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4. *Porphyridium sordidum* Geitler 1932 (plate 1: fig. 4)

Cells grey-green, olive-green or yellowish, 5.5–8.5 μm in diameter; cell membrane very thin; colonies loose or clustered, usually in one layer.

Occurrence: Occurs on thalli of *Phormidium* in runlets from dungheaps. Europe: Found in Pinggau, eastern Austria.

2. *Chroothece* Hansgirg 1884

*Petrovanella* Kylin 1956

Colonies mucilaginous, irregular; cell membranes layered. Dimensions given without envelope.

**Key to the species:**

<table>
<thead>
<tr>
<th>1a</th>
<th>Cells &lt; 10 μm in diameter</th>
<th>................................................................. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1b</td>
<td>Cells &gt; 20 μm in diameter, up to 44 μm long</td>
<td>1. <em>C. mobilis</em></td>
</tr>
<tr>
<td>2a</td>
<td>Cells 6–10 μm in diameter, 15–18 μm long</td>
<td>2. <em>C. richteriana</em></td>
</tr>
<tr>
<td>2b</td>
<td>Cells 5–7 μm in diameter, 9–15 μm long</td>
<td>3. <em>C. rupestris</em></td>
</tr>
</tbody>
</table>

1. *Chroothece mobilis* Pascher et Petrova 1931 (plate 2: fig. 4)

*Petrovanella mobilis* (Pascher et Petrova) Kylin 1956

Cells without envelope 24 μm in diameter, up to 44 μm long, located on stalks coalescent with their bases to a mucilaginous mass. Cells have apertures at their tips by which mucus is excreted.

Occurrence: In peat-bogs.

2. *Chroothece richteriana* Hansgirg 1884 (plate 2: fig. 2)

Cells without envelope 6–10 μm in diameter, 15–18 μm long; thallus slimy, 2–4 mm thick, blue-green, becoming brownish, yellowish to orange by age. Cell envelope distinctly layered, in older cells unilaterally developed.

Occurrence: On humid clay-rich soil at ± saline sites; Europe: Great Britain, Spain.

3. *Chroothece rupestris* Hansgirg 1884 (plate 2: fig. 3)

Cells without envelope 5–7 μm in diameter, 9–15 μm long; thallus shapeless, at first light-blue then orange-yellow. Chromatophore coarsely star-shaped.

Occurrence: On wet rocks; Europe: Czech Republic, Spain.


Unicellular, cells with one to more chloroplasts without pyrenoid; asexual reproduction by binary division or autospores.

**Note:** For discussion of genus separation see Albertano et al. (2000) and Kumano (2002).

**Key to genera:**

<table>
<thead>
<tr>
<th>1a</th>
<th>Reproduction by binary cell division</th>
<th>................................................................. 1. <em>Cyanidioschyzon</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>1b</td>
<td>Reproduction by autospores or endogenic cell division</td>
<td>................................................................. 2</td>
</tr>
<tr>
<td>2a</td>
<td>4 autospores formed</td>
<td>2. <em>Cyanidium</em></td>
</tr>
<tr>
<td>2b</td>
<td>4–32 autospores formed</td>
<td>................................................................. 3</td>
</tr>
<tr>
<td>3a</td>
<td>Several parietal chloroplasts per cell; reproduction by endogenic cell division or by 4–32 autospores</td>
<td>................................................................. 3. <em>Rhodospora</em></td>
</tr>
<tr>
<td>3b</td>
<td>Cells contain one, parietal chloroplast without pyrenoid; asexual reproduction by autospores</td>
<td>................................................................. 4. <em>Galdieria</em></td>
</tr>
</tbody>
</table>
Plate 2: Fig. 1. Cyanidium caldarium (original author, Geitler 1932): a – vegetative cells; b – autospore development. Fig. 2. Chroothece richteriana (original author, Hansgirg 1884). Fig. 3. Chroothece rupestris (original author, Israelson 1949): a – young colony; b – cells with stellate chloroplast; c – growing colony. Fig. 4. Chroothece mobilis (original authors, Pascher & Petrov 1931): a – part of colony with cells at tops of mucilage stalks; b – single cell at the top of mucilage cord; c – single vegetative cell; d – single cell under division. Fig. 5. Rhodospora sordida (original author, Geitler 1932): a – part of colony showing autospore formation; b – group of cells; c – vegetative cells; d – resting cell.
1. **Cyanidioschyzon** De Luca et al. 1978 in NCU-3 1993
Cell with one ovoidal chloroplast without pyrenoid. Asexual reproduction by binary cell division. One species described.

**Cyanidioschyzon merolae** De Luca, Taddei et Varano 1978 (plate 4: fig. 1)
Cells blue-green, club-shaped, 3–4 μm long and 1–2 μm in diameter; one elongated chloroplast without pyrenoid. Cell walls very thin or invisible even at higher magnification. Before division is completed, chloroplast divides longitudinally thus causing a V-shape of the cell. Occurrence: Occurs worldwide as thin layers on stones in acid hot springs; Europe: Italy.

2. **Cyanidium** Geitler 1933 in NCU-3 1993
**Rhodococcus** Hirose 1958, non **Rhodococcus** Hansgirg 1885

**Cyanidium caldarium** (Tilden 1898) Geitler 1933 (plate 2: fig. 1)
**Rhodococcus caldarius** (Tilden 1898) Hirose 1958
Cells blue-green, spherical or rounded pyramidal, 4–6 μm in diameter. Autosporangium with 4 trihedrally arranged autospores (2–3 μm in diameter each). Occurrence: Ecology and occurrence as for **Cyanidioschyzon**; worldwide distributed and living on stones in acid hot springs. Europe: Italy.

3. **Rhodospora** Geitler 1927
Cells with several parietal chloroplasts; occurring as irregular colonies on wet stones. Reproduction by endogenic cell division or by 4–32 autospores. Monospecific genus.

**Rhodospora sordida** Geitler 1927 (plate 2: fig. 5)
Cells up to 18 μm in diameter, chloroplasts brownish, olive green, green or violet brown, varying between cells. Occurrence: On wet rocks; Europe: Austrian Alps, Spain, Sweden.

4. **Galdieria** Merola in Merola et al. 1982 in NCU-3 1993

**Galdieria sulphuraria** (Galdieri 1899) Merola in Merola et al. 1982 (no figures)
**Cyanidium sulphuraria** (Galdieri 1899) Ott in Ott & Seckbach 1994
Cells blue-green, spherical, 7–14 μm in diameter, forming powdery layer on stones. Autosporangium with 4–16(–32) trihedrally arranged autospores, 2–5 μm in diameter each. Occurrence: Worldwide on stones in acid hot springs. Europe: Garderi in Italy.
2. Order **Goniotrichales** Skuja 1939

Thalli diffuse uniseriate filaments, sometimes arising from a pseudoparenchymalous base. Sexual reproduction unknown.


**Key to families**:

1a Cells forming ± distinct filaments, each cell having one stellate chloroplast containing a central pyrenoid. Reproduction by monospores ................................................................. 1. **Goniotrichaceae** (p. 23)

1b Thallus filamentous with false and true branching; cells comprise several parietal chloroplasts without pyrenoid. Reproduction by small spores (microgonidia) .................................................. 2. **Phragmonemataceae** (p. 23)

1. **Family Goniotrichaceae** G.M. Smith 1933

Cells located in ± distinct filaments; cells with stellate chloroplast containing a central pyrenoid. Reproduction by naked monospores.

**Chroodactylon** Hansgirg 1885

* Asterocytis * (Hansgirg 1885) Gobi et Schmitz in Engler et Prantl 1896

Unbranched or irregularly false branched filaments; cells elongated-elliptical to flat-spherical or rounded cubic with a thick gelatinous matrix. In alkaline waters containing *Cladophora* and *Rhizoclonium*.

**Note**: See Entwisle & Kraft (1984) and Vis & Sheath (1993) for taxonomic discussion on synonyms.

**Chroodactylon ornatum** (C. Agardh 1824) Basson 1979 (plate 3: fig. 2; plate 4: figs. 3–4)


Pseudofilaments with false branching, 0.024–10 mm long and surrounded by thick gelatinous matrix; cells rectangular to ellipsoidal with one blue, stellate chloroplast with central pyrenoid. Cell diameter 5.8–11.6(–20) μm, cell length 7.1–16.6 μm. Occurrence: Epiphytic on aquatic plants (*Cladophora* and *Rhizoclonium*) or epilithic in hard-water ponds. Europe: Austria, Denmark, Hungary, The Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.

2. **Family Phragmonemataceae** Skuja 1939

Thallus filamentous with false and true branching; cells containing several parietal chloroplasts without pyrenoid. Reproduction by small spores (microgonidia).

**Key to the genera**:

1a Thalli and cells polymorphic; cells containing several parietal chloroplasts; colour grey-violet, pink or olive ........................................... 1. **Phragmonema**
Plate 3:  Fig. 1. Phragmonema sordidum (original author, Friedmann 1956): a – status filamentosus; b – status coccoideus; c – status pseudoparenchymatosus; d–f – status dendroideus; g–i – status palmelloideus; j–k – status autosporogeneus. Fig. 2. Chroodactylon ornatum (original authors, Geitler 1924, Belcher & Swale 1960): a – branching filament; b – cells with stellate chloroplast. Fig. 3. Kyliniella latvica (original author, Skuja 1926): a – discoid base and erect filaments; b – detail of erect filament; c – cross section of thread. Fig. 4. Bangia atropurpurea (original authors, Bourrelly 1970: a, d; Wołoszyńska 1935: b, c, e): a – an apex of filament; b – lower part of filament with developing rhizoids; c – multiseriate filament; d – filament with cells having stellate chloroplasts; e – cross-section of filament.
1b Filamentous arising from pseudoparenchymatous base; chloroplasts red-violet ........................................... 2. Kyliniella

1. Phragmonema Zopf 1882
Thalli and cells polymorphic; cells containing several parietal chloroplasts; colour grey-violet, pink or olive.

Phragmonema sordidum Zopf 1882 (plate 3: fig. 1)
6 different forms with different shape and arrangement of cells can be distinguished:

- status *filamentosus*
- status *coccoideus*
- status *pseudoparenchymatosus*
- status *dendroideus*
- status *palmelloideus*
- status *autosporogeneus*

Description given for the status *filamentosus*: filaments unbranched or false branched, containing only a few cells; cells cylindrical, 4–10 μm wide, 5–28 μm long with thin mucilage layer.

Occurrence: Austria (Vienna, Schönbrunn park), Germany (Berlin, botanical garden), Italy (cave near Neapel), Spain (Pico de Europa).

2. Kyliniella Skuja 1926
Filaments arising from a pseudoparenchymatous base; chloroplasts red-violet, without pyrenoid. Monospecific genus.

Kyliniella latvica Skuja 1926 (plate 3: fig. 3)
Pseudofilaments 2–3 cm long, growing from a discoid base with tightly arranged rectangular cells embedded in a gelatinous matrix. Cells 7.4–14.8 μm in diameter, 4.9–17.3 μm long; chloroplasts red-violet to blue.

Occurrence: Occurs epiphytic on *Phragmites*; Europe: Austria, Latvia (Lake Usma), Sweden, Baltic Sea (Kylin 1956).

3. Order Compsopogonales Skuja 1939
Uniseriate filaments with small cells making cortication around central axis row. Parietal chloroplast in young cells, later this chloroplast is fragmented into many small discoid chloroplasts. Asexual reproduction by monospores by an unequal division of the parental cell. Sexual reproduction unknown.

**Important references:** Starmach (1977); Vis et al. (1992); Rintoul et al. (1999); Kumano (2002); Yoon et al. (2006)

**Note:** See Rintoul et al. (1999) for taxonomic discussion.

1. Family Compsopogonaceae Schmitz in Engler et Prantl 1896
The only family in this order contains two genera, *Compsopogon* and *Compsopogonopsis*, which the latter does not occur in Europe (is found in East Asia and in Pacific Ocean islands).
Plate 4: Fig. 1. *Cyanidioschyzon merolae* (photo: modified after G. Pinto 2007). Fig. 2. *Porphyridium purpureum*. Fig. 3–4. *Chroodactylon ornatum* (photo by F. Hindák in Wolowski, Kowalska & Hindák 2007) Fig. 5–7. *Bangia atropurpurea*: 5. multiseriate thread; 6. sporangium; 7. basal part of thallus.
Compsopogon Montagne in Bory et Durieaux 1846

Thalli filamentous, branched, growing apically; composed of an axial thread covered with a cortex of compactly arranged smaller cells. Mainly tropical genus.

Key to the species:

1a Thalli up to 25 cm long ................................................................. 2
1b Thalli 25–200–(300) cm long ....................................................... 3
2a Thallus sparsely branched, branching from the base, branches directed forwards in an acute angle ........................................... 1. C. chalybeus
2b Branches loose, dispersed; older erect filaments have short, aculeate branchlets ......................................................... 2. C. aeruginosus
3a Erect filaments sparsely branched .............................................. 3. C. hookeri
3b Erect filaments rich branched ................................................... 4. C. coeruleus

1. Compsopogon chalybeus Kützing 1849 (plate 5: fig. 1)

Compsopogon corinaldii (Meneghini 1841) Kützing 1857, Lemanea corinaldii Meneghini 1841

Thalli up to 20 cm high, branching from the base; threads at transversal walls of axial cells incised, in parts producing cortex 100–250 μm wide; cells of cortex 9–19 μm in diameter, 16–28 μm long; monosporangia 9–16 μm wide.

Occurrence: Tropical species growing in rivers and streams. Europe: Italia (tropical aquarium in Catania, Sicily), Ukraine.

2. Compsopogon aeruginosus (J. Agardh 1847) Kützing 1849 (plate 5: fig. 2; plate 6: fig. 1–5)

Pericystis aeruginosa J. Agardh 1847

Thalli heterotrichous, consisting of a prostrate holdfast and erect, dark blue-green filaments, 25–50 cm in length and 0.7 mm in diameter; prostrate system (holdfast) 180–390 μm in diameter; filaments rich branched with many short aculeate branchlets; cortex with 1–2 cell layers; cortical cells 12–30 μm in diameter, 16–40 μm long. Monosporangia spherical, 10–15 μm in diameter.

Occurrence: Occurs in streams; Europe: Austria (River Pulkau), Poland (in a botanical garden pond, Cracow).

3. Compsopogon hookeri Montagne 1846 (plate 5: fig. 4)

Thalli heterotrichous with basal disc, 140–250 μm in diameter and erect, dark blue-green filaments, up to 20–50 cm high, 0.5–2 mm in diameter, sparsely branched. Cortical layer with 1–2 cell layers; cortical cells 10–21 μm in diameter, 15–35 μm long. Monosporangia spherical, 13–19 μm in diameter; microsporangia in groups on main axis and branches, spherical 8–12 μm in diameter.

Occurrence: Known mainly from Asia; Europe: France (River Erth, affluent of Rhone).

4. Compsopogon coeruleus (Balbis ex C. Agardh 1824) Montagne 1846 (plate 5: fig. 3)

Conferva coerulea Balbis ex C. Agardh 1824; Compsopogon oishii Okamura 1915; Compsopogon helwanii El-Gamal et Salah El-Din 1999
Plate 5: Fig. 1. Compsopogon chalybeus (original author, Kützing 1849): a – habitus of the plant; b – part of thallus with lateral branch. Fig. 2. Compsopogon aeruginosus (original author, Skuja 1938b): a – habitus of the plant; b – details of the thallus and branching; c – longitudinal section of thallus showing axial cells and cortical layer; d – longitudinal section of the young branch; e – cross-section of branch. Fig. 3. Compsopogon coeruleus (original authors, Jao 1941: a; Kützing 1849: b, c): a – habitus of the plant; b – detail of the thallus; c – part of cross-section of the branch. Fig. 4. Compsopogon hookeri (original author, Friedrich 1966): a, b – development stages of the young thallus; c – detail of a young branch; d – longitudinal section of an older branch, e – two cells with chloroplasts.
Thalli heterotrichous with basal disc, 300–500 μm in diameter; erect filaments dark blue-green, up to 10–80 cm high, 1–3 mm in diameter, rich and coarsely branched. Cortical layer with 2–3 cell layers; cortical cells 10–27 μm in diameter, 15–36 μm long. Monosporangia spherical, 15–20 μm in diameter.

Occurrence: In tropical rivers in Asia, Australia, Central and South America; Europe: Great Britain (Reddish Canal, Manchester), Malta, Spain.

4. Order **Bangiales** Schmitz in Engler 1892

For marine members, a life-cycle including sexual reproduction is known. Filaments pass through a diploid microphase called *Conchocelis* stage with pit connections (aperture in a cross wall between two cells with a plug and plug cap) (*Bangia*) and a macroscopic haploid phase without pit connections. In the genus *Boldia* (described only from America) thalli are saccate with 1–2 cells in thickness. Asexual reproduction by monosporangia; for freshwater species sexual reproduction is unknown.

**Important references:** Starmach (1977); Garbary et al. (1980); Sheath (1984); Müller et al. (1998, 2001); Kumano (2002)

**Family Bangiaceae** Engler 1892

Cells covered with a polysaccharide matrix divide transversally and longitudinally forming filaments with uniseriate to multiseriate structure. One species in freshwaters.

**Note:** According to Kumano (2002), the family Bangiaceae comprises two genera, *Bangia* and *Porphyra*. Nelson (2007) described a new monotypic genus *Bangiadulcis* (syn. *Bangia atropurpurea* (Roth) C. Agardh), which is distinguished from the other members of the Bangiales on the basis of cytological, reproductive and ecological characters.

**Bangia** Lyngbye 1819

Uni- or multiseriate filaments growing attached to stones or wood by rhizoids.

**Bangia atropurpurea** (Roth 1806) C. Agardh 1824 (plate 3: fig. 4; plate 4: fig. 5–7)

*Conferva atropurpurea* Roth 1806

Freshwater species; threads up to 15 cm long, unbranched, 13–98 μm in diameter, dark red, dark olive green or brownish. Young filaments consist of a single row of cylindrical cells, 6 μm wide and 8 μm long. Lateron, cells appear disc-shaped, 6–15 μm in diameter and 20 μm long. After longitudinal cell divisions, threads become polysiphonous (multiseriate). Cells 6 μm in diameter, 10 μm long are containing a stellate chloroplast with a central pyrenoid. Asexual reproduction by monosporangia, which develop in monosporangia located in mature filaments Sexual reproduction unknown.

Occurrence: In hard-water lakes and rivers, often nearby coastal areas; Europe: Found all over Europe.

**Important references:** Geesink (1973); Starmach (1977); Müller et al. (1998, 2001); Woolcot & King (1998); Kumano (2002)
Plate 6:  Fig. 1–5. Compsopogon cf. aeruginosus (photos: 1. Z. Žáková; 2–5. F. Hindák): 1. habitus of the plant; 2. part of thallus showing short spinous branchlets; 3. multiseriate cortex cells of a side branch; 4. plants with typical ramification; 5. cells with parietal chloroplasts.
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