaments.

Six taxa have been recorded from Australia (Day et al. 1995; Entwisle et al. 1999), most records being from New South Wales and Queensland.

Key to *Tolypothrix* in Australia

1 Sheath close fitting; heterocytes two or more at each junction 2

1* Sheath loose-fitting; heterocyte solitary ..... **2a. T. conglutinata**

2 Trichomes of quadrate to cylindrical cells, 5–8 µm wide; filaments 10–12 µm wide ..... **2b. T. tenuis**

2* Trichomes of discoid to quadrate cells, 8–12 µm wide; filaments 12–18 µm wide ..... **2c. T. distorta**

2a. Tolypothrix conglutinata Borzi ex Bornet and Flahault, *Ann. Sci Nat. Bot.*, 7s, 5:125 (1887).

Intermixed with detritus and other algae on cases of insects; *thallus* an interwoven mat; *sheath* loose-fitting, clear, marginally crenulated; *filaments* 15–18(–20) µm wide; *trichomes* of bluish, granular, quadrate to cylindrical cells 10–12 µm wide; *heterocytes* solitary, subglobose to rounded cylindrical, L/B 1–2, 15 µm in diameter. *Hormogonia* of six to ten cells in series, separated by necridia, terminal in filaments. (Fig. 2 d–f).

Distribution and ecology: recorded from Italy, the United States and India, not previously from Australia. On boulders in rapids in fast flowing cold streams.

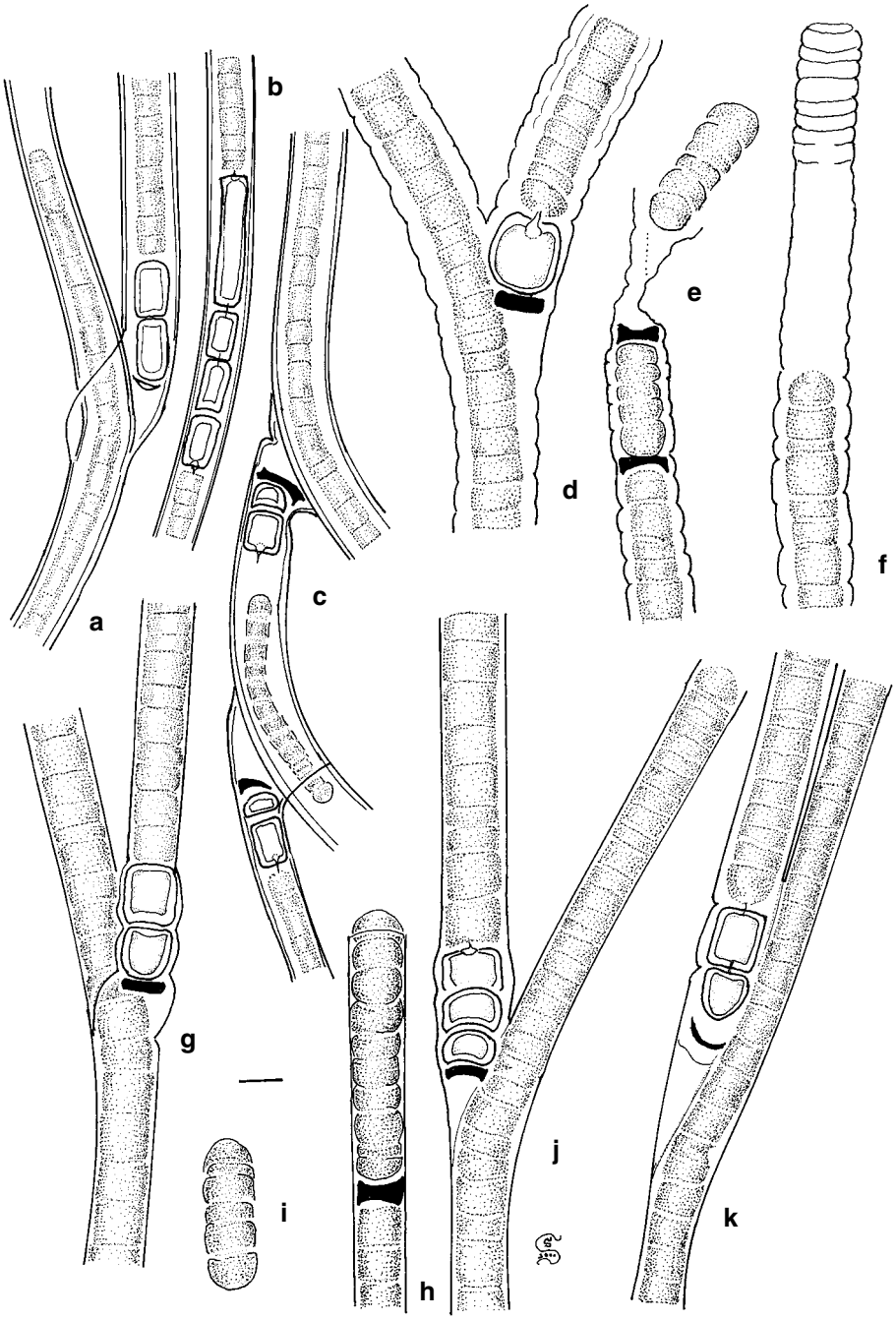

Fig. 2. Tolypthrix a–c *T. tenuis*, **a,** tangential false branching, with pair of heterocytes; **b,** series of four intercalary heterocytes; **c,** hormogonium (from *Skinner 0078*); d–f *T. conglutinata*, **d,** false branch filament, with heterocyte; **e,** hormogonium released from tip of filament; **f,** annulate tip of filament sheath and domed apical cell of trichome (from *Skinner 0138*); g–k *T. distorta* **g,** false branching filament; **h,** hormogonium; **i,** hormogonium separated from trichome by necridium; **j,** branch junction with series of three heterocytes (from *Leischman, 2000*); **k,** calypterate branch junction (from *Entwisle 2815*). Scale bar = 10 µm.

Notes: While the heterocyte is not *exacte sphæricis* as in Bornet and Flahault (1887) our collection fits their description as well as that of Prescott (1951). Although the cells are slightly larger than described by Geitler (1932) the specimens are otherwise concordant with that description.

Specimens examined: New South Wales: Northern Tablelands: Little Murray R., rapids below bridge on Tyringham–Dorrigo rd, E of Bostobrick, *Skinner 0138*, 23 May 2000 (NSW).

2b. Tolypothrix tenuis Kützing ex Bornet and Flahault, *Ann. Sci Nat. Bot.,* 7s, 5:122 (1887).

Spreading, floating among aquatic vegetation; *thallus* tightly intertwined, branching penicillate; *sheath* clear to dirty yellow, close fitting but lamellate, slightly inflated at false branch junctions, filaments (7–)10–12 µm wide; *trichomes* of yellowish blue-green grainy quadrate to cylindrical cells (4.5–) 5–8 µm in diameter, terminal cell rounded; *heterocytes* at junctions or intercalary, hemispherical, domed cylindrical, in series of two to four, L/D 1–2.5 occasionally greater, 8.5–12 µm diam. *Hormogonia* formed in terminal parts of filaments, of 6 –10 or more cells, separated by a necridium. (Fig. 2 a–c).

Distribution and ecology: cosmopolitan, previously recorded from Queensland (Möbius 1895). Found once in this study, in slow flowing, cold water drainage channels at Guyra.

Notes: Möbius' (1895) description encompasses our material, including the note that Bornet and Flahault (1887) placed value on the bulging of the sheath at junctions. Desikachary (1959) includes *T. lanata* Waltmann in *T. tenuis* and so allows both rounded and cylindrical heterocytes in the species; Geitler (1932) keeps *T. lanata* separate. Playfair (1917, 1918) recorded *T. lanata* from New South Wales but his description fits better with *T. distorta* (see note below).

Specimens Examined: New South Wales: Northern Tablelands: Mother of Ducks Lagoon, Guyra, *Skinner 0078, 0079*, 22 May 2000 (NSW).

2c. Tolypothrix distorta Kützing ex Bornet and Flahault, *Ann. Sci Nat. Bot.,* 7s, 5: 119 (1887).

Tufted or spreading, grey-green to blue-green; *thallus* interwoven, more or less erect filaments of penicillate falsely branching trichomes; *sheath* clear, thin and closely adpressed to the trichomes, except at junctions where there is a slight belling of the sheath to accommodate the branch, 12–15 µm across; *trichomes* heteropolar of similar width cells throughout, terminal cell domed and often protruding just beyond the sheath, vegetative cells discoid to more generally quadrate, blue- or grey-green and grainy, L/D 0.5–1, 12–14.5 µm diam.; *heterocytes* at junctions or more rarely intercalary, in groups of two, three or four, basal one domed, those above cylindrical, connected by pores and subtended by a necridium, contents golden, 12–25 µm long, 15–16 µm diam. *Hormogonia* in terminal sections of trichomes, equivalent to six to ten or more cells, ends rounded, and separated from remainder of trichome by necridia. (Fig. 2 g–k).

Distribution and Ecology: cosmopolitan, but previously only recorded in Australia by Watts (1864), from Warnambool, Victoria. In A.C.T. as turf in creek bed, at Long Creek forming a cover on rocks in deep pools.

Notes: Australian material closely resembles the descriptions in Prescott (1951) and Desikachary (1959) for *T. distorta,* but with more consistently quadrate cells and having only the basal heterocyte subglobose. The description of *T. distorta* var. *penicillata* (C. Ag.) Lemm. in Geitler (1932) fits the mainland material well, but the Lord Howe Island specimen is closer to the type description sense. The presence of the inflation of the sheath at junctions is not noted in those descriptions but is illustrated in

Desikachary (1959), and the dimensions of Australian material are slightly greater than those for elsewhere. *Playfair 265* (out of weeds, near intake of Nymboidea River, Grafton, 8 Oct 1915) was examined, but only the diatoms were preserved. However, from Playfair's (1918) figure and description, it may be that his *T. lanata* is similar to the material discussed here, rather than *T. tenuis*, for which it appears to be too large.

Specimens examined: New South Wales: North Coast: Long Ck, Findon Creek Rd, 8.4 km from Old Grevillea, *Entwisle 2815,* 15 Jul 1997 (MEL); Lord Howe Island, *Brown (2000/151,153) Conn & Downs*, 16 Nov 2000 (NSW). Southern Tablelands: Gibraltar Ck, Tidbinbilla Rd crossing, Pierces Ck Pine Plantation, *Leishman 80,* 6 Aug 2000 (NSW);

3. Petalonema Berkeley

A genus of few species with distinctive funnel-like sections making up the sheath, the branching having much in common with *Tolypothrix*, while sharing a superficial resemblance in sheath structure with section *Myochrotes* of *Scytonema*. Not previously recorded from Australia. Komárek and Anagnostidis (1989) accept it as a valid genus and place it close to *Tolypothrix*, as they both show heteropolarity.

Petalonema velutinum (Rabenhorst) Migula., *Krypt.-Fl.* 2(1): 131 (1907).

Symphyosiphon velutinus Kützing, *Phycologia generalis* 219 (1843).

Forming dark tufted felt on rock in water; *thallus* interwoven; *sheath* clear on outside, dark brown within, of imbricate funnel-like sleeves, with an outer clear coating, closed at ends, about 8–9 µm thick, filaments 25–35 µm diam., branching tangential or irregularly geminate, with the two basal heterocytes together or separated by a short cell group; *trichomes* solitary except for short overlaying at some branches, heteropolar, of grainy brown-blue discoid to quadrate cells, slightly constricted at crosswalls, (4–)6–8(–12) µm diam., endcell domed; *heterocytes* basal and intercalary, basals hemispherical to subglobose, with one pore, 8–10 µm diam., intercalary quadrate, with two pores, 10–15 µm diam. *Hormogonia* in short, open, narrow laterals, with four to twenty rounded units. (Fig. 3).

Distribution and ecology: Europe and Asia, with two widely dispersed records from Australia.

Notes: Australian material fits the description in Geitler (1932). The broad variation in cell size indicated above is seen in the variability of width in sections of trichomes between heterocytes, especially in branching regions of the thallus, but not involving any taper between such sections. Some sections of sheath appear to be even and continuous, and the funnels are often obscured, so that the sheath looks as if it has parallel divarications. *Petalonema* may be more widespread in Australia.

Specimens examined: New South Wales: Central Coast: Woronora R., 500 m below Dam wall, *Entwisle 2946*, 28 Jan 1999 (NSW).

Northern Territory: Tributary of the Reynolds R., crossing on Litchfield Park Rd, 1.7 km from Tolmer Falls turnoff, Lichfield National Park, *Entwisle 2680 & 2686*, 1 Jun 1997 (MEL).

Scytonemataceae

4. Scytonema C. Agardh

Nine species of *Scytonema* have been recorded for Australia. The most frequently recorded species has been *S. hofmannii* C. Ag., although this name has been applied in a very broad sense (e.g. Entwisle 1989).

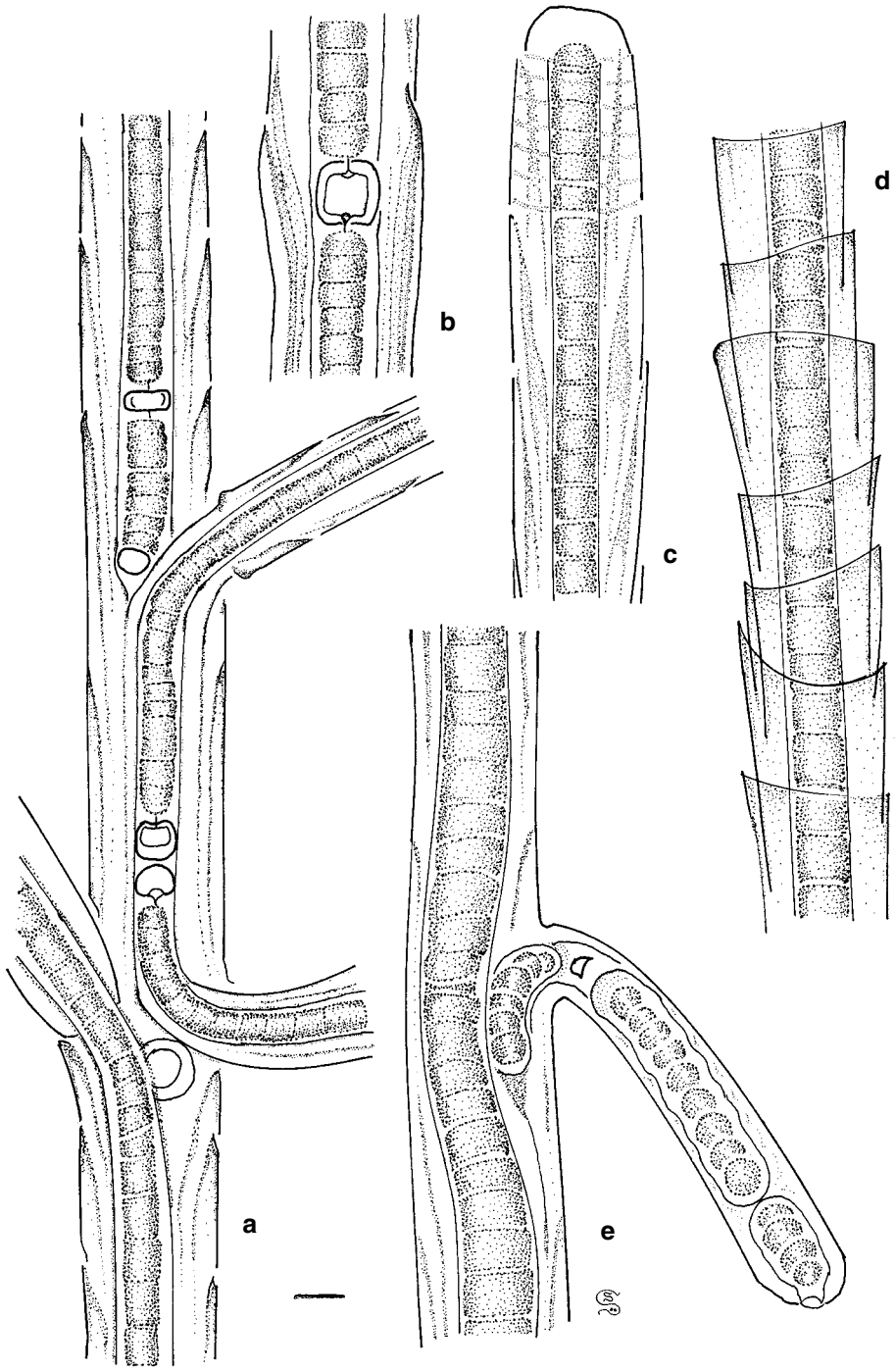

Fig. 3. Petalonema velutinum a, branching filament showing tangential and isopolar geniculate-like false branching; **b,** quadrate intercalary heterocyte; **c,** apex of filament with closed sheath and domed apical cell of trichome; **d,** section of filament with divaricate lamellae; **e**, short hormonal lateral (from *Entwisle 2946*). Scale bar = 10 µm.

Key to species of *Scytonema*

1 Sheath clear or coloured, smooth, often with laminations parallel to the direction of growth 2

1* Sheath clear outside, with darker laminations diverging from the direction of growth in the tips, and belts of pigmentation in the rest of the sheath ..... **4a. Scytonema mirabile**

2 Sheath clear; cells discoid to quadrate, about 9–18 µm in diameter .... **4b. Scytonema cincinnatum**

2* Sheath clear to coloured; cells quadrate to cylindrical, less than 10 µm in diameter 3

3 Sheath tea coloured and laminated, filaments whip-like; cells 4–7 µm wide .... **4c. Scytonema subtile**

3* Sheath clear or coloured, not distinctly laminated, filaments interwoven; cells more than 7 µm in diameter ..... **4d. Scytonema hofmann-bangii**

4a. Scytonema mirabile (Dillwyn) Bornet, *Bull. Soc. Bot. France* 36: 155 (1889).

Conferva mirabilis Dillwyn *Brit, Conf*. 96 (1808).

Aquatic, often in rafts or pontoons of algae around aquatic plants; thallus interwoven with geminate branching; sheath clear outside, darker laminations within with fine belts of pigmentation , sometimes with clearly divaricate lamellae towards tips, and annulae along inner wall, to 3 µm thick, filaments 15–18 µm diam.; trichome of blue-green to reddish brown grainy quadrate to cylindrical cells 7–10 µm diam., end cell domed; heterocyte quadrate to long cylindrical, L/D 1–3, 7–9 µm diam. Hormogonia not observed. (Fig. 4 a–c).

Distribution and ecology: cosmopolitan, widespread in Australia, in a range of aquatic habitats.

Notes: Australian material is consistent with the descriptions in Geitler (1932) and elsewhere. It is probably much more common than present collections indicate.

Specimens examined: New South Wales: Northern Tablelands: Swamp on road to Barokee Rest Area, Cathedral Rock National Park, *Skinner 0167*, 24 May 2000 (NSW). Central Coast: Woronora R., Eckersley Ford, 11 km below Woronora Dam, *Entwisle 2948*, 28 Jan 1999 (NSW); Mill Ck, 5 km E of Wisemans Ferry, *Entwisle 3019*, 29 Apr 2000 (NSW);

Tasmania: River into Old R, 5 km W of Mt Castor, South West National Park, *Entwisle 2525*, 5 Mar 1996 (MEL).

Northern Territory: Wangi Falls, Litchfield National Park, *Entwisle 2694*, 1 Jun 1997 (MEL).

4b. Scytonema cincinnatum Thuret ex Bornet and Flahault, *Ann. Sci Nat. Bot.*, 7s, 5: 89 (1887).

S. crispum (C. Agardh) Bornet, *Bull. Soc. Bot. France* 36: 156 (1889).

Aquatic, forming a spreading felt on rocks or vegetation; *thallus* of interwoven filaments with geminate and occasionally tangential false branching; *sheath* clear, wide, laminated, usually internally annulate (cincinnate), occasionally brown stained, 2–4 µm thick, closed except for hormogone release, filaments (18–)21–30 µm diam.; *trichome* of blue-green to brownish green grainy discoid to quadrate cells, 9–15(–18) µm in diam., end cell shallowly domed; *heterocytes* common or sparse, discoid to quadrate, 15–18(–21) µm diam. *Hormogonia* terminal in filaments, usually equivalent to ten to twenty cells, may be capped by calyptrae. (Fig. 4 d–h).

Distribution and ecology: widespread. In Australia, often found as greenish or brownish felt on rocks in cold, shallow, fast-flowing water in eastern Australia. Earlier

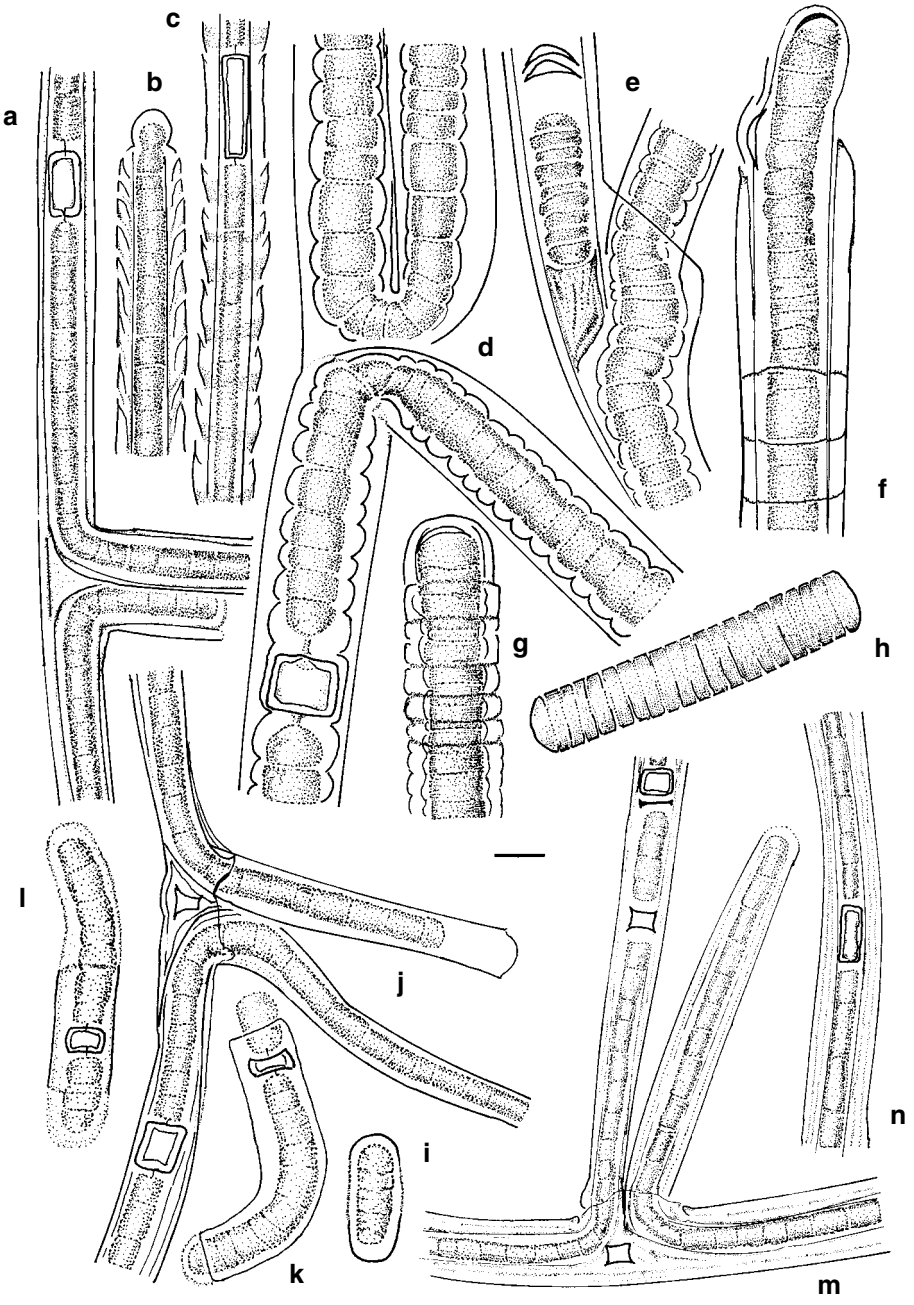

Fig. 4. Scytonemataceae a–c *Scytonema mirabile* **a,** geminate false branching; **b,** tip showing divarications and rounded end-cell; **c,** part of filament showing banding associated with unexpanded sheath segments (from *Skinner 0167*); d–h *S. cincinnatum* **d,** geminate branching; **e,** tangential branching and immature hormogonium; **f,** secondary tip after start of further growth; **g,** primary tip; **h,** mature hormogonium.(from *Entwisle 2739*); i–l *S. hofmann-bangii* **i, k, l**, three hormogones showing stages of isopolar growth (from *Skinner 0266*); **j,** geminate branching (from *Coveny 18547*). m, n *S. subtile* **m,** geminate branching and hormogonal formation; **n,** part of filament showing cylindrical heterocyte (from *Cherry 276*). Scale bar = 10 µm.

Queensland records (Bailey 1895, Möbius 1895) as described by Möbius, agree well with more recent collections.

Notes: Australian material is regularly annulate along the inside of the sheath, at least in part of a sample. The descriptions of *S. crispum/S. cinncinatum* in the literature are broad, and a number of taxa may be presently encompassed within them. Trichomes are often capped with one or a series of lunate calypterae. These are pushed aside when growth in that filament restarts.

Specimens examined: Queensland: Murray Falls, Murray R., 25 km NW of Cardwell, *Entwisle 2339*, 12 Sept 1993 (MEL).

New South Wales: Northern Tablelands:: Coombadjha Ck, Washpool National Park, *Skinner 0100*, 22 May 2000 (NSW). Central Coast: McCarrs Ck, Ku-Ring-Gai Chase National Park, *Entwisle 2929*, 3 Jan 1999 (NSW) Waratah Gully Ck, 750 m E of Berowra Railway Station, *Entwisle 3014*, 5 Mar 2000 (NSW). Central Tablelands: Bridal Veil Falls, Govetts Leap, Blackheath, *Entwisle 2991*, 4 Sept 1999 (NSW); South Coast: Endrick R., 4 km NE of Nerriga, *Entwisle 1878*, 6 Feb 1991 (NSW).

Northern Territory: The Rocks Waterhole, Kakadu National Park, *Entwisle 2739*, 5 Jun 1997 (MEL); Florence Falls, Litchfield National Park, *Entwisle 2687*, 1 Jun 1997 (MEL); Walker Ck, Litchfield National Park, *Entwisle 2689*, 1 Jun 1997 (MEL).

4c. Scytonema subtile M Möbius, *Flora, Jena* 75: 448 (1892).

Aquatic or terrestrial, forming rusty to dark brown tufts or skins on moist rock surfaces; *thallus* of frequently geminately branched, wiry, interwoven filaments; *sheath* smooth, laminate and tea-brown in colour, especially when mature, sometimes encrusted with tannins, filaments 12–15 µm wide; *trichome* of blue-green grainy quadrate to cylindrical cells, 4–6 µm diam.; *heterocytes* quadrate to cylindrical, 5–7 µm diam. *Hormogonia* rare, short, equivalent to about ten cells, 6–7 µm diam., usually in terminal section of branch. (Fig. 4 m, n).

Distribution and ecology: Recorded also from the Indian subcontinent, this species is probably quite widespread in damp terrestrial and semiaquatic situations in Australia. Like many other innocuous algae, it is rarely collected because it blends into its substrate.

Notes: short sections in the middle of the sheath, possibly marking previous ends of growth, may show annulae and a small number of divarications. Recent collections fit Möbius'(1892) description well.

Specimens examined: New South Wales: Central Coast: McCarrs Ck, Ku-Ring-Gai Chase National Park, Entwisle 3040, 5 Aug 2000 (NSW); Brisbane Waters National Park, Coveny 18558, 20 May 2000 (NSW); Sydney International rowing Course, Penrith Lakes, Skinner 0045, 11 Mar 2000 (NSW); Gap Ck Falls, Olney State Forest, Cherry 276, 10 Jul 2000 (NSW).

Northern Territory: billabong 25 km SW of Bullita Outstation, Gregory National Park, *C A Coles 91*, 13 Apr 1996 (MEL).

4d. Scytonema hofmann-bangii C. Agardh ex Bornet & Flahault, *Ann. Sci Nat. Bot.*, 7s, 5: 97 (1887).

Scytonema hoffman-bangii C. Agardh *Disp. Alg. Suec.*: 39 (1812).

Scytonema hoffmannii C. Agardh *Syn. Alg. Scand.*: 117 (1817).

Terrestrial, tufted but spreading, a few millimetres high, darkish green, brown or burgundy sometimes with a velvet sheen; *thallus* a filament suite of geminately branching individual trichomes, part of a network of isopolar 12–15(–18) µm diam. filaments with branch initiation at a distance from heterocytes; *sheath* of one, two or three layers, clear to yellow or brown, especially the middle layer, outer layer occasionally shallowly divaricate; *trichomes* of greenish grey to bluish cells, discoid to shortly cylindrical, L/D 0.2–0.75(–1.25), 7–9(–10) µm diam., and circular in cross-

section, end cell domed; *heterocytes* quadrate to cylindrical, rarely discoid, with two pores, always intercalary, single, 10–12 µm diam. *Hormogonia* short, equivalent to two, four or eight cells often including a discoid heterocyte, germination heteropolar; absent in many collections. (Fig. 4 i–l).

Distribution and ecology: cosmopolitan. Frequently recorded from Queensland, as well as the Northern Territory and Victoria (Day et al. 1995). May form as a fibrous or mealy crust or as a quite thick moss-like turf on both soil and rock in regularly moist or areas seasonally subject to drought. Where this species grows along the margins of watercourses, it may be frequently if irregularly inundated, often for only a matter of hours at a time. The crustose forms show clear geminate branching, while thicker turf formers may exhibit more tangential false branching because of the compact nature of the whole thallus and the erect disposition of most filaments.

Notes: this is the name most frequently associated with organisms of this genus in Australia. Bornet and Flahault (1887) discuss the calcification of the colonies of this taxon, commenting on the pearly sheen that this calcification gives them. Australian material shows little sign of lime encrustation but may display a velvet sheen. While the cells and heterocytes are generally morphologically similar to the descriptions in Bornet and Flahault, the range of variation, even within one specimen, in sheath structure is very wide. Anecdotal evidence suggests that around Sydney, *S. hofmann-bangii* is perhaps the most frequently encountered organism at the aquatic/terrestrial interface. As there are several variants in spelling for the specific epithet, and this taxon has been referred to each of them in even recent literature, we have included the two original forms used by Agardh.

Komárek and Anagnostidis (1989) emphasise isopolarity of growth in Scytonemataceae, and consistent heteropolarity in growth in *Coleodesmium, Tolypothrix* and *Petalonema* as reason for their inclusion in the Microchaetaceae. A number of specimens of *Scytonema* in our collection show geminate branching indicating isopolarity, and tangential lateral branching, possibly indicating some degree of heteropolarity, within the same trichome suite.

Other superficially similar organisms have been collected on soil and rock. *Porphyrosiphon notarisii* Kützing (e.g. Tinnallallie State Forest, *Entwisle 3044*, 9 Jul 2000) has cherry red sheaths, which are usually tapering and closed, and trichomes without heterocytes or geminate branching. Taxa ascribable to the form genus *Plectonema* have also been encountered in recent collections, but may be forms of *Scytonema* not producing heterocytes under their conditions of growth at time of collection.

Specimens examined: New South Wales: North Coast: Washpool, Karuah R., 6 km NNW of Stroud, *Entwisle 1942*, 8 Feb 1991; Transit Hill, Lord Howe Island, *Leishman 76*, 5 Jun 2000 (NSW). Central Coast: Deep Ck, Wakehurst Pathway, Elanora Heights, *Entwisle 2966*, 20 Mar 1999; Wheeney Ck, 10 km WSW of Colo, *Entwisle 2640 & 2641*, 24 Jul 1996; tropical house at Royal Botanic Gardens Sydney, *Skinner 0266*, 29 Aug 2000 (NSW). Central Tablelands: Bowens Ck, 29 km E of Lithgow, Mt Wilson-Bilpin road, *Entwisle 1930*, 8 Feb 1991 (NSW); Emerton, *Coveny 18547*, 9 Apr 2000 (NSW). South Coast: Wallagaraugh R., Newtons Crossing, 5 km S of Rockton-Eden rd, *Entwisle 1851*, 4 Feb 1991.

Western Australia: Fernbrook Falls, Deep R., Mt Franklin National Park, *Entwisle 2319*, 5 Jan 1994 (MEL).

Stigonemataceae

As circumscribed by Anagnostidis and Komárek (1990) this family includes genera with both main and lateral axes capable of polysticheous growth (i.e. the cells divide, after initial longitudinal division, perpendicular to the axis of growth, forming parenchymateous tissue). The family contains three genera, of which collections in

Australia have produced examples of only *Stigonema*. Anagnostidis and Komárek (1990) places *Capsosira* in another family, Capsosiraceae, emphasising their reproduction by nanocytes and monocytes, *Fischerella* in the Fischerellaceae, with main axes or trichomes of variously shaped cells and branch trichomes of cylindrical cells, and *Hapalosiphon* in the Mastigocladoideae of the Mastigocladaceae, where the trichomes are uniseriate, and not easily separable into main and branch axes. All three genera have been encountered in recent collections, but have not been included in the present paper. It is hoped that it will be possible to prepare descriptions of these taxa in the near future.

5. Stigonema C. Agardh ex Bornet & Flahault

A number of names have been applied, generally correctly, to specimens of this genus from Australian collections. The early Queensland records (Möbius 1892, 1895; Bailey 1893, 1895, 1913) are well documented, while later ones (Cribb, 1976, 1986, 1987) include mostly field data without detailed microscopic observations. Because the trichomes are usually multiseriate, at least in part, the branches are referred to as thallus axes rather than filaments. Cribb (1986, 1987) records *S. muscicola* (Thuret) Borzi ex Bornet & Flahault (= *Fischerella muscicola* (Thuret) Gomont). Geitler (1932) explained the inclusion of *S. muscicola* in *Fischerella* and the grounds for separation of *Fischerella* from *Stigonema*.

Key to species of *Stigonema*

1 Trichomes uniseriate or biseriate with occasional haphazard cortication 2

1* Trichomes with primary cortication in principal axes, followed by further cortical development with maturity 3

2 Trichomes uniseriate or, less frequently biseriate; axes 12–15 µm wide, consistently with rounded apices ..... **5a. S. hormoides**

2* Trichomes frequently biseriate, occasionally showing cortication; axes up to 46 µm wide, sometimes with clavate ends ..... **5b. S. ocellatum**

3 Plants often inconspicuous, among other algae; primary and secondary cortication only; hormogonia many celled and terminal ..... **5c. S. informe**

3* Plants usually readily conspicuous, self supporting; cortication may include tertiary rosettes; hormogonia generally with ten or fewer cells 4

4 Thallus axes with little if any tertiary cortication 5

4* Thallus axes, especially main axes, with well developed tertiary cortical rosettes 6

5* Principal axes less than 50 µm in diameter, secondary cortication within the primary whorl, cell ranks obscured; hormogonia very short ..... **5d. S. minutum**

5* Principal axes greater than 50µm in diameter, secondary cortication on surface of primary whorl, cells in distinct ranks; hormogonia two to three times longer than *S minutum* ..... **5e. S. multipartitum**

6 Axes rarely more than 100µm in diameter; short hormogonal laterals commonly verticillate ..... **5f. S. mamillosum**

6* Axes 100–150 µm in diameter; very short hormogonal laterals scattered, uncommon .... **5g. S. robustum**

5a. Stigonema hormoides Kützing ex Bornet and Flahault, *Ann. Sci. Nat. Bot.*, 7s, 5:68 (1887).

Spreading, radiating, frequently branching, usually less than 1 mm in extent, among other algae, clear or yellowish; *thallus axes* terete and even, mostly uniseriate or biseriate, with occasional sections of whorls of three to five cells, 12–15 µm diam.; *sheath* wide, not lamellate, clear to yellowish; *cells* globose to depressed globose, blue green or brown, 5–7µm diam., single or in pairs in individual wide chambers, pit connections distinct; *heterocytes* uncommon, intercalary or lateral, occasionally terminal, domed but similar to vegetative cells, prismatic and densely cytoplasmic. *Hormogonia* infrequent, terminal or on short laterals, a tightly packed uniseriate parcel of 4–8(–12) grainy cells. (Fig. 5).

Distribution and ecology: cosmopolitan. In Australia found with other algae in the coatings of rocks, seepages and waterfalls.

Notes: Australian material conforms well with descriptions in Bornet & Flahault (1887), Desikachary (1959) and elsewhere. Silva and Sant'Anna (1996) accept three varieties for Brazilian collections; with so few collections to date, we are unable to outline or assess taxonomically such variation in Australian material. *S. aeruginium* Tilden from Victoria = *S. hormoides*. While *S. hormoides* and similar species (*S. flexuosum* West & West; *S. gracile* Silva & Sant'Anna) have generally uniseriate axes, the width and nature of the sheath, and chains of chambered cells, rather than filament-like columns of cells, distinguish these taxa from either *Fischerella* or *Hapalosiphon*.

Specimens examined: Queensland: Rainbow Ck, Blackdown Tableland, *Cribb 800.11*, 2 Sept 1974 (BRI); Eungella Range, *Cribb 739.23*, 14 Jan 1973 (BRI).

New South Wales: North Coast: Lord Howe Island, *Brown 2000/130, Conn & Downs*, Nov 2000 (NSW). Central Tablelands: Adelina Falls, Lawson, *Coveny, Brown (223) & Downing*, 14 Mar 2001 (NSW).

5b. Stigonema ocellatum (Dillwyn) Thuret ex Bornet & Flahault**,** *Ann. Sci. Nat. Bot.*, 7s, 5: 69 (1887).

Conferva ocellata Dillwyn *Brit. Conv*. 60 (1809).

Tufted, less than 5mm high, wine coloured or yellowish brown; growth pattern stoloniferous with erect axes having widely separated alternate branches of variable length; *thallus axes* mostly uniseriate, with sections of whorls of two or three cells especially in stolons and main erect axes, 20–45(55) µm diam.; *sheath* thick, lamellated, yellow to brown, lamellae in tips divaricate downwards; *cells* depressed globose to quadrate, (7–)15–35 µm diam., in thick-walled chambers, pit connexions distinct; *heterocytes* infrequent, intercalary or lateral, where trichome biseriate, as one of the pair of cells in shape, prismatic and densely cytoplasmic. *Hormogonia* terminal on most axes, granulate, 30–35 µm long, 15 µm diam.; sheath with terminal pore and divergent lamellae. (Figs 6, 7 a).

Distribution and ecology: cosmopolitan. Attached to boulders and vegetation at margins of upper reaches of rivers, on granite boulders in tablelands, on rocks in coastal areas even perhaps in the splash zone. Herbarium records show this species in Queensland, from the tropics to the Darling Downs, and in the coast and ranges of New South Wales. Cribb (1986, 1987) records this species from a small lagoon on the Jardine River, and Lower Kroombit Creek, inland from Gladstone, Queensland.

Notes: this species is almost certainly much more widespread than our records show. It is probably the predominant species forming purple black smudges at the margins of soakages in sandstone and granite country, but is either overlooked or more or less invisible in dry weather. The differences between this species and the uniseriate or

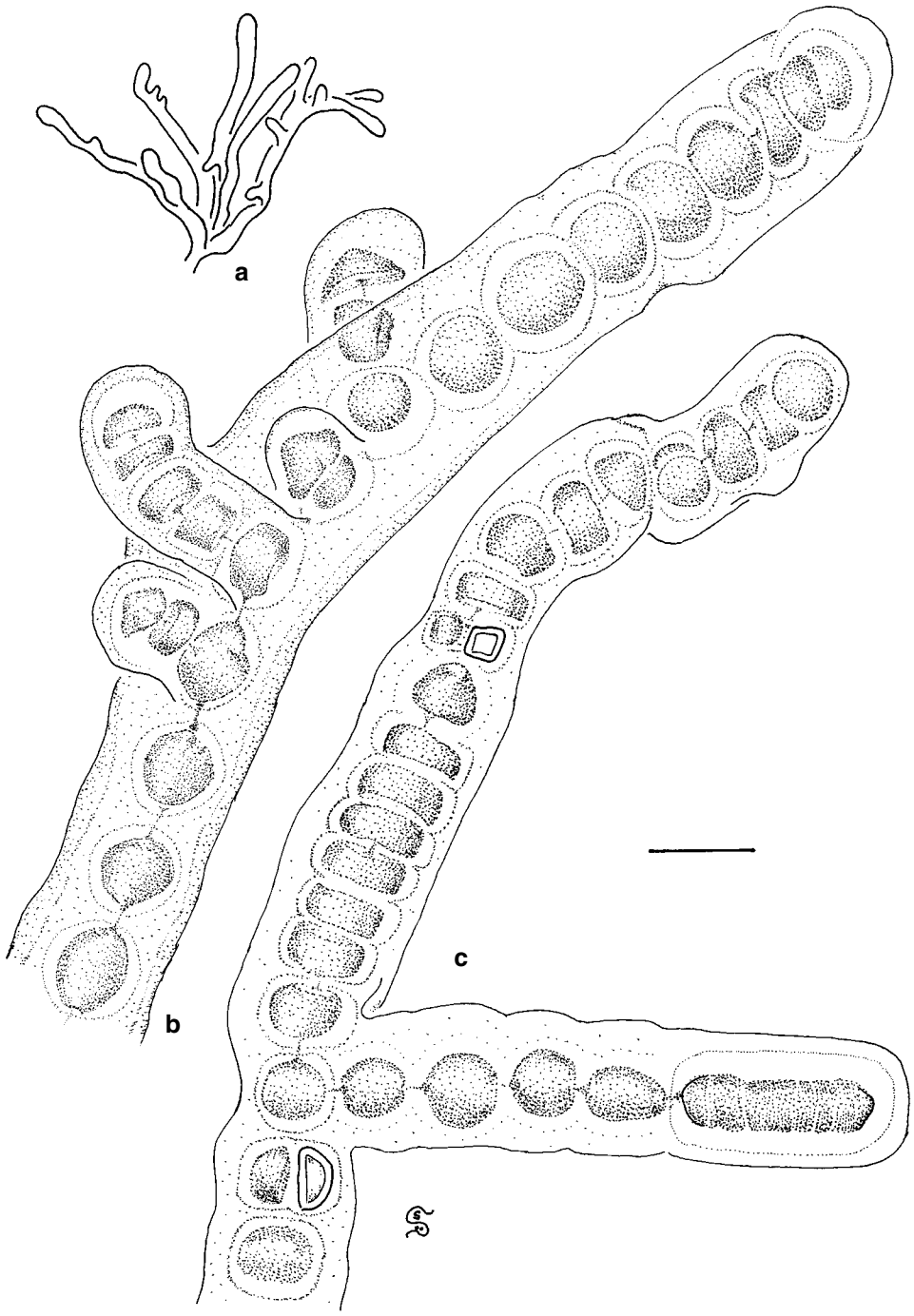

Fig. 5. Stigonema hormoides a, tracing to show habit; **b,** vegetative axis, with lateral initials; **c,** vegetative axis, with lateral hormogonal branch (from *Brown (2000/130) Conn & Downs*). Scale bar = 10 µm, tracing not to scale.

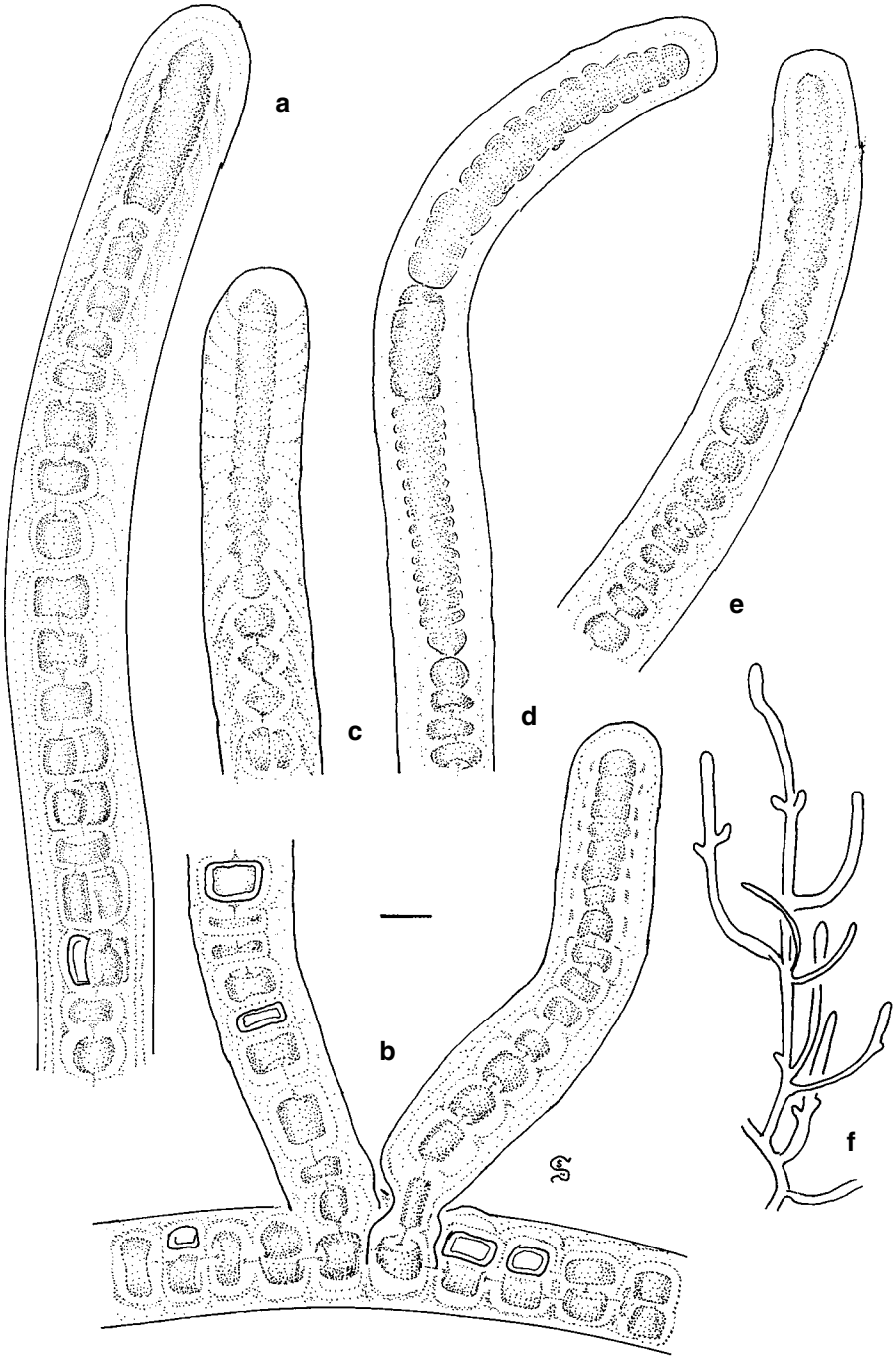

Fig. 6. Stigonema ocellatum a, b, vegetative axes, showing branching and apical development (from *Skinner 0167*); **c,** apex with concentric lamellae; **d,** mature hormogonia in tip of axis; **e,** developing hormogonium; **f,** trace to show habit, fragment (from *Skinner 0174*). Scale bar = 10 µm, tracing not to scale.

slightly corticated laterals of more corticated species are not great and it may be that this species represents the least complex of a range of forms in one very plastic taxon.

More narrowly, the group of morphologically similar taxa to which *S. ocellatum* belongs are not readily separated. The fragmentary specimens from Tomah Spur (*Cherry 224, 227 & 228*) could be placed in *S. turfaceum* (Berkeley) Cooke because of the degree of primary cortical development in parts of the thalli, but it seems more appropriate to include them in *S. ocellatum* until further collections are made in the area.

The Hamilton and Lucas collection has had an interesting history. As far as we are aware, Lucas did not pass a sample on to Playfair, although at least six duplicates were made, and one at least lodged at Sydney University for some time. No *Stigonema* is cited in Playfair (1917). Lucas labelled Hamilton and his collection as *S. ocellatum*, but may have had reservations, or may have intended to seek overseas verification. While conforming to the species in most aspects, and being towards the upper limits of dimensions, this collection shows lateral hormogonal tubes rather than the modified axial tips described for the species.

Specimens examined: Queensland: Twin Falls, Canal Ck (Cape York), *Cribb 1198.2*, 14 Mar 1992 (BRI); Bruster Ck, Cape York, *Cribb 1039.3*, 29 Aug 1985 (BRI).

New South Wales: Northern Tablelands: Round Mountain Rd, near Barokee Rest Area, Cathedral Rocks National Park, *Skinner 0167*, 24 May 2000 (NSW); Oakey R., Cathedral Rocks National Park, *Cherry* (*Skinner 0174)*, 24 May 2000 (NSW).

Central Coast: Quarantine Station, North Head, Sydney Harbour National Park, *Skinner 0058*, 8 May 2000 (NSW); Woronora R., Heathcote, *Hamilton & Lucas s.n.*, 4 Oct 1915 (NSW A2157–2160). Central Tablelands: tributary of Gadara Ck, Bilpin, *Cherry 99/6,* June 1999 (NSW); Tomah Spur, *Cherry 224, 227* & *228*, 28 Mar 2000 (NSW).

5c. Stigonema informe Kützing ex Bornet & Flahault, *Ann. Sci. Nat. Bot.*, 7s, 5:75 (1887).

Minute tufted fragmentary thalli, among other turf organisms, brown; *thallus axes* multiseriate, primarily corticated (4 to 6 cells per whorl) or uniseriate, 25–35(–40) µm diam., occasional patches of secondary cortication; *sheath* moderately closefitting, yellow brown, lamellate, especially in hormogonangia; *cells* blue-green, compressed globose in uniseriate areas, or subquadrate and domed in areas of primary cortication, L/D 1–1.5, 6–9 µm diam.; *heterocytes* lateral, scattered, not uncommon, similar to vegetative cells. *Hormogonia* formed in terminal sections both main and lateral axes or in short lateral branches, 45–60(–65) µm long and 8–10 µm diam; hormogonial sheath lamellate, diffusely flared, opening by a wide-mouthed pore, persistent. (Fig. 7 b–d).

Distribution and ecology: widespread. In Australia, recorded from coastal waterways.

Notes: This species may be seasonal, as much of the thallus has empty sheaths and cell walls in some specimens and the plant does not form the concentrated masses of 'old steel wool' that some others do. The axes are mostly uniseriate or primarily corticated, with short sections of regular secondary cortication in basal positions, and other axial areas where the cells are disjunct and irregularly displaced in the sheath.

Specimens examined: Queensland: Tributary of Sanamore Lagoon, Cape York, *Cribb 1043.3*, 3 Sept 1985 (BRI).

New South Wales: North Coast: Lord Howe Island, *Brown 2000/130, Conn & Downs*, Nov 2000 (NSW). Central Coast: McCarrs Ck, Ku-Ring-Gai Chase National Park, *Entwisle 3044*, 5 Aug 2000 (NSW).

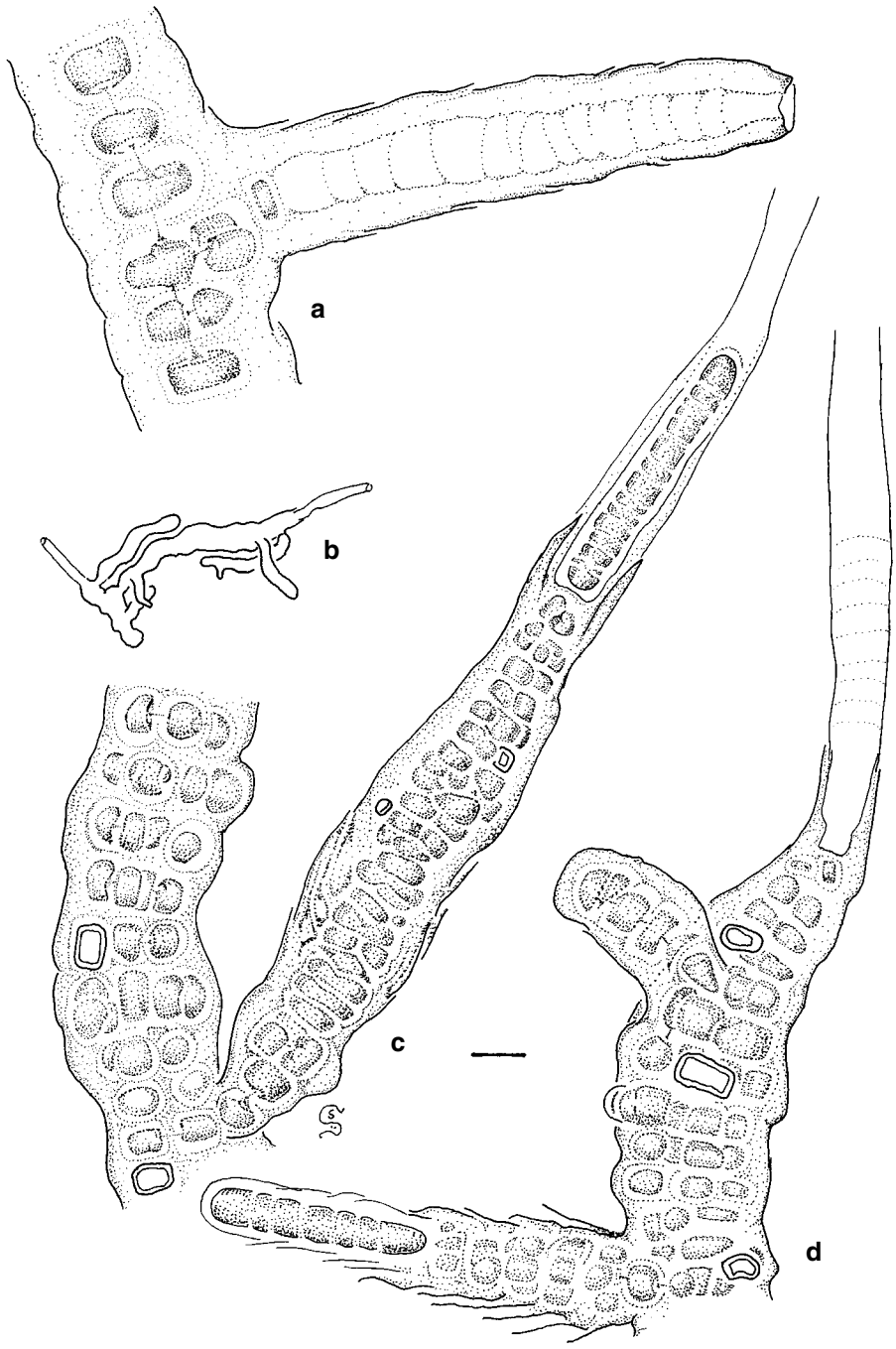

Fig. 7. Stigonema a, *S. ocelletum* empty hormogonial lateral (from *Hamilton & Lucas 1915*); b–d, *S. informe* **b,** habit tracing of whole plant; **c, d,** thalli with terminal hormogonia in lateral axes (from *Brown (2000/130), Conn & Downs*). Scale bar = 10 µm, tracing not to scale.

5d. Stigonema minutum Hassall ex Bornet & Flahault, *Ann. Sci. Nat. Bot.*, 7s, 5:72 (1887).

Closely entangled, tufted, to 5 mm high, rusty brown or darker; *thallus axes* much branched, uniseriate at first, becoming primarily and secondarily corticated at the same level, primary divisions longitudinal, secondary divisions oblique or longitudinal, or more rarely transverse, and mother cell wall retained so becoming rosette-like, giving rise to whorls of (6–)8–10(–12) cells, axes 35–45(–120) µm diam.; *sheath* closefitting, lamellate and moderately thick, usually tinted yellow to brown; *cells* subquadrate and domed, thick walled, 15–20 µm long, 10–20 µm diam.; *heterocytes* variable in occurrence, lateral and usually similar in shape to vegetative cells. *Hormogonia* developed singly or in series in specialized laterals, which may or may not continue to develop later, 21–25 µm long, 10–12(–15) µm diam. (Fig. 8 a–c).

Distribution and ecology: cosmopolitan. Usually growing as turf at margins of waterways, especially over rock, in Australia.

Notes: Australian specimens match descriptions in Bornet and Flahault (1887) and in Geitler (1932) for form of thallus, but show a greater differentiation of cells in cortication, at least in parts of *Cribb 789.11* and *Skinner 0089*. The material is clearly distinct from *S. informe*, having short and generally lateral hormogonia, rather than long terminal ones however it may be that our collections represent a less well developed form of *S. mamillosum*.

Specimens examined: Queensland: Sow and Pigs, Amiens, *Cribb 789.9 &789.11*, 14 Apr 1974 (BRI), and *J.M. Cribb s.n.*, 24 Mar 1978 (BRI 453542).

New South Wales: Northern Tablelands: Boundary Creek Falls, Moogem State Forest, *Skinner 0089*, 22 May 2000 (NSW).

5e. Stigonema multipartitum Gardner, *University of California Publications in Botany* 14: 9 (1927).

Conspicuous, turf forming, to a few millimetres high, brown to black (especially when dry); *thallus* of principal axes with widely spaced clumps of secondary axes and hormogonal laterals; principal axes to 80 µm wide with distinct whorls of six to eight cell chambers in ranks; lateral axes attenuated at bases and narrower than principal axes; axes with an apical domed cell, primary cortication into whorls of cell chambers occurring within the first five divisions; secondary cortication by both transverse and perpendicular division of primary cortical cells inside the cell chambers, so that the axis has the appearance of more or less ordered ranks of cells; *sheath* following the outline of the whorls, wide, somewhat lamellate, yellow to tea- or rusty brown; *cells* generally quadrate to subcylindrical, or domed, grainy, bluegreen, about twice as big when primary than when secondary, at first in whorls of 6 to 8 (10), then singly in cell chambers in primary cortication, then 2 to 4 or more per cell chamber in secondary cortex, 8–15(–25) µm diam.; *heterocytes* scattered, occasional to frequent, domed, among other cells in whorl, similar in dimensions to secondary cells. *Hormogonia* either lateral to axis or apical in short laterals, associated with regions of branching, flattened cylindrical, about ten cell equivalents, 40–70 µm × 15–20 µm, sheath persistent, clear. (Figs 8, d, e, 9).

Distribution and ecology: previously recorded from China. Common in clean, fast flowing permanent and transient waterways in eastern Australia. Found as a spongy turf-like emergent on rock.

Notes: with the cortication in neat bulging rings, the main axes look rather like pieces of some archaic Michelin Man. The Australian material conforms well to both the original description of Gardner (1927) and with Geitler (1932). It differs from

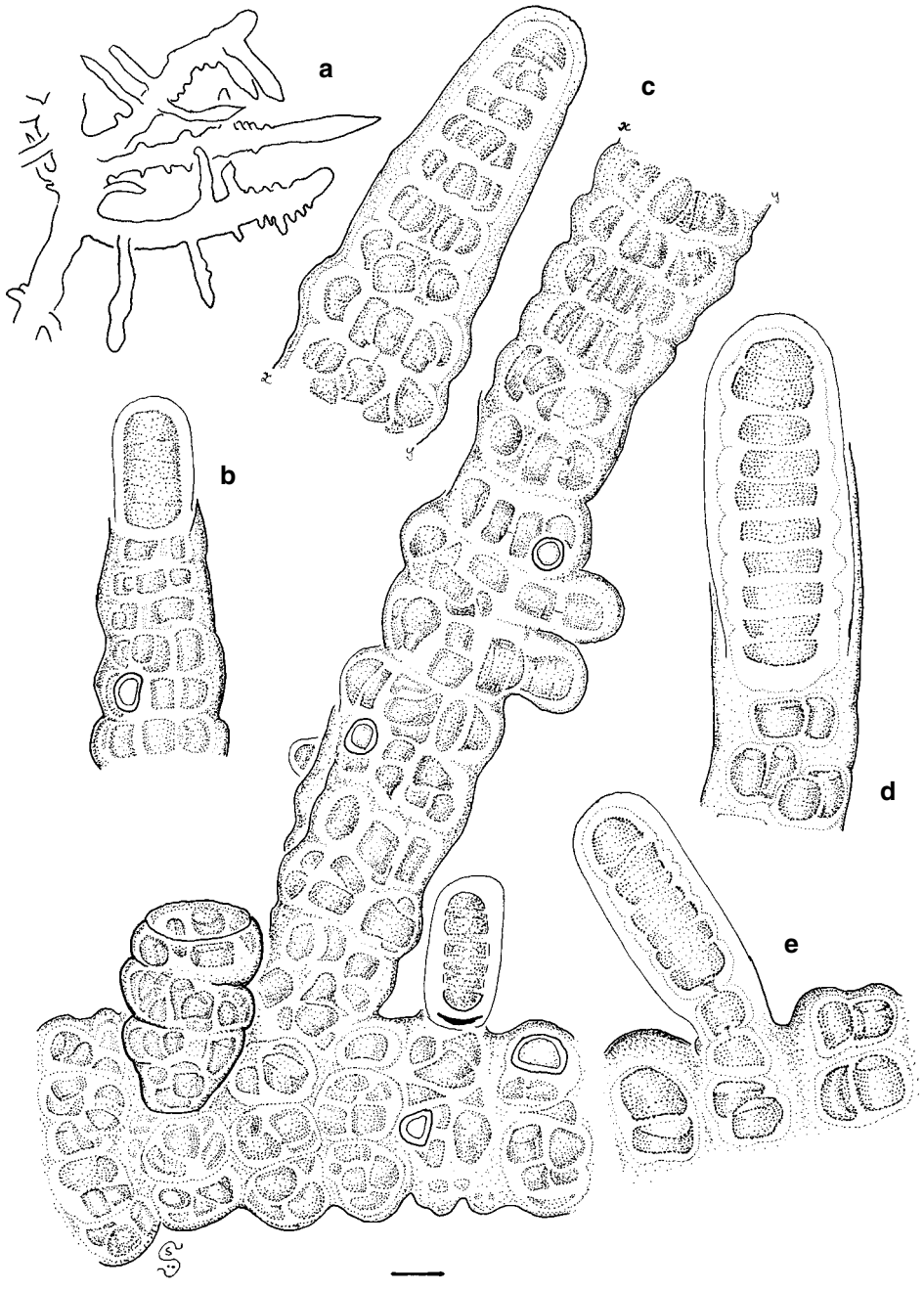

Fig. 8. Stigonema a–c, *S. minutum* **a,** habit tracing of part of thallus; **b,** terminal hormogonium; **c,** lateral axis arising from main axis, with lateral hormogonium on main axis (from *Skinner 0089*); d, e, *S. multipartitum* **d,** terminal hormogonium; **e,** lateral hormogonium (from *Entwisle 2973*). Scale bar = 10 µm, tracing not to scale.

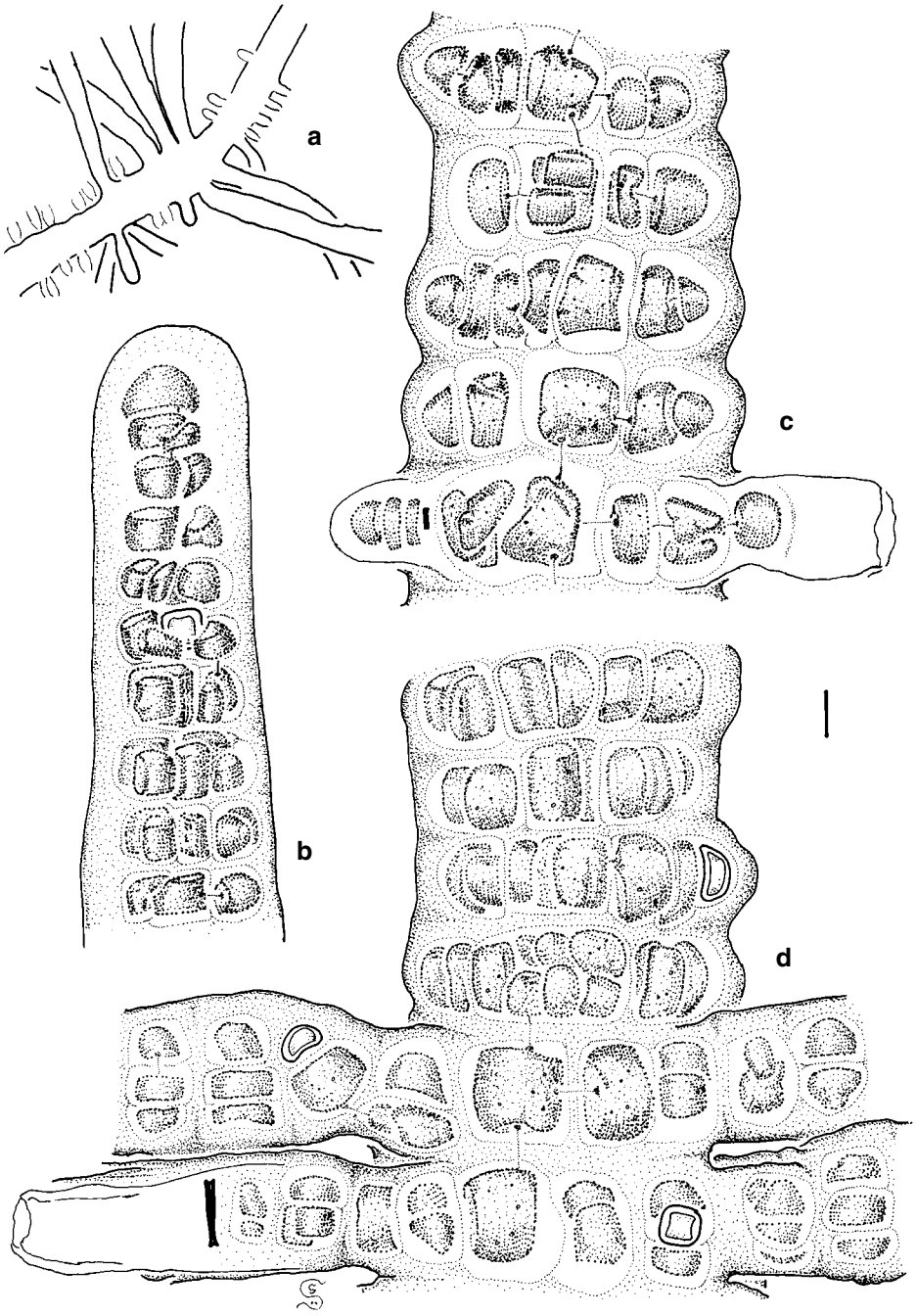

Fig. 9. Stigonema multipartitum a, tracing of branching region of thallus; **b,** apical tip with primary cortication; **c,** secondary cortication and lateral initials; **d,** lateral bases, showing attenuation (from *Entwisle 2978*). Scale bar = 10 µm, tracing not to scale.

S. minutum in generally forming larger plants, and having a neat, ranked appearance in both primary and secondary cortication, as well as having hormogonia more than twice as large. Generally similar to *S. mamillosum* in field appearance, *S. multipartitum* rarely shows tertiary cortication, and this is less rosette-like than *S. mamillosum*, and the hormogonia are large, grouped but not in whorls.

The specimens from Carrington Falls, near Robertson (*Entwisle 3016*) show two kinds of mature thallus. Some thalli have older axes with well developed secondary cortication, where the cells in the whorls are large and rather square in face view and from which arise the hormogonangia. Others have axes with tertiary cortication of rosettes of smaller cells and few if any hormogonia.

Specimens examined: Queensland: Birthday Ck Falls, Palmira Range, *Cribb 719.4*, 20 Dec 1973 (BRI); Bowen Ck, Hinchinbrook Island, *Cribb 894.6*, 25Aug 1979 (BRI); Rainbow Ck Falls, Blackdown Tableland, *Cribb 800.2*, 3 Sept 1974 (BRI).

New South Wales: North Coast: Boggy Ck, above Minyon Falls, Minyon Drive, off Nimbin–Gonnengerry Rd, *Entwisle 2978*, 14 Jul 1999 (NSW). Central Tablelands: Bridal Veil Falls, Govetts Leap, *Entwisle 2991*, 4 Sept 1999 (NSW); Douglas Ck, the Pheasant Grounds, *Entwisle 1902*, 6 Feb 1991 (MEL); Carrington Falls, Kangaroo R., *Entwisle 3016*, 17 Apr 2000 (NSW). Central Coast: Deep Ck, near Wakefield Pathway, Elanora Heights, *Entwisle 2967*, 20 Mar 1999 (NSW); West Head, Ku-Ring-Gai Chase National Park, *Entwisle 2927*, 3 Jan 1999 (NSW); McCarrs Ck, Ku-Ring-Gai Chase National Park, *Entwisle 3040*, 5 Aug 2000 (NSW). Southern Tablelands: creek into Lake Cootapatamba, Kosciuszko National Park, *Entwisle 3012*, 17 Jan 2000 (NSW).

5f. Stigonema mamillosum (Lyngbye) C. Agardh ex Bornet & Flahault, *Ann. Sc. Nat. Bot.*, 7s, 5: 77 (1887).

Bangia mamillosa Lyngbye, *Tent. Hydroph. Dan*. 85 (1819).

Forming dark brown to black moss-like turfs, 5–10 mm high; *thallus* much branched primary axes, secondary axes widely spaced, often arising in twos or threes; primary axes 50–85(–100) µm diam., secondary axes to 70 µm; apical region of 5 to 10 discoid cells, terminal cell domed; primary cortication of a whorl of 8 to 12 cells; secondary cortication by both longitudinal and transverse division into 2 to 8 cells per cell chamber; tertiary cortication into rosettes of 4 to 8 cells, in 5 or 6 groups of cell chambers, 3 to 5 groups per whorl; mature axes distinctly verticillate; *sheath* thick, lamellate, following contours of cell whorls, reddish to tea-brown; *cells* small, irregular subglobose to quadrate, grainy, bluegreen, 5–8(–10) µm diam.; *heterocytes* occasional to common, domed subglobose or quadrate, similar in dimensions to surrounding cells. *Hormogonia* short, usually in whorls lateral to axes, occasionally solitary, terminal on short laterals, of 6 to 8 cell equivalents, 15–25 µm long and 14–16 µm diam., in chambers with inner clear sheath and sometimes lamellate persistent outer sheath. (Fig. 10).

Distribution and ecology: cosmopolitan. Most frequently found in cold unpolluted fast flowing streams in rocky terrain, as moss-like turf emergent at front and sides of boulders, sometimes among bryophytes and other algae on faces of waterfalls, in eastern Australia.

Notes: Australian material conforms to descriptions in Geitler (1932) and Silva and Sant'Anna (1996). The distinctive rosettes of tertiary cortication and hormogonia in whorls separate it from *S. multipartitum*, while *S. robustum* is usually larger, with less regular tertiary cortical whorls, and smaller, lateral hormogonia.

There is a wide range in size of clumps from short barely macroscopic pieces through 1 or 2 mm high tightly branched tufts to wiry, open branching, spreading moss-like easily visible patches, which may be hummock forming. Anecdotal evidence suggests that this taxon or a related one may be responsible for hummocks in bogs and fens in

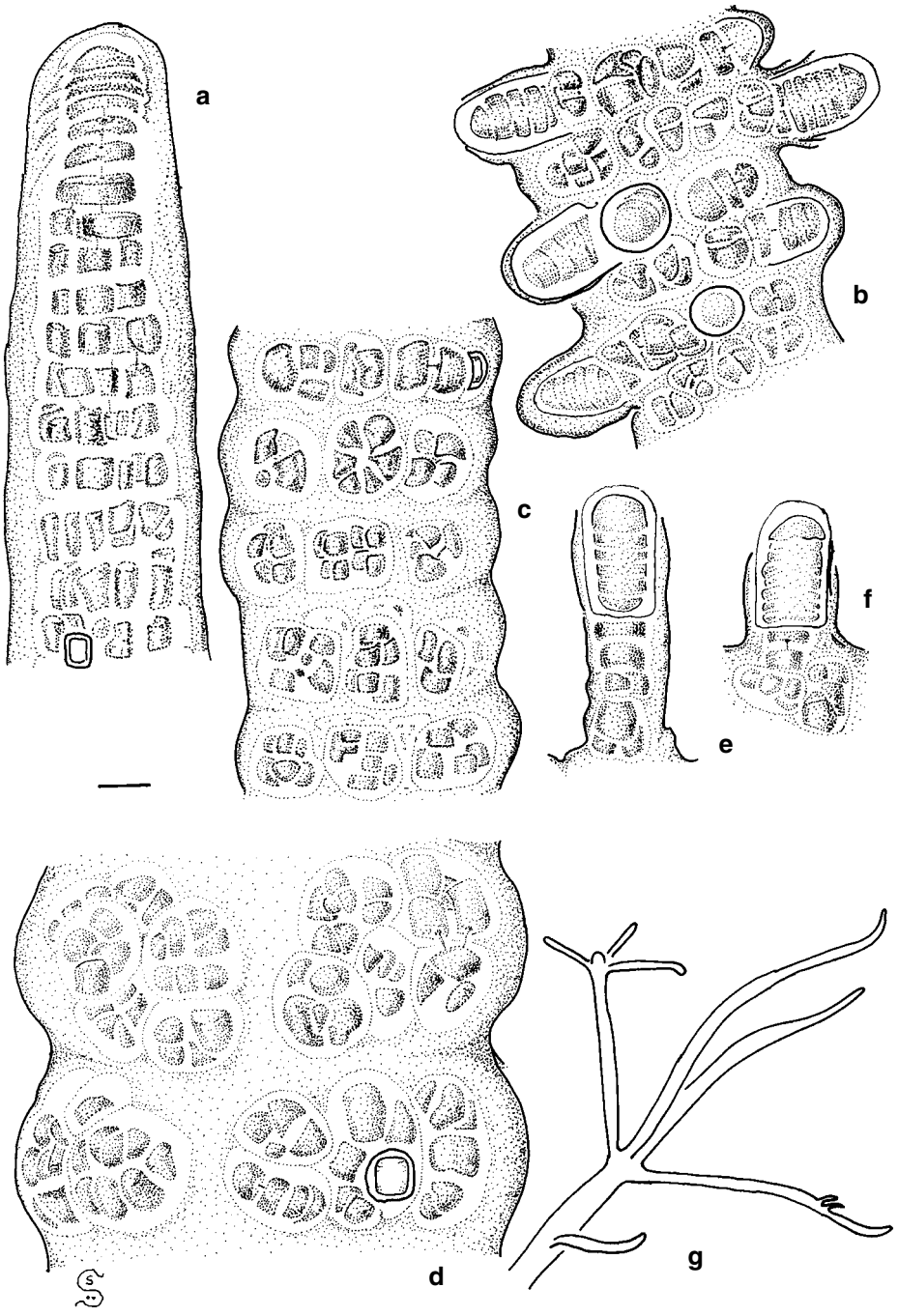

Fig. 10. Stigonema mamillosum a, apical tip with primary cortication; **b,** secondary cortication; **c,** rosettes of tertiary cortication (from *Skinner 0096*); **d,** developing whorls of hormogonia; **e,** hormogonium on short lateral; **f,** sessile hormogonium (from *Duretto 714*); **g,** tracing of upper region of axes, to show branching (from *Skinner 0096*). Scale bar = 10 µm, tracing not to scale.

high country on the New England tableland. Other specimens with well developed tertiary cortication (*Duretto 701*) have a warty appearance about the axes.

Specimens examined: Queensland: Lamington National Park, *Cribb 544.2,* 10 Sept 1963 (BRI).

New South Wales: Northern Tablelands: Boundary Ck Falls, Moogem State Forest, *Skinner 0096*, 22 May 2000 (NSW); Coombadjha Ck, Washpool National Park, *Skinner 0103*, 22 May 2000 (NSW). Central Coast: Lovett Bay, Ku-Ring-Gai Chase National Park, *Entwisle 2926*, 3 Jan 1999 (NSW). South Coast: Tianjara Falls, *Duretto 701*, 30 Oct 1995 (MEL); tributary of Plain Back R., Wadbilliga National Park, *Duretto 714*, 1 Nov 1995 (MEL).

5g. Stigonema robustum Gardner, *University of California Publications* 14: 9 (1927).

Moss-like tufts, 5 mm or higher, often spreading widely, yellowish, reddish or bluish brown when live, drying black, sometimes attached to the substrate by calloused rhizoidal pads (Fig. 11c); *thallus axes* multiseriate, except in tips, primary cell divisions longitudinal, giving rise to whorls of 10–12 cells, secondary cortication by further longitudinal division or by transverse or oblique division, with radiating tertiary cortication perpendicular to the axis leading to a single or double whorl of cells in rosettes which may become defluent, mature axes distinctly verticillate, (75–)90–120(–150) µm wide; *sheath* relatively thin, becoming worn and tattered on older axes, lamellate and yellow stained when young becoming darker and opaque with age; *cells* subquadrate in face view, with thick cell chambers, to 15 µm long, 6–10(–15) µm diam. but usually much smaller; *heterocytes* lateral, similar to vegetative cells, variable in occurrence. *Hormogonia* very short, in own envelope, 10–15 µm long, 8–10 µm wide, in apices of short lateral axes, with terminal pore, divergently lamellated sheath, which is persistant. (Fig. 11).

Distribution and ecology: recorded from China and Brazil. The Australian collections are mostly montane, in or beside running water, in association with other clean water algae.

Notes: Both Gardner (1927) and Geitler (1932) describe hormogonia crowded in short branches. Silva and Sant'Anna (1996) did not observe reproductive structures of any kind. Australian material showed short, encapsulated hormogonia in the tips of short laterals, not readily distinguishable from new growth in other apices except for the opening of the chamber. These were not 'congested'. In other respects the material appears to fit published descriptions of this taxon.

Some ends of branches in *Betche* Feb 1903 are calloused. While not as marked, small areas of irregular lateral development can be seen in some other specimens, and may be points of contact or attachment with surrounding surfaces, similar to rhizoidal development in other organisms.

A number of specimens of the last two taxa show infection by a microfungus, which lives in the outer sheath layers of the axes and pushes through the sheath to release its propagules. The presence of the fungus does not seem to affect the health of the host plant.

Although we have circumscribed seven species in Australia, there may in reality be only one or two species in the strict biological sense. Specimens such as *Cribb 789.11*, which show the form of *S. ocellatum* at the edges of an extensive mat with increasing cortication in older parts, indicate that maturity and habitat may play very considerable parts in the expression of the phenotype. We have seen many collections where fragments exhibit features of several taxa. There is considerable scope for culturing and molecular studies on the Stigonemataceae, which may clarify relationships and ranges of variability.

Specimens examined: New South Wales: Northern Tablelands: Boundry Ck, Moogem State Forest, *Walsh s.n.,* 16 Sept 1994 (MEL); Bullock Ck, Point Lookout Rd, *Skinner 0117a*, 24 May 2000 (NSW).

Central Tablelands: Rodriguez Pass, Blackheath, *Betche s.n.*, Feb 1903 (NSW). Central Coast: creek going into Lovett Bay from West Head Rd, Ku-Ring-Gai Chase National Park, *Entwisle 2926 & 2927*, 3 Jan 1999 (NSW). Southern Tablelands: Snowy R., Charlotte Pass, *Entwisle 1574*, 12 Nov 1988 (MEL); Spencers Ck, Charlotte Pass, *Entwisle 1569*, 11 Nov 1988 (MEL); Merrits Ck, *Entwisle 3006, 3007b*, 17 Jan 2000 (NSW); Endrick R., 5 km NE of Nerriga, *Entwisle 1879*, 6 Feb 1991 (MEL).

Conclusions

There is clearly much collecting and research to be done to achieve a more complete picture of these Cyanophytes in Australia. We have yet to find any endemic taxa in the three families documented here. Biogeographical information is at present inadequate to indicate connexions with other floras, other than to suggest some links with the north-west Pacific.

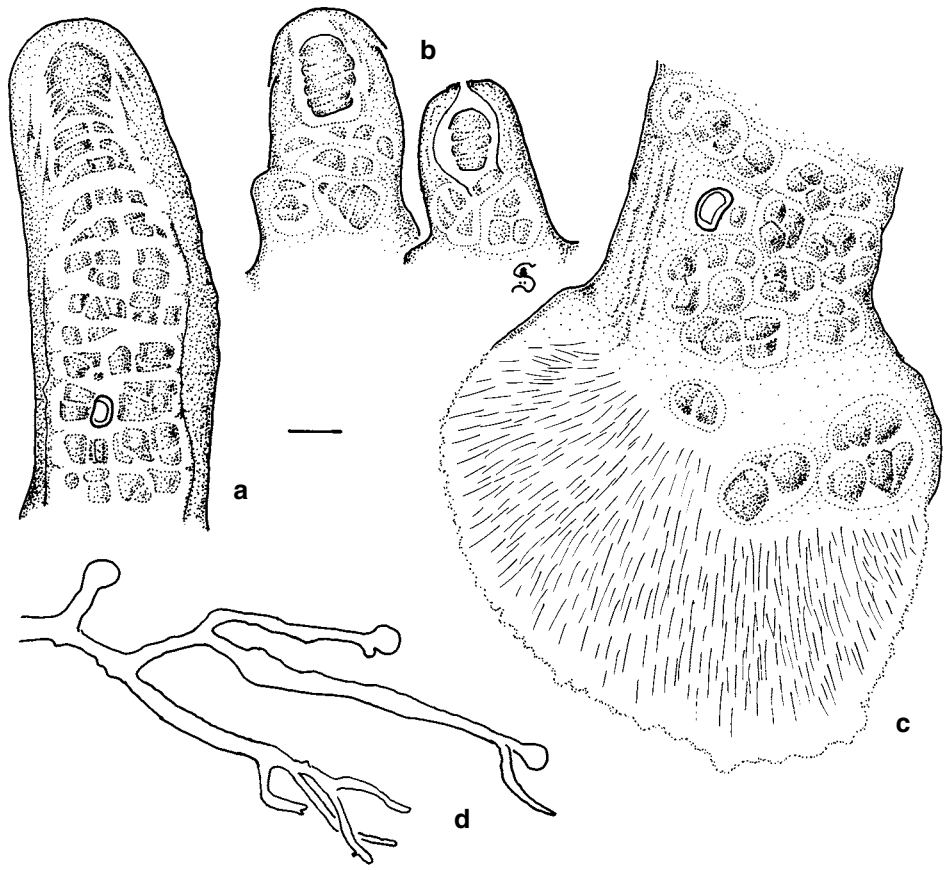

Fig. 11. Stigonema robustum a, apical tip; **b,** two short laterals with hormogonia (from *Skinner 0177a*); **c,** rhizoidal pad; **d,** tracing of tip of thallus, to show branching and pads (from *Betche 1903*). Scale bar = 10 µm, tracing not to scale.

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