

Several Cyanoprocaryotes from Sagarmatha National Park, Nepal Himalayas

By

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Abstract This article is our second floristic-taxonomic study concerning the microflora of cyanoprocaryotes (blue-green algae, cyanophytes, cyanobacteria) of Nepal Kingdom. In the first part (WATANABE & KOMÁREK 1988) 63 species from the Kathmandu Valley were presented; this second part contains documentation (descriptions, drawings, photos) of further 21 taxa, from which five were recognized as new species. The morphological variation and deviations from the commonly distributed populations are discussed in all samples. The high diversity of cyanoprocaryotes in high mountain biotopes was repeatedly recognized.

The cyanoprocaryotic flora of the Himalaya region has been studied by numerous authors (see, e.g., citations in WATANABE & KOMÁREK 1988, p. 1), but the enormous diversity of biotopes, the extent of the whole area and occasional, usually not specialized collections are the main reasons why the knowledge of Himalayan cyanoprocaryotes is still rudimentary. Also our present study concerns only a few selected taxa from a lot of samples, which were collected by the first author (M. W.) from the Sagarmatha (Mt. Everest) National Park, at 2700 to 5300 meters a.s.l. in Eastern Nepal, during the Botanical Expeditions to the Himalayas sent by the National Science Museum, Tokyo, from October 1st to December 22nd 1980 (Fig. 1). All the water biotopes were of catharobic character, with temperatures slightly above 0°C. All specimens were fixed by 3–4% formol or 1% glutaraldehyde and are deposited in the herbarium of the National Science Museum, Tsukuba Botanical Garden (TNS), including the type specimens.

List of studied samples:

- 51773—Oct. 9, 1980. Under a cliff with dripping water at Phakdingma, 2700 m.a.s.l.
51774—Oct. 9, 1980. Same as above.
51775—Oct. 10, 1980. At a watering place between Lardze and Namche Bazar, 3100 m.a.s.l.
51781–51784—Oct. 14, 1980. In a small pond N. W. of Pangpoche, 4550 m.a.s.l.
51790—Oct. 16, 1980. In a small lake N. N. W. of Amai Dablang, 4650 m.a.s.l.
51795—Oct. 17, 1980. In a shallow streamlet N. E. of Chhukung,

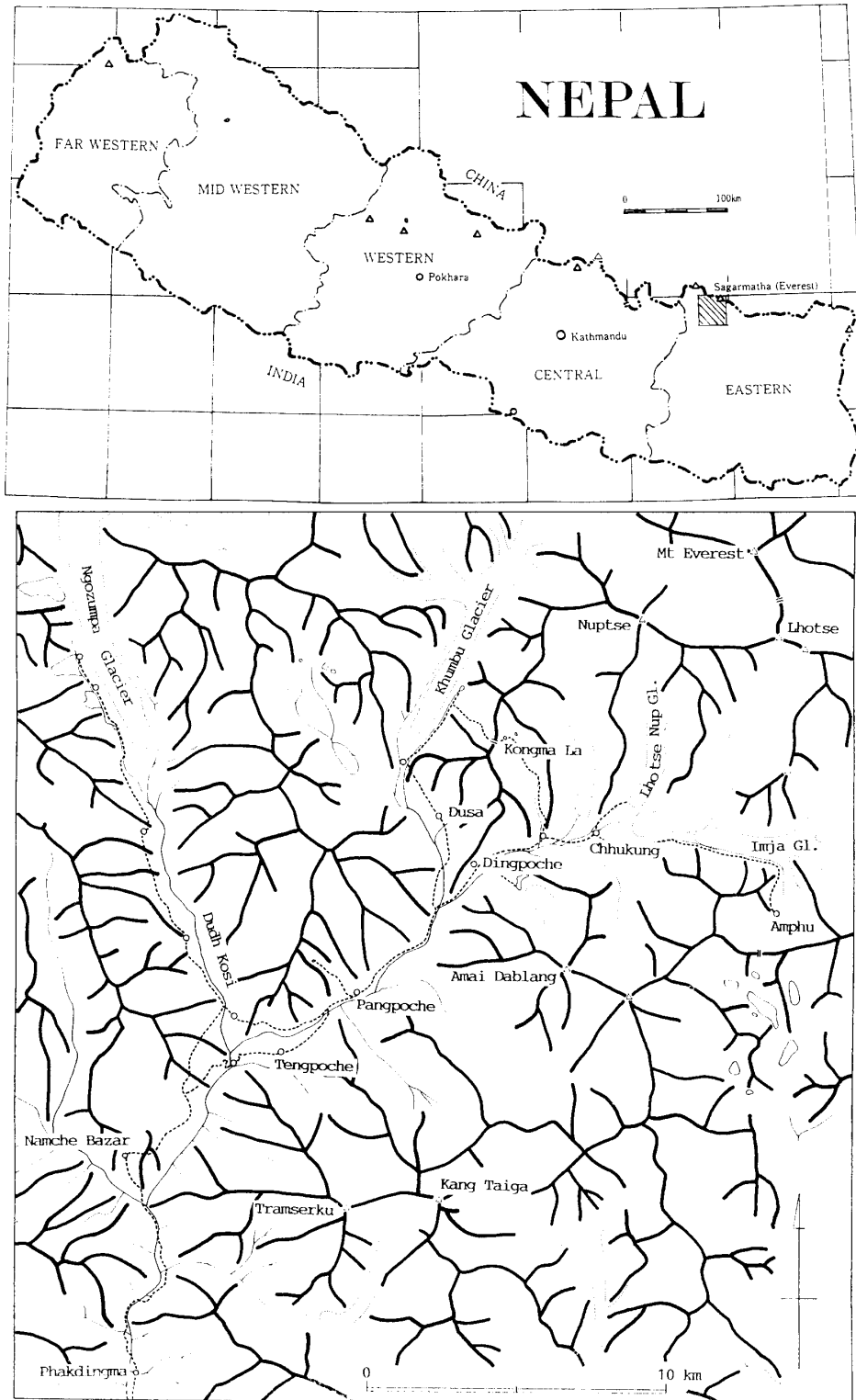


Fig. 1. Map of studied area (Sagarmatha National Park, eastern Nepal).

- 51798—Oct. 18, 1980. In a stream between Chhukung and Amphu, 4770 m.a.s.l.
 51806—Oct. 22, 1980. In a shallow lake E. N. E. of Kongma La, 5300 m.a.s.l.
 51807—Oct. 22, 1980. Same as above.
 51809—Oct. 22, 1980. Same as above.
 51820—Oct. 23, 1980. In a stream at Dusa, 4530 m.a.s.l.
 51821—Oct. 23, 1980. Same as above.

Results:

1. *Aphanothece* cf. *nidulans* RICHT. in WITTR. et NORDST. 1884

(Fig. 2; Plate 1: 1-2)

Colonies micro- up to macroscopic with irregularly arranged cells, colourless or slightly greyish-greenish, more or less spherical in outline and up to 80 μm in diameter, with sharply limited margin (sometimes slightly refractive) when young, later amorphous, with colourless, not structured and diffuent slime; around cells (or their small groups) not recognizable or only rarely slightly visible fine, not striated colourless envelopes. Cells oval, $2.3\text{--}3 \times 2\text{--}2.6 \mu\text{m}$, with pale greyish-blue content. In the slime several types of fine endogloeic filamentous cyanoprocaryotes (*Leptolyngbya*, etc., not included in our study).

Locality: Sample no. 51773.

Comments: The name "*Aphanothece nidulans*" was used many times for different small *Aphanothece* species from various biotopes (thermal springs, soil, saline biotopes, plankton, benthos, etc.). According to the original concept, *A. nidulans* represents a species forming micro- up to macroscopic, more or less spherical, slightly greenish or grey colonies, living epipellic or metaphytic in clear (not polluted) freshwater pools, ponds and swamps. It is distributed mainly in temperate and northern areas.—The aerophytic *A. saxicola*, which is sometimes unified with *A. nidulans*, with cells of more or less similar size and shape as *A. nidulans*, represents another species (differentiated by type of colonies, pigmentation, ecology, and cytomorphological details).—Cf course, the *Anacystis nidulans*, based on the same basionym (DROUET & DAILY 1952) is quite the wrong name for the famous experimental model strain, occurring in the literature under the same name (= *Synechococcus nidulans*).—Our material resembles typical *Aphanothece nidulans*, but we are not quite sure about this identification: the cells are thicker, life cycle is not evidently identical and also the ecology is a little different from populations known from Europe.

2. *Aphanothece* cf. *castagnei* (KÜTZ.) RABENH. 1865

(Fig. 3; Plate 1: 3-4)

Colonies microscopic, oval or irregular, limited when young, later fine, diffuent, amorphous. Cells distributed irregularly, enveloped by own, sometimes 2- or several-

layered envelopes, which have sometimes “granular” character; envelopes around cells intensely yellow or yellow-brown, outer layers pale yellow to colourless. Own envelopes disappear in old, multicellular colonies. Common colonial mucilage yellowish or colourless. Cells oval, $5.2\text{--}10 \times 4.5\text{--}5.5 \mu\text{m}$, with pale grey-blue content, sometimes with solitary distinct granules.

Locality: Sample no. 51773.

Comments: *A. castagnei* is an aerophytic species (data from aquatic biotopes are very questionable), and occurs commonly on wet rocks, often on limestone, but it is known also from other substrates. Our material corresponds mainly with this species, or with *A. pallida*.—Within the genus *Aphanothece* surely exist numerous morpho- and ecotypes, the taxonomy of which is still open. Probably a lot of species exist, particularly in tropical regions, identified by various names selected from GEITLER’s (1932) monograph, but representing ecologically very different and special taxa.

3. *Aphanocapsa* sp.

(Fig. 4)

Microscopic up to macroscopic, amorphous colonies, with scarcely and irregularly arranged cells (with distances usually $6\text{--}11 \mu\text{m}$ one from another), but in old colonies usually more densely disposed (with distances $1\text{--}3 \mu\text{m}$). Mucilage fine, colourless, diffuent, not structured, only sometimes very fine, slightly visible (staining!) envelopes around solitary cells or their small groups. Cells spherical, $0.6\text{--}1 \mu\text{m}$ in diameter, with pale grey-blue content, sometimes slightly elongated before division; after division occur occasionally two (or four) cells near together. Cell division by cleavage.

Locality: Sample no. 51773.

Comments: Not a determinable species from our samples. Our material belongs to such populations, which are not identifiable exactly with any known species morphologically or ecologically. The diversity of the genus *Aphanocapsa* is substantially greater than that included in the present monographs.

4. *Merismopedia* cf. *glauca* (EHRENB.) KÜTZ. 1845

(Fig. 5)

Colonies microscopic, flat, with numerous cells (up to 256 in one colony) arranged regularly in one layer in perpendicular rows. Mucilage fine, colourless, diffuent, overlapping the cells up to $5 \mu\text{m}$. Cells spherical, later oval or subspherical, after division hemispherical, dividing regularly according to two perpendicular planes in

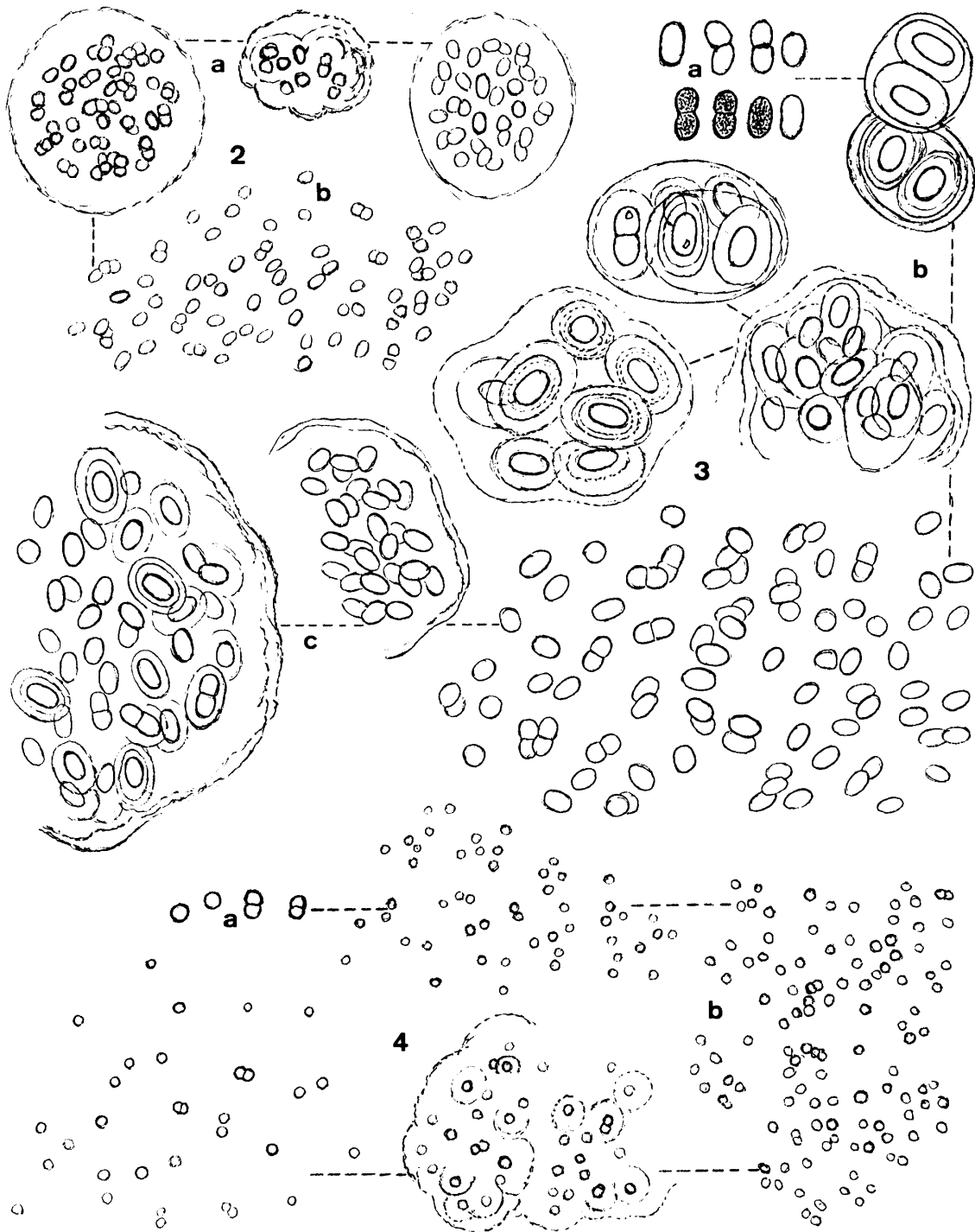


Fig. 2. *Aphanothece cf. nidulans*: a=young colonies, b=distribution of cells in old colonies. (All drawings are orig.).

Fig. 3. *Aphanothece cf. castagnei*: a=solitary cells, b=young colonies, c=parts of old colonies.

Fig. 4. *Aphanocapsa sp.*: a=solitary cells, b=arrangement of cells in old colonies.

succeeding generations. Cells with pale, grey-blue content, sometimes with one or several refractive granules irregularly arranged in plasma, 3–4.5 μm in diameter.

Locality: Sample no. 51798.

Comments: This species is similar to *M. glauca*, but differs from the usual populations by having larger, regular colonies (local ecomorphosis?).

5. **Woronichinia kuselae** spec. nova

(Fig. 6; Plate 2: 7–10)

Colonies free-living, more or less spherical or irregular-spherical, usually composed from several, up to 9 subcolonies, with very densely, parallelly arranged cells in the peripheral layer, 15–50 μm in diameter. Cells elongated, obovoid to club-shaped, without aerotopes, pale olive-green, 2.2–3 \times 1–1.5 μm , before division –2.2 μm wide, joined to the fine, colourless, wide mucilaginous stalks (as wide as the basal part of cells), radiating from the colonial center and visible only in atypical or destroyed colonies with less cell density (staining!). Cell division by lengthwise binary fission, reproduction by disintegration of colonies.

Locality: Sample no. 51806.

Diagnosis: Coloniae sphaericae, subsphaericae, vel cum subcoloniis compositae, ad 50 μm in diametro. Cellulae obovatae, dense peripherice paralleliter radialiterque aggregatae, 2.2–3 \times 1–1.5 μm , contenu pallide olivaceo-viridi, ad stipitibus hyalinis, plus minusve latis et de centro coloniae radiantibus adherentes, longitudinaliter dividuntur. Reproductio disintegratione coloniis.—Typus: lamina 51806 (TNS), iconotypus: figura nostra (Plate) 2: 7–10.—Habitatio: Metaphytice in lacu vadoso prope Kongma La, Montes Emodi, Nepalia.

Comments: This species is similar to *W. compacta* and *W. karelica*, however, the cells are smaller, the colonies are more agglomerated, composed usually of several subcolonies, and the ecology is different (comp. KOMÁREK & KOMÁRKOVÁ-LEGNEROVÁ 1992).—*W. kuselae* was reported from the same locality (Sagarmatha National Park) by KUSEL-FETZMANN (1969) as “*Gomphosphaeria* sp.”; the author correctly recognised and documented by photo the specificity of Himalayan specimens. The new species is therefore dedicated to her.

6. **Eucapsis himalayensis** spec. nova

(Figs. 7, 8; Plate 2: 1–4)

Cells arranged in free-living, more or less packet-like, cubic or irregular mucilaginous, microscopic colonies, usually composed of subcolonies. Cells spherical, hemi-

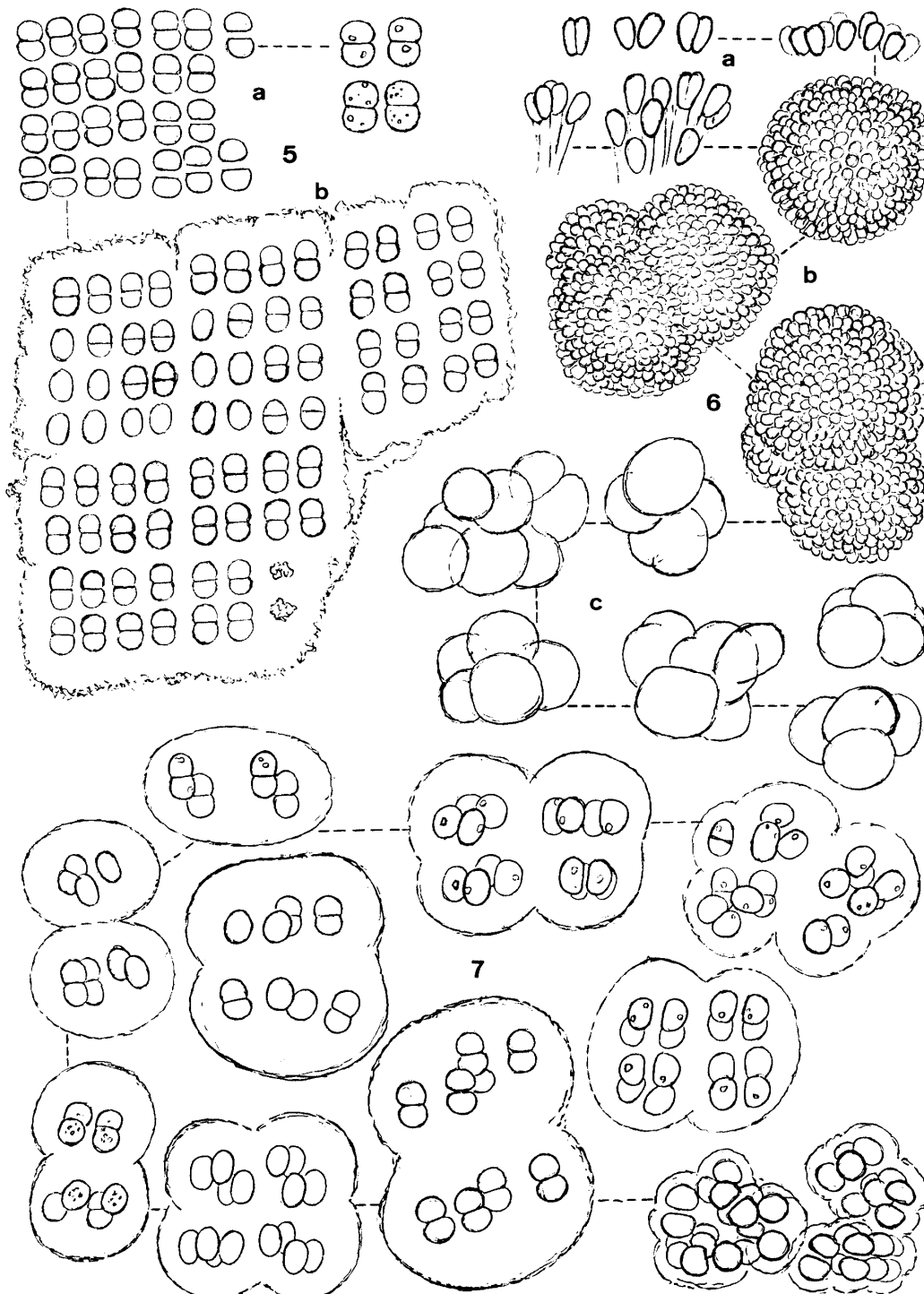


Fig. 5. *Merismopedia cf. glauca*: a=details of colonies, b=small colony.

Fig. 6. *Woronichinia kuselae*: a=detail of cells, b=colonies, c=shape of composed colonies.

Fig. 7. *Eucapsis himalayensis*: different shapes of young colonies.

spherical (after division), or slightly elongated, widely oval, blue-green or olive-green, sometimes with few or several prominent granules in the plasma, (3) 5–7.5 (10.5) × (3) 3.5–7.5 μm , in colonies slightly distant one from another, in short, indistinct, perpendicular rows. Density of cells is higher if cells divide intensely. Mucilaginous envelopes around cells widened (with 3–15 μm wide margin), rounded, fine, colourless, hyaline, not stratified, limited or slightly diffuent, usually not recognizable without staining; mucilage around colony more or less of rounded outline. Cell division regularly in three perpendicular planes; cells after division slightly distant one from another, grow to the original size and form before next division.

Locality: Samples nos. 51806, 51807, 51773.

Diagnosis: Coloniae microscopicae, libere natantes, ambitu plus minusve sphaericeo, ovali vel irregulariter rotundato, cum mucilagina homogeneo, tenui, diffuenti, sine colore, paucim visibili; in centro coloniae cellulae plus minusve agglomeratae vel paucim distantae, plus minusve cubice perpendiculariterque ordinatae. Cellulae sphaericae vel ovaes, post divisionem hemisphaericae, contentu aerugineo vel olivaceo, tantum cum granulis parvis, 3–10.5 × 3–7.5 μm .—Typus: lamina 51806 (TNS), iconotypus: figura nostra (Plate) 2: 1–4.—Habitatio: Metaphytice in lacu vadoso prope Kongma La, Montes Emodi, Nepalia.

Comments: *E. himalayensis* differs greatly from all other species of this genus. The most similar is the tropical *E. parallelepipedon*, which differs by the more regular arrangement of cells and by ecology (comp. KOMÁREK & HINDÁK 1988).

7. *Chroococcus varius* A. BR. in RABENH. 1876

(Fig. 9)

Micro- or macroscopic, irregular agglomerations of small, (1) 2–4-celled sub-colonies. Cells oval, after division hemispherical or subspherical, pale blue-green, with homogeneous content, 1.3–2.8 μm in diameter. Around cells or their groups more or less limited, oval, slightly lamellated, colourless or yellowish mucilaginous envelopes.

Locality: Occurs commonly in the sample no. 51773.

Comments: Common aerophytic species on wet rocks, mainly in mountains. Our specimens are almost identical with the original description, but they have smaller cells (in the original description = 2–4 μm in diameter) and a slightly different ecology. In spite of this, we suppose that our population lies in the range of variation of *C. varius*.

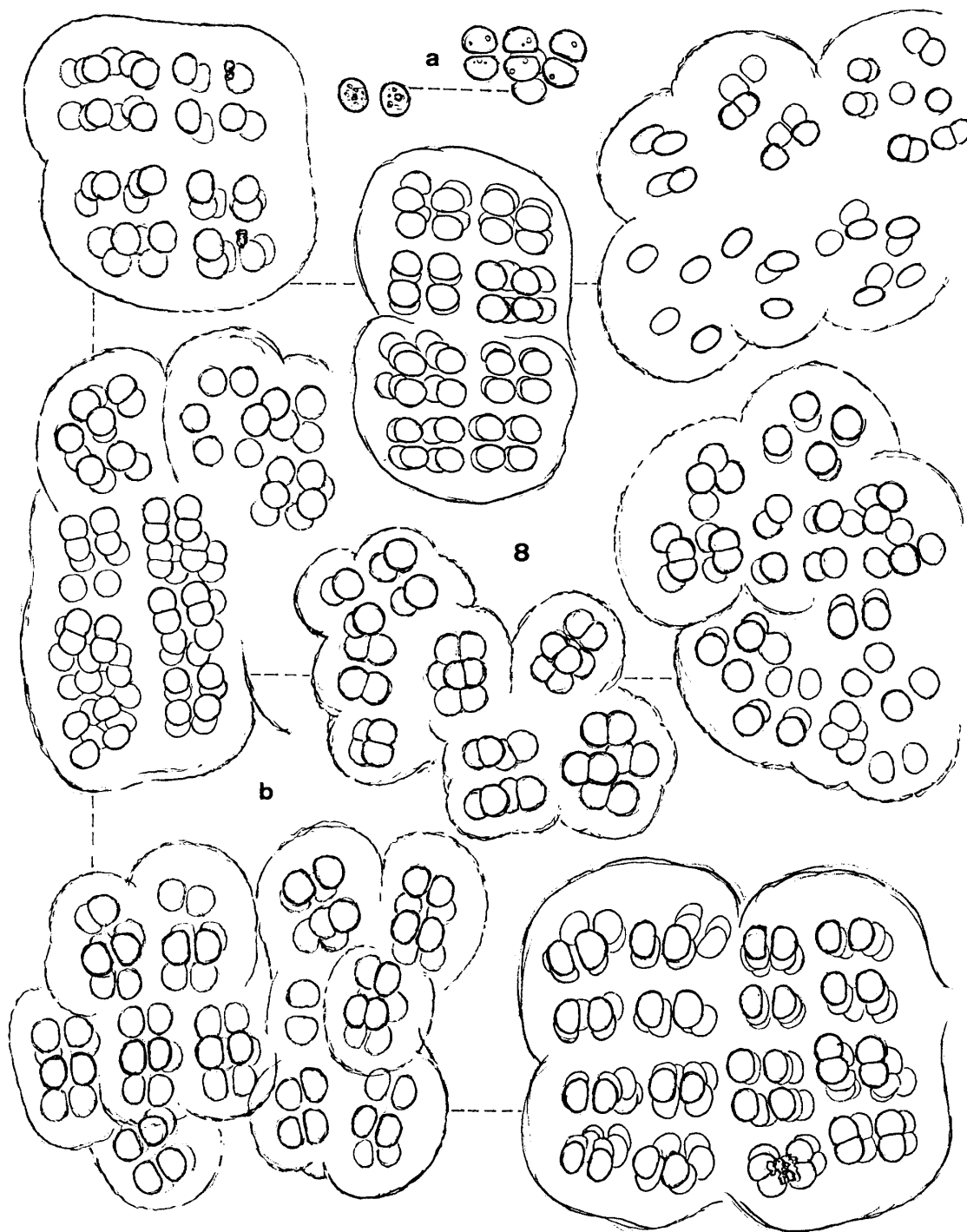


Fig. 8. *Eucapsis himalayensis*: a = detail of cells, b = different shapes of colonies.

8. *Chroococcus* cf. *minutus* (KÜTZ.) NÄG. 1849

(Fig. 10)

Usually solitary cells or in pairs. Cells spherical, subspherical or oval, after division hemispherical, enveloped by thin, hyaline, homogeneous, colourless and diffuent, slightly visible slime (visible after staining). Cells pale blue-green, with finely and regularly granular content (rarely with several larger granules), 7.6–12.5 μm in diameter or 7.6–12.5 \times 5–10.5 (11.2) μm .

Locality: Metaphytic in a shallow lake near Kongma La, 5300 meter a.s.l., common also below ice cover (sample no. 51807).

Comments: Our specimens are mostly similar to *C. minutus*, which is known from the metaphyton and plankton of lakes and reservoirs in temperate zones. The slight differences are in the size of cells and morphology of small colonies (particularly in slime consistency). In our samples solitary cells commonly occurred, which are rare in other populations of *C. minutus*.

9. *Chroococcus* cf. *turicensis* (NÄG.) HANSG. 1887

(Fig. 11; Plate 2: 6)

Colonies microscopic, usually two-celled, rarely solitary cells or four-celled agglomerations; sometimes groups of up to four 2-celled colonies occur. Cells oval or irregularly oval, after division hemispherical or in a form of sphere-section, pale blue-green, with densely, finely granulated, homogeneous content, without recognizable chromatoplasma, and often with few scattered, brownish, larger granules. Mucilaginous envelopes colourless, well visible and more or less refractive, but not sharply limited, sometimes slightly diffuent, 2.2–4 μm wide, only by immersion is indistinct lamellation recognizable. Cells quite without visible envelopes rarely occur, or vice versa, with one wide, diffuent, very slightly visible, up to 11 μm wide outer envelope around the inner refractive mucilage; the colonies with very fine, colourless and diffuent, up to 30–35 μm wide gelatinous envelopes were also found, but their identity with *C. turicensis* is not quite proved. Cell dimensions: 17.5–30 (37.5) μm in diameter, after division sometimes only 13–15 μm wide. Division typical chroococcoid, but exceptionally piching was also observed.

Locality: Very common in sample no. 51807.

Comments: *C. turicensis* is known from wet rocks, usually in mountainous localities in Europe, but probably is commonly distributed in corresponding localities, particularly in high mountains. The evaluation and comparison of different populations from distant areas would be interesting. Similar species, *C. deltoides*, was recently described from tropical swamps (KOMÁREK & NOVELO 1994).

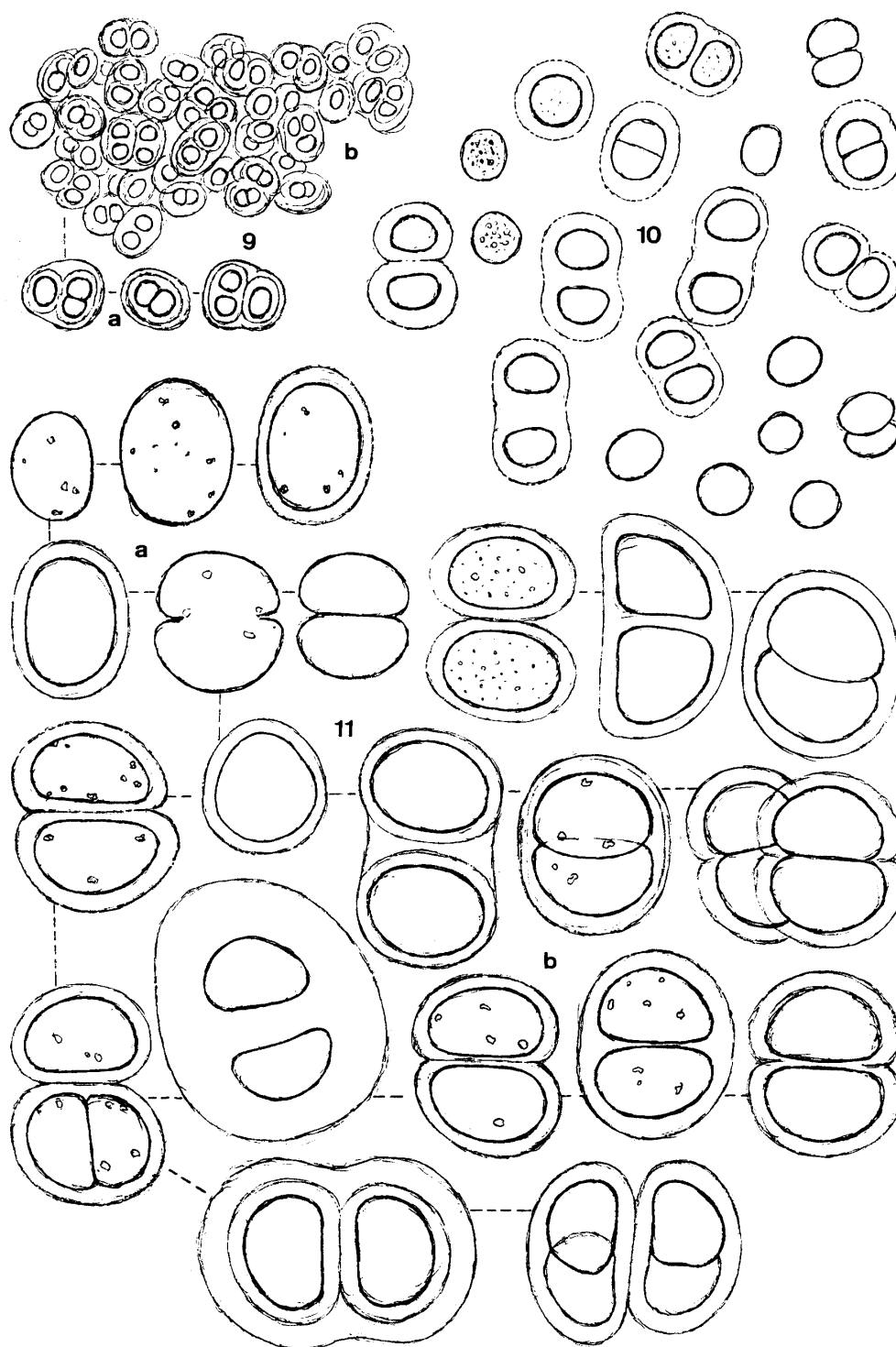


Fig. 9. *Chroococcus varius*: a= single colonies, b= typical agglomeration of colonies.

Fig. 10. *Chroococcus* cf. *minutus*: solitary colonies and single cells without mucilaginous envelopes.

Fig. 11. *Chroococcus turicensis*: a= single cells with and without gelatinous envelopes, b= 2-celled colonies with gelatinous envelopes.

10. **Chroococcus tenax** (KIRCHN.) HIERON. 1892

(Fig. 12; Plate 2: 5)

Rarely solitary cells, usually 2–4 (–12–16) -celled colonies. Cells oval, after division hemispherical rounded or rounded-rectangular, with pale grey-blue, very finely to indistinctly granular content, sometimes with a few small, prominent brown granules, irregularly distributed in the plasma; cells dimensions 10–21.4 × 6.2–12.5 μm. Mucilaginous envelopes sharply limited, intensely and densely lamellated, with inner layers colourless, outer yellowish. In our population cells of similar morphology and size also occur (11.2–21.2 μm in diameter), but quite without envelopes and with bright blue-green content. Between both types no transitions exist. It was impossible to decide from our samples, if they are two different species.

Locality: Common in our sample no. 51773.

Comments: Described from wet rocks, known mainly from mountains, particularly from the European Alps, the localities from lowland (and from submersed biotopes) should be revised. The distribution is unknown because of many misidentifications.

11. **Chlorogloea simplex** spec. nova

(Fig. 13; Plate 3, 4: 1)

Cells more or less agglomerated to irregular microscopic up to macroscopic colonies, organized in groups or short rows, enveloped by fine, colourless, diffuent mucilage; young colonies (and dormant stages) sometimes closed within limited, widened, colourless and not lamellated gelatinous sheaths, which split at the beginning of the vegetation period. Cells spherical, olive-green or pale blue-green, which divide in more planes, but sometimes predominantly in one plane, from which arise short pseudofilamentous formations composed of rounded cells; cell dimensions: 2.6–4 μm in diameter.

Locality: Sample no. 51773.

Diagnosis: Cellulae aggregatae in coloniis microscopicis haud macroscopicis, irregularibus amorphisque, sine ordine vel in pseudofilamenta curta, paucicellularia ordinatae; coloniae cum mucilago tenui, achroo, diffuenti vel rare limitati, non lamellosi. Cellulae plus minusve sphaericae, 2.6–4 μm in diametro, contentu aerugineo, plus minusve homogeneo, in planis diversis vel in plano uno in generationes subsequentes dividuntur.—Typus: lamina 51773 (TNS), iconotypus: figura nostra (Plate) 3: 2.—Habitatio: Metaphytice in lacu vadoso prope Amai Dablang, Montes Emodi, Nepalia.

Comments: Our species corresponds well to the generic diagnosis (structure of

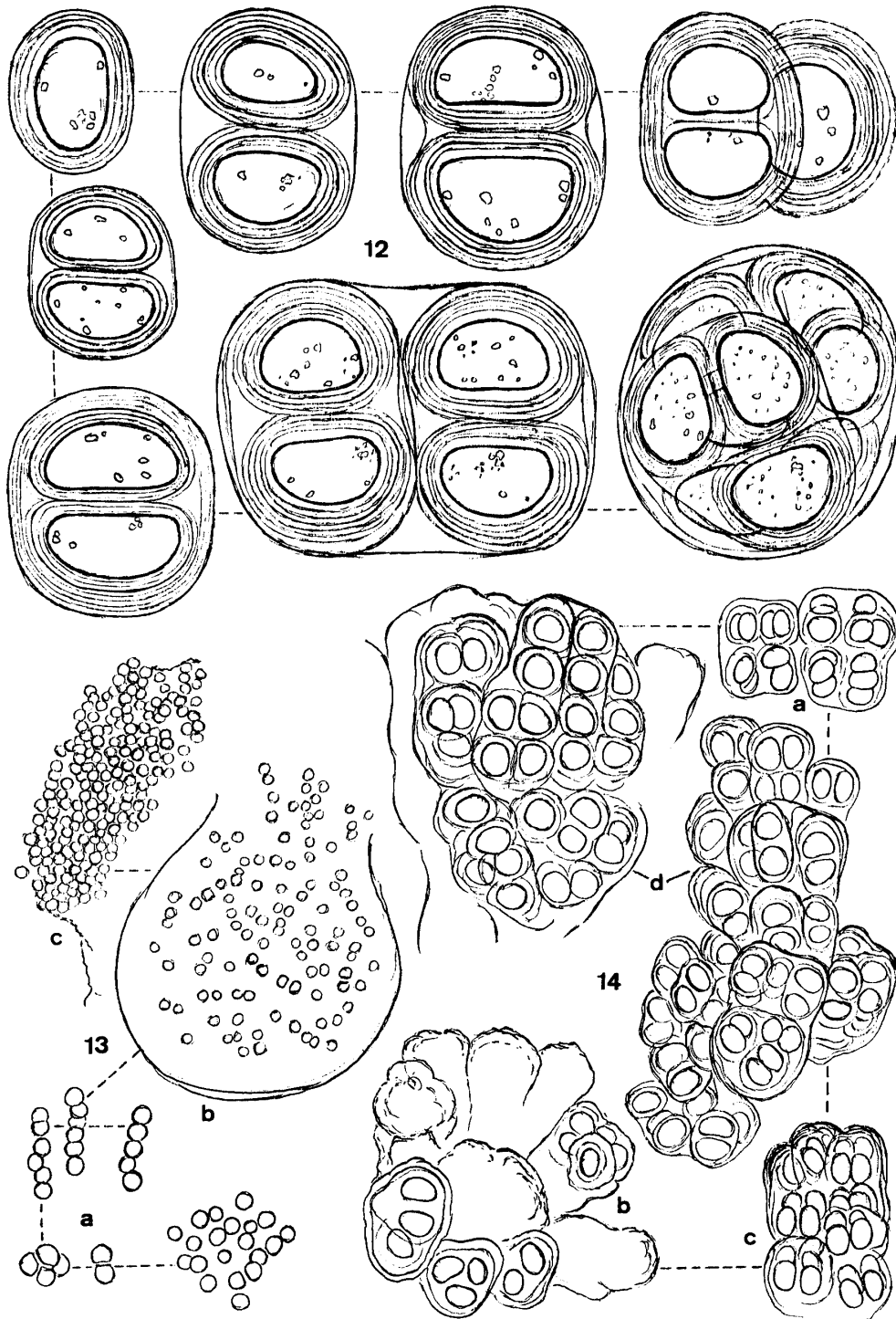


Fig. 12. *Chroococcus tenax*: different types of colonies with intensely striated envelopes.

Fig. 13. *Chlorogloea simplex*: a=details of cell arrangement, b=young colony ("germinating" dormant stage), c=margin of old colony.

Fig. 14. *Entrophysalis rubra*: a-c=young colonies, d=parts of old colonies (intensely red mucilage).

colonies, type of cell division), but differs from all described *Chlorogloea* species (comp. KOMÁREK & MONTEJANO 1994).

12. ***Entophysalis rubra*** spec. nova

(Figs. 14, 15; Plate 4: 2)

Colonies microscopic up to recognizable macroscopically, granular-mucilaginous, with polarized growth, composed of numerous subcolonies, in colonies radially arranged. Cells in groups situated irregularly or in short, more or less radiating rows, irregular rounded, oval, semiglobose or hemispherical after division, pale grey-blue, 1.2–3 μm in diameter. Around cells special lamellated sheaths, groups of cells surrounded by firm, limited, lamellated and intensely reddish or yellow-brown sheaths. Cell division by binary fission, in different planes, but in radially growing colonies probably with predominantly crosswise fission.

Locality: Samples no. 51806, 51820.

Diagnosis: Cellulae in coloniis microscopicis haud macroscopicis, mucilagino-granulosis, amorphis aggregatae, cum subcoloniis numerosis dense radialiter consociatis; coloniae plus minusve heteropolares. Cellulae cum tegumentis firmis, lamellosis, ad grupos irregularibus vel in seriebus curtis radiatim consociatae, etiam cum tegumentis firmis, lamellosis, intense rubris vel brunescens circumdatae. Cellulae ovaes, subsphaericae vel rotundate polygonales, post divisionem hemisphaericae, contentu griseo-aeruginoso, 1.2–3 μm in diametro. Divisio cellularum in partes duas, nunquam in nanocytis, irregulariter in planis diversis.—Typus: lamina 51820 (TNS), iconotypus: figura nostra 14.—Habitatio: Epilithice ad saxa in aquis fluentibus prope Dusa, ad 4530 m supra mare, Montes Emodi, Nepalia.

Comments: The genus *Entophysalis* is little known. Various species occur particularly in tropical biotopes, they are, however, still taxonomically undefined. *E. rubra* evidently belongs to this genus, the red envelopes are distinct for this species.

13. ***Jaaginema*** sp.

(Fig. 16)

Trichomes irregularly coiled, solitary or in free clusters, always without sheaths, cylindrical, not constricted at cross walls, 2.5–3.5 μm wide, with slightly narrowed 1–3 terminal cells. The end cells are more or less conical and rounded. Cells more or less isodiametric or slightly longer or shorter than wide, pale greyish blue-green, with scattered granules.

Locality: Sample no. 51773.

Comments: The genus *Jaaginema* was established by ANAGNOSTIDIS & KOMÁREK (1988) for thin, filamentous, unbranched and immotile cyanoprocaryotes without sheaths. This genus comprises species with thin trichomes, occurring mainly epipelic, metaphytic and endogloeic. The generic classification is evidently provisory, because the eubacterial character of numerous species can be recognized. Also our material is, therefore, indefinable and needs further investigation; we studied only the preserved samples (motility ?).

14. *Microcoleus* sp.

(Fig. 17; Plate 4: 3–6, 5)

Filaments solitary, irregularly waved, mixed with other algae, containing one, several to many trichomes in one sheath which are densely fasciculated and coiled one around another, up to 56 μm wide. Mucilaginous sheaths widened, forming distinct, up to 19 μm wide margin around trichomes or trichome fascicles, firm, limited, colourless, sometimes covered by small detritus particles on the surface, sometimes indistinctly striated near the margin, open at the ends (often with trichomes passing out from sheaths). Trichomes thin, cylindrical, 2.5–3 μm wide, not constricted or rarely slightly constricted at cross walls. Cells longer than wide, (2.8) 3–7.5 (9) μm long, with pale yellow green content; terminal cells conically narrowed, with a very small, rounded calyptra.

Locality: Sample no. 51820.

Comments: Probably a new species of the genus *Microcoleus* (subg. *Trichocoleus*), defined by cell and trichome morphology; however, the calyptrate end cells (?) resemble rather typical *Microcoleus* morphology. Our specimens do not correspond with any *Microcoleus* species with cells always longer than wide, and trichomes up to 3 μm wide (comp., e.g., STARMACH 1966). The generic identification should be solved in the frame of the whole subfamily Microcoleoideae (the recognition of fine structure is important).

15. *Schizothrix radius-solis* spec. nova

(Fig. 19; Plate 6)

Thallus microscopical up to macroscopically recognizable, composed from polarized, free, fasciculated or parallelly arranged filaments of changing width, joined by their bases and irregularly, simply finger-like divaricated. Filaments up to 25 μm wide, containing one or many parallelly and densely arranged trichomes, which are waved and coiled irregularly together. Sheaths slightly overlap trichomes or their fascicles, limited, slightly parallelly lamellated and intensely, shiny gold-yellow (only the ends are colourless), but sometimes violet (especially at filament bases), attenuated and more or less pointed towards the ends, almost closed or terminated with indistinct,

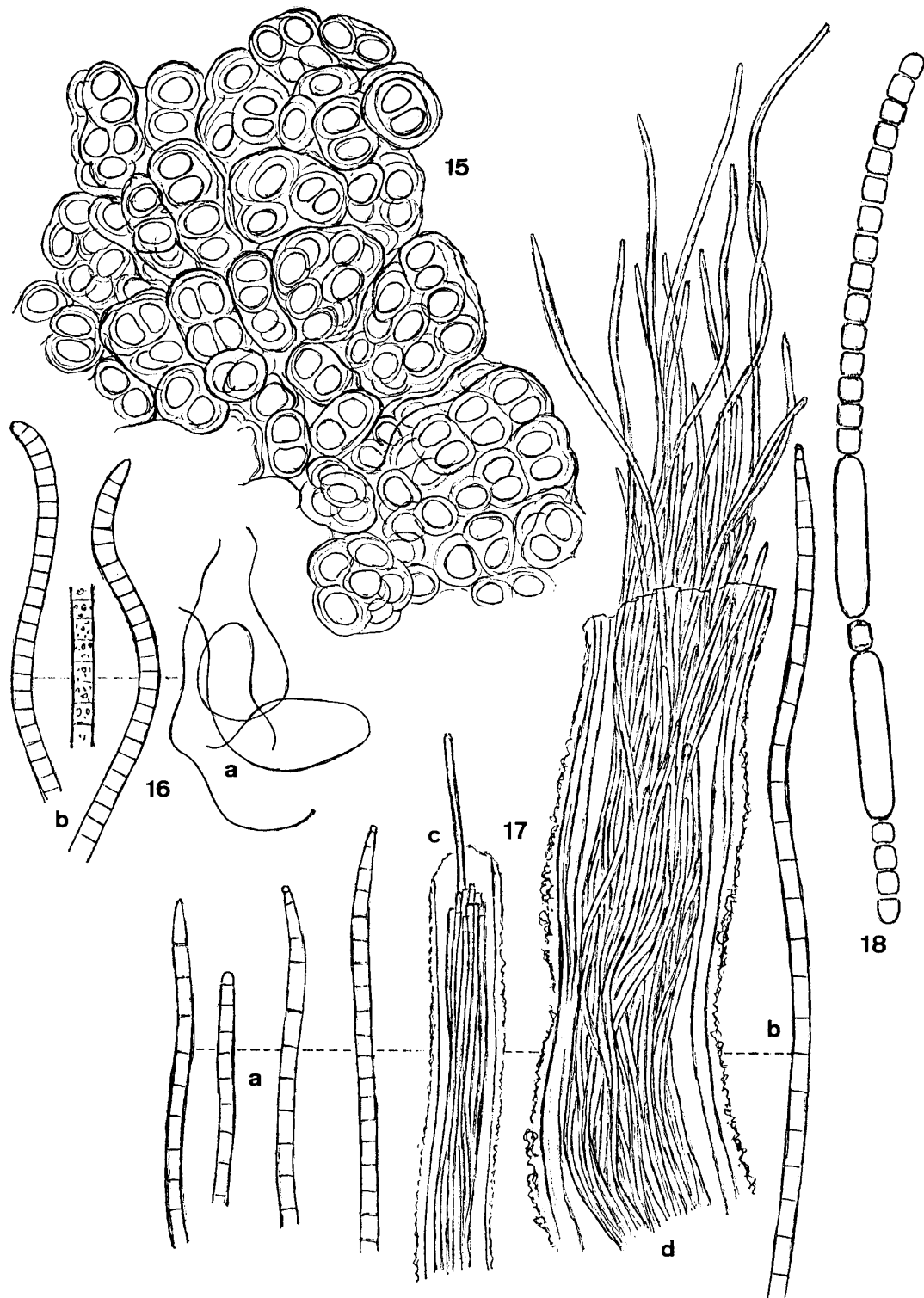


Fig. 15. *Entrophysalis rubra*: part of old colony.

Fig. 16. *Jaaginema* sp.: a = shape of coiled filaments, b = detail of trichomes.

Fig. 17. *Microcoleus* sp.: a = ends of trichomes, b = solitary trichome, c = end of filament, d = end of old filament with numerous trichomes.

Fig. 18. *Anabaena* sp.: single trichome with akinetes at both sides of an intercalary heterocyte.

small openings. Trichomes cylindrical, 1.8–1.3 μm wide, very slightly constricted at cross-walls (immersion!). Cells always longer than wide (up to 2.5-times), but after division almost isodiametrical, with homogeneous, pale grey-blue content; end cells rounded, or rarely slightly narrowed and rounded.

Locality: Near Pangpoche, in a shallow, cold, catharobic, small lake about 30×50 m, submersed in shallow water, metaphytic or periphytic on rocks; coll. in October 14th, 1980. (Samples nos. 51781, 51782, 51783, 51784).

Diagnosis: Filamenta ad 25 μm lata, cum trichomatibus sparsis vel numerosis, dense paralleliter consociatis et paucim contortis, ad apices attenuata et acuta. Vaginae mucilaginosae paucim amplae, limitatae, intense aureo-luteae interdum violascentes, solo cum apicibus sine colore. Trichoma simplicia, plus minusve cylindracea, ad dissepimentis not vel paucim constricta, 0.8–1.3 μm lata; cellula apicalis rotundata vel rotundate-attenuata. Cellulae cylindraceae, ad $2.5 \times$ longiores quam latae, contentu homogeneo, palescente griseo-aerugineo.—Typus: lamina 51782 (TNS), iconotypus: figura nostra 19.—Habitatio: Metaphytice vel periphytice ad saxa submersas prope Pangpoche in aquis catharobis, Montes Emodi, Nepalia.

Comments: Only few species are clearly recognizable and repeatedly indentifiable from the very polymorphic genus *Schizothrix*. However, our Himalayan specimens do not correspond with any species with yellow-coloured sheaths. The most closely related is *S. affinis* LEMM., with only few (1–2) trichomes within yellowish-brown sheaths, described from aquatic localities in Asia. All other species have distinctly wider trichomes and usually also a different ecology.

16. *Microchaete* cf. *aequalis* (FRÉMY) DESIK. 1959

(Fig. 20)

Filaments solitary or in free groups, distinctly heteropolar with basal heterocytes and free apical ends, usually terminated by free (empty) sheaths, attached by the basal end to the substrate (epiphytic on subaerophytic algae, mosses and liverworts). Filaments usually simply curved, often with a creeping basal part (4.5–6 μm wide) and later more or less erect; initial stages creeping. Sheaths firm, thin, distinct, colourless, more or less of the same width along the whole length or lightly widened toward the ends (5–7 μm), open at the apex, sometimes slightly lamellated (visible at the ends). Trichomes slightly widened at the base (more or less 3.5–4.5 μm wide), later usually a little narrowed (in about $1/3$ of length = 2.4–3 μm), at the apical end again up to 5 μm wide, distinctly constricted at the cross walls. Cells of different length (4.5–10 μm long), elongated at the base, but sometimes, on the contrary, with short, up to isodiametric basal cells and longest cells more or less in $1/3$ of total length. In the middle of trichome and towards the end the cells are almost isodiametrical or shorter than

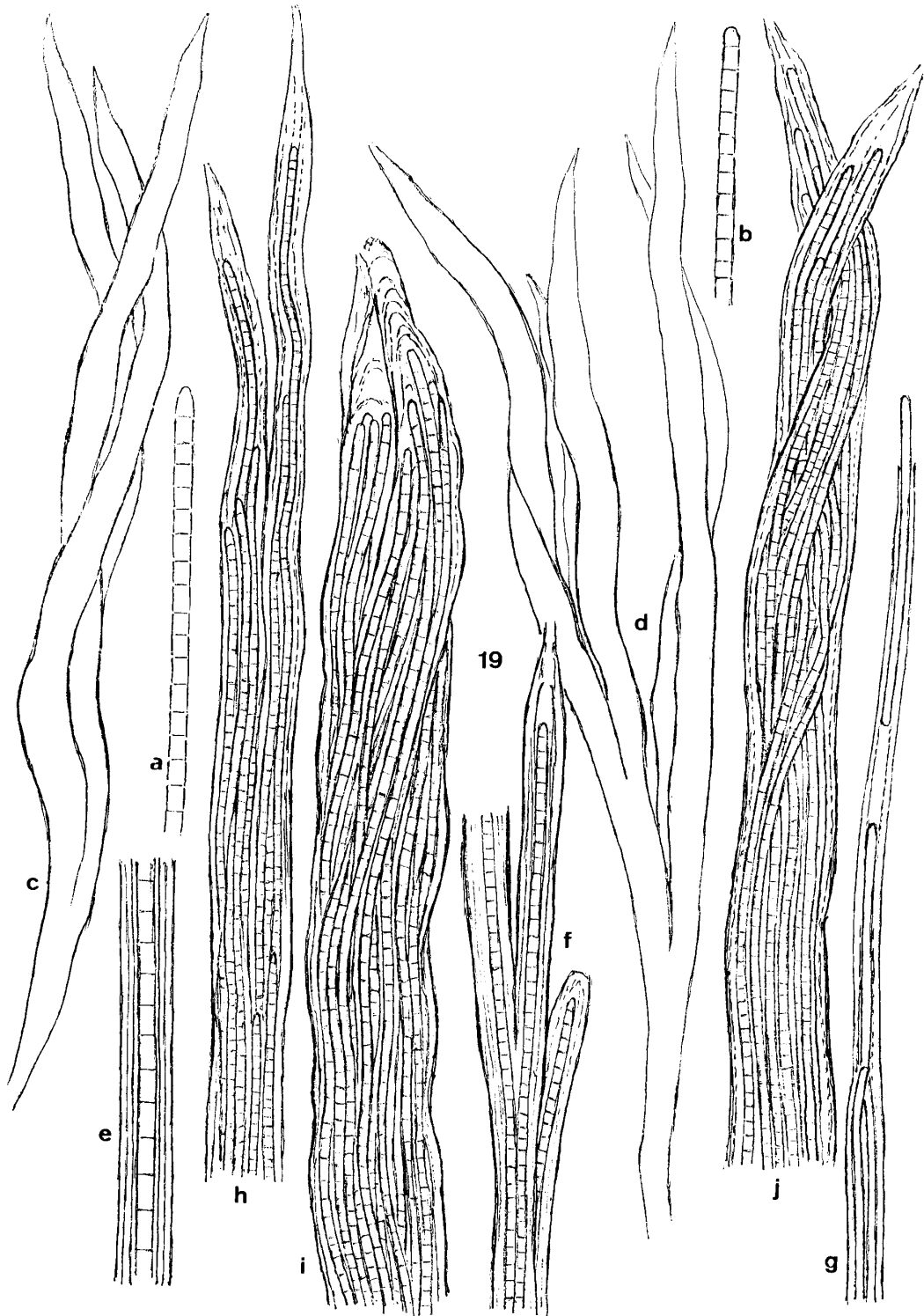


Fig. 19. *Schizothrix radius-solis*: a-b=ends of trichomes, c-d=shape of falsely branched filaments, e-g=details of young filaments, h-j=ends of old filaments.

wide; near the apex indistinct meristematic zones occur. Reproduction by hormogonia, which germinate only at one end, at the base a basal heterocyte very soon arises. Cell content blue-green, usually slightly irregularly granular, without visible chromatoplasma. Terminal cells rounded. Heterocytes obligatory basal, usually spherical or slightly oval or shorter than wide, outside a sheath, more or less $5\ \mu\text{m}$ in diameter. In lower parts of trichomes (about in $1/5$ – $1/4$ of trichome length) solitary intercalary heterocytes sometimes develop, which are cylindrical, up to $10\ \mu\text{m}$ long.

Locality: Subaerophytic, epiphytic species, growing on mosses and liverworts in dripping water and on wetted localities, on rocks and free roots of trees. Sample no. 51774.

Comments: We identified our specimens as *M. aequalis*, as most similar to FRÉMY's (1942) drawings of "*Fremyella aequalis*", in spite of slightly wider trichomes and discrepancies in data of previous authors (DESIKACHARY 1959 writes, e.g., that the trichomes are not constricted at the cross walls, in contradiction to FRÉMY's drawings, etc.). However, the tropical species of the genus *Microchaete* are little known and should be revised by further investigations.

17. **Fortiea** sp.

(Fig. 21)

Filaments more or less solitary or near to one another, distinctly heteropolar with basal heterocytes and free apical ends with widened trichomes, but sheaths are more or less of the same width along the whole length. Attached to the substrate by the basal end, irregularly waved, at the basis (3.6) 7.4 – $9.5\ \mu\text{m}$, at the apex (5) 6.2 – $7.6\ \mu\text{m}$. Sheaths firm, more or less thick (in the middle part up to $2.4\ \mu\text{m}$), but not very distant from the trichome, colourless, slightly lamellated, open at the apex. Trichomes distinctly narrowed at the base and particularly in lower two thirds of the whole length or slightly widened at the base, but later very narrow (1.2 –about $2.5\ \mu\text{m}$ wide), with long, cylindrical cells, up to 4.5 x longer than wide, without constrictions at cross walls. Ends of trichomes distinctly widened, 5 – $7.6\ \mu\text{m}$ wide, with shorter (up to isodiametrical or slightly shorter than wide) cells with distinct constrictions at cross walls, up to barrel-shaped. Cell content greyish, pale blue-green or olive-green, with solitary small granules. End cell widely rounded. Reproduction by hormogonia was not observed. Heterocytes basal, outside sheaths or within sheaths (above of the basal heterocyte or secondary after hormogonia formation ?), spherical, or (mainly) oval or slightly ovoid, up to $7.5\ \mu\text{m}$ in diameter. Rarely intercalary, cylindrical, narrow, slightly longer than wide heterocytes in the basal trichome parts.

Locality: Found in the sample 51773.

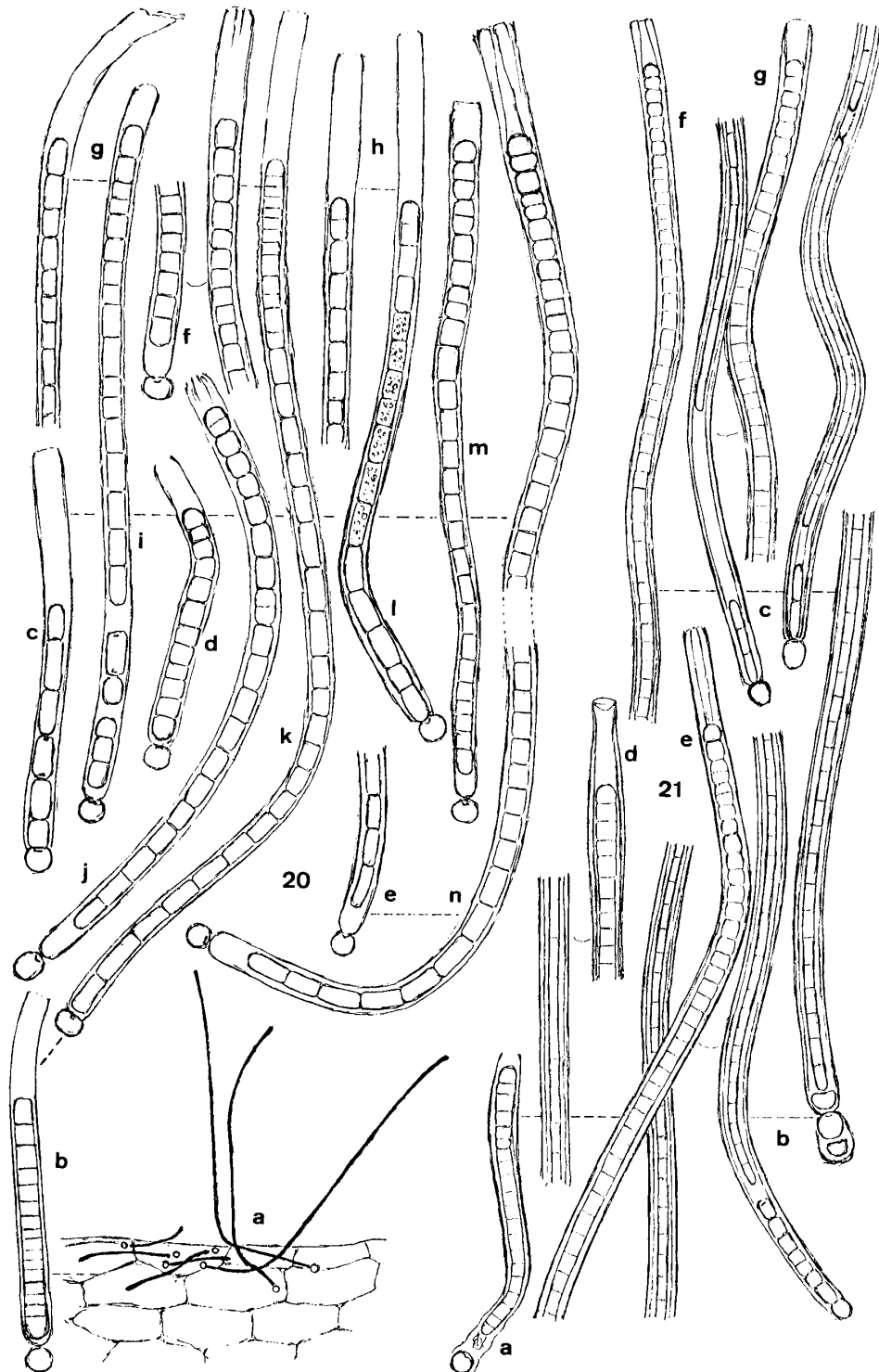


Fig. 20. *Microchaete* cf. *aequalis*: a = group of filaments on the substrate, b-d = young filaments, e-f = filament bases, g-h = filament ends, i-n = old filaments.

Fig. 21. *Fortiea* sp.: a = young filament, b-c = filament bases, d-g = filament ends.

Comments: Because this species was found very near to and in similar habitats to *Microchaete aequalis*, and because the dimensions are similar, we can not identify this species with certainty. Moreover, in the iconotype of FRÉMY's (1942) *Fremyella aequalis* (basonym of *Microchaete aequalis*) the basal parts of the trichomes are also distinctly narrower than in the upper parts (see also in DESIKACHARY 1959, fig. 81: 16). However, our specimens have some important differences from the *Microchaete* described above (morphology of cells and trichomes), that this to say the population can hardly be classified with *M. aequalis*; it has all the generic features of *Fortia*. The variability of these species must be therefore revised.—If compared with other species of the genus *Fortia* (GEITLER 1932 under *Leptobasis*, DESIKACHARY 1959, STARMACH 1966, KOMÁREK 1984), our material is nearest to *Fortia monilispora* KOMÁREK from Cuba, which differs, however, by larger dimensions and more thick and striated sheaths in the central part of filaments.

18. **Cylindrospermum cf. breve** WELSH 1965

(Fig. 22)

Epiphytic in solitary trichomes or small groups of trichomes without sheaths. Trichomes are very short, almost straight, usually slightly arcuated or a little waved, maximally with 24 vegetative cells, uniserial, more or less cylindrical, with clear constrictions at cross walls, usually with heterocytes at both ends (sometimes of different size), rarely only at one end; in this case the apical vegetative cell is rounded. Cells shortly cylindrical or slightly barrel-shaped, usually isodiametrical or slightly shorter or longer than wide, pale blue-green, with solitary prominent granules, $1.5-4.8 \times 2.2-3 \mu\text{m}$. Heterocytes only terminal, more or less spherical, with hyaline or yellowish, homogeneous content, $1.8-2.4 \mu\text{m}$ in diameter (*i.e.*, usually narrower than vegetative cells). Akinetes develop only at one end of trichomes (in our sample!), cylindrical, solitary or very rarely in twos, with slightly granular content, usually $6-8 \times 3-5 \mu\text{m}$ (mature ?). In filaments solitary or coupled hyaline, not deformed (not nekridic), a little enlarged cells sometimes occur, beside the heterocytes or in intercalary position, occasionally also between a heterocyte and an akinete. Their content is quite colourless, but sometimes there occur solitary granules. Their function is not clear.

Locality: Epiphytic on *Scytonema*, among wet mosses on rocky substrate and on roots of trees in streaming and dropping water (our sample no. 51773).

Comments: The species *C. breve* WELSH 1965 is known from S. Africa and Cuba (WELSH 1965, KOMÁREK 1989). The Himalayan specimens do not correspond exactly with the Cuban samples (which have larger oval akinetes). Also interesting are the hyaline cells in our samples.

19. *Cylindrospermum indicum* RAO 1936

(Fig. 23)

Colonies macroscopic, with waved trichomes without sheaths; mucilage very fine, indistinct, diffuent. Trichomes cylindrical, of the same width along the whole length, clearly constricted at cross walls; heterocytes mainly at one, rarely at both trichome ends, apical cells rounded. Cells more or less cylindrical or slightly barrel-shaped, isodiametrical or a little shorter than long up to 2-times longer than wide, $3.2\text{--}7 \times 3.2\text{--}4.5 \mu\text{m}$, with pale blue-green, olive-green or yellow-green content, with scarce, irregular, small granules. Heterocytes only terminal, spherical ovoid, oval up to cylindrical with rounded ends, with hyaline or slightly yellowish content, $5.5\text{--}13.5 \times 5.5\text{--}7.2 \mu\text{m}$. Akinetes oval to cylindrical with widely rounded ends, with yellow-brown episporium, which is radially striated (apparently short spiny). Content of akinetes evenly granular. Ripe akinetes = $18\text{--}28 \times 12.5\text{--}20 \mu\text{m}$.

Locality: Thin mats on a rocky substrate, continually overflowed by clear, catharobic spring water (our sample 51775).

Comments: Our material corresponds almost perfectly with the description of *C. indicum*, the small differences (*e.g.*, in the size of akinetes) are surely in the frame of its variation. *C. indicum* is evidently a well delimited and distinguishable species.

20. *Anabaena* sp.

(Fig. 18)

Filaments solitary or in small, free groups, without sheaths or envelopes, slightly irregularly waved, not attenuated at the ends, more or less cylindrical, distinctly constricted at cross walls. Cells more or less isodiametrical, cylindrical, with pale grey-blue content, $2.2\text{--}2.6 \mu\text{m}$ wide; terminal cells rounded. Heterocytes intercalary, solitary, shortly cylindrical, $2.5\text{--}3 \times 2.3\text{--}2.6 \mu\text{m}$. Akinetes at both sides of heterocytes, long, cylindrical, with smooth episporium, usually $12\text{--}13 \times 3 \mu\text{m}$.

Locality: This species was found only in solitary trichomes among other algae (sample no. 51821).

Comments: This species is similar to *Anabaena cylindrica*, but differs by having smaller dimensions (*e.g.*, trichomes are up to $2.6 \mu\text{m}$ wide, while in *A. cylindrica* $3\text{--}4 \mu\text{m}$ wide), and heterocytes are more rectangular. Because we do not have rich material and akinetes occurred only sparsely in the sample (their variability was not well recognized), we do not identify the species.

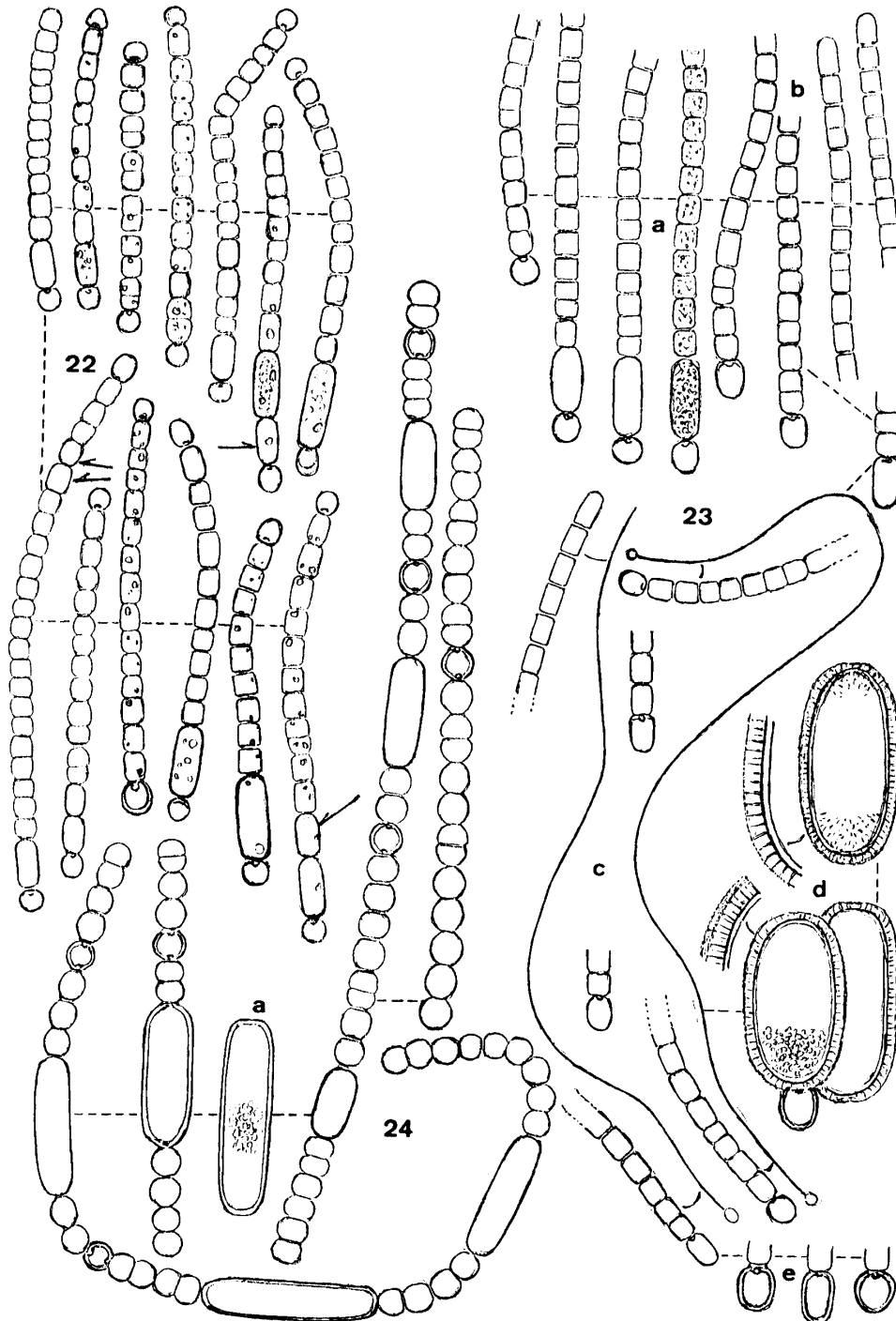


Fig. 22. *Cyindrospermum breve*: different shapes of trichomes (arrows indicate hyaline cells).

Fig. 23. *Cyindrospermum indicum*: a=ends of trichomes with heterocytes and young akinetes, b=ends of trichomes without heterocytes, c=shape of trichomes with details of ends, d=ripe akinetes, e=variation of heterocytes.

Fig. 24. *Anabaena cf. laxa*: trichomes with intercalary heterocytes and akinetes, a=ripe akinete.

21. *Anabaena* cf. *laxa* (RABENH.) A. BR. in BORN. et FLAH. 1885

(Fig. 24)

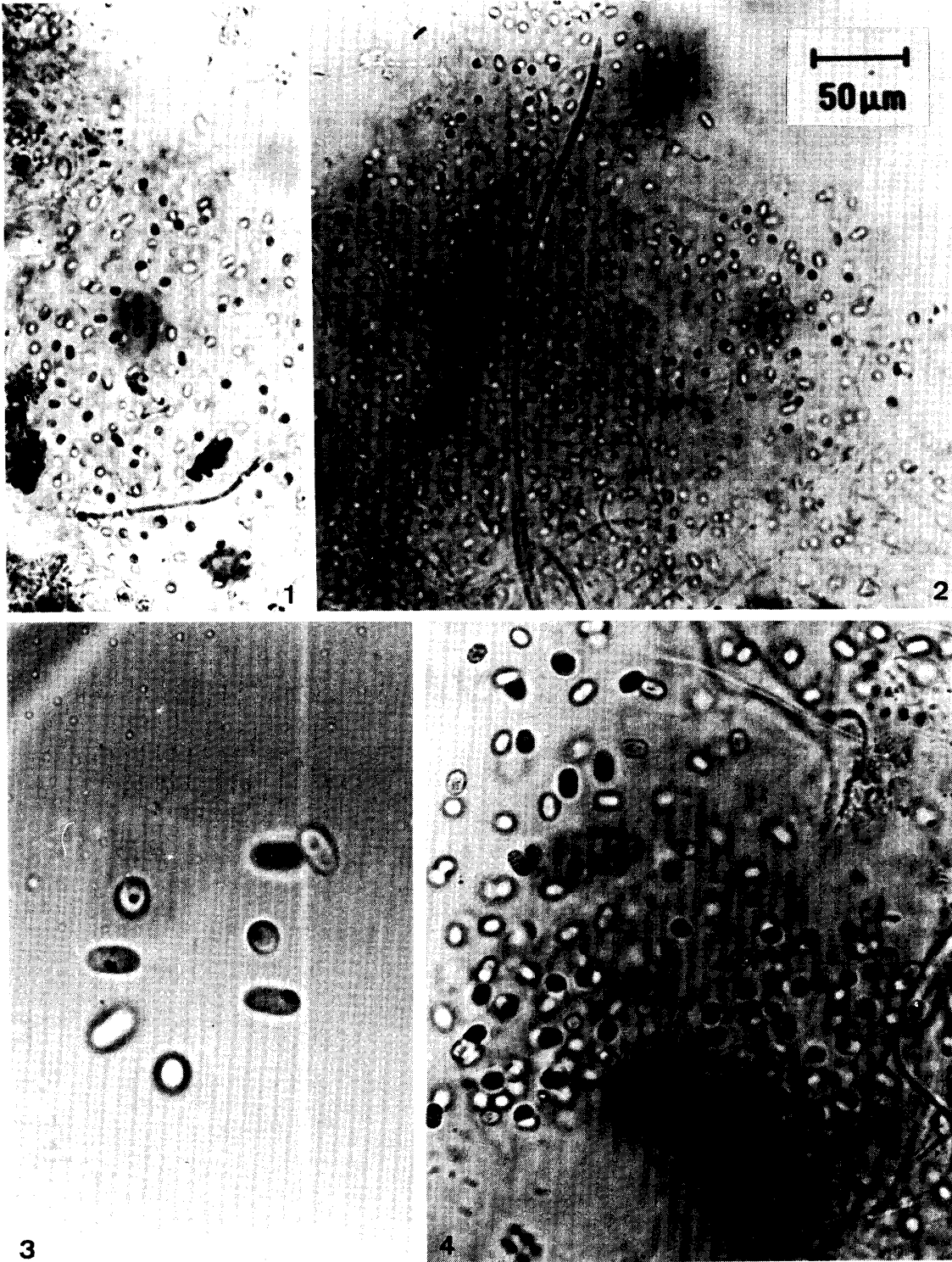
Filaments solitary or in small groups, more or less straight or irregularly freely coiled, clearly metameric, not attenuated at the ends; akinetes slightly distant from heterocytes, separated by 1–4 cells, but rarely akinetes develop far from heterocytes; akinetes develop solitarily, the doubles were not found. Cells spherical or slightly lemon-shaped or barrel-shaped, with deep constrictions at cross-walls, pale blue-green, without aerotopes, 2.8–7 μm wide. Heterocytes spherical, more or less of the same size as vegetative cells, 3.5–7 μm in diameter. Akinetes cylindrical, 15–22.5 \times 5–10 μm , with colourless, smooth epispore.

Locality: Metaphytic among other algae (samples nos. 51774, 51795, 51809).

Comments: In our samples a wide variability of this species occurs, particularly in the sizes of all of the kinds of cells. In samples 51795 and 51809 the trichomes are 2.8–3.6 and 3.5–4 μm wide, respectively, in the sample 51774 they are 5–7 μm wide. Differences were also found in akinete size (15–20 \times about 5 μm and about 22.5 \times 10 μm) and a little in cell form. The connecting cell wall in the “larger” type (51774) was narrower than in other samples. However, because the ecology and all other characters are almost the same, all these differences probably belong to the one variation range.—*Anabaena laxa* is a little known species, which was synonymized by GEITLER (1932) and DESIKACHARY (1959) with *A. inaequalis* and *A. oblonga*. STARMACH (1966) distinguishes both species (*A. inaequalis* and *A. laxa*), but the differential features are not clear. In several papers *A. laxa* occurs in other meanings (e.g., as a planktic species). According to our experience, the tropical *A. oblonga* is distinctly separated from this cluster of related species. Our material from Sagarmatha National Park was variable, but also different from this species, as well as from our populations of *A. inaequalis* from the temperate zone, particularly from central Europe. In these populations the trichomes are always slightly thinner, cells are not spherical but rather barrel-shaped, akinetes usually occur in series 2–3 (but also solitarily), etc. The variability of this complex of species is not well known, we retain therefore the name “*Anabaena laxa*” provisionally for this species.

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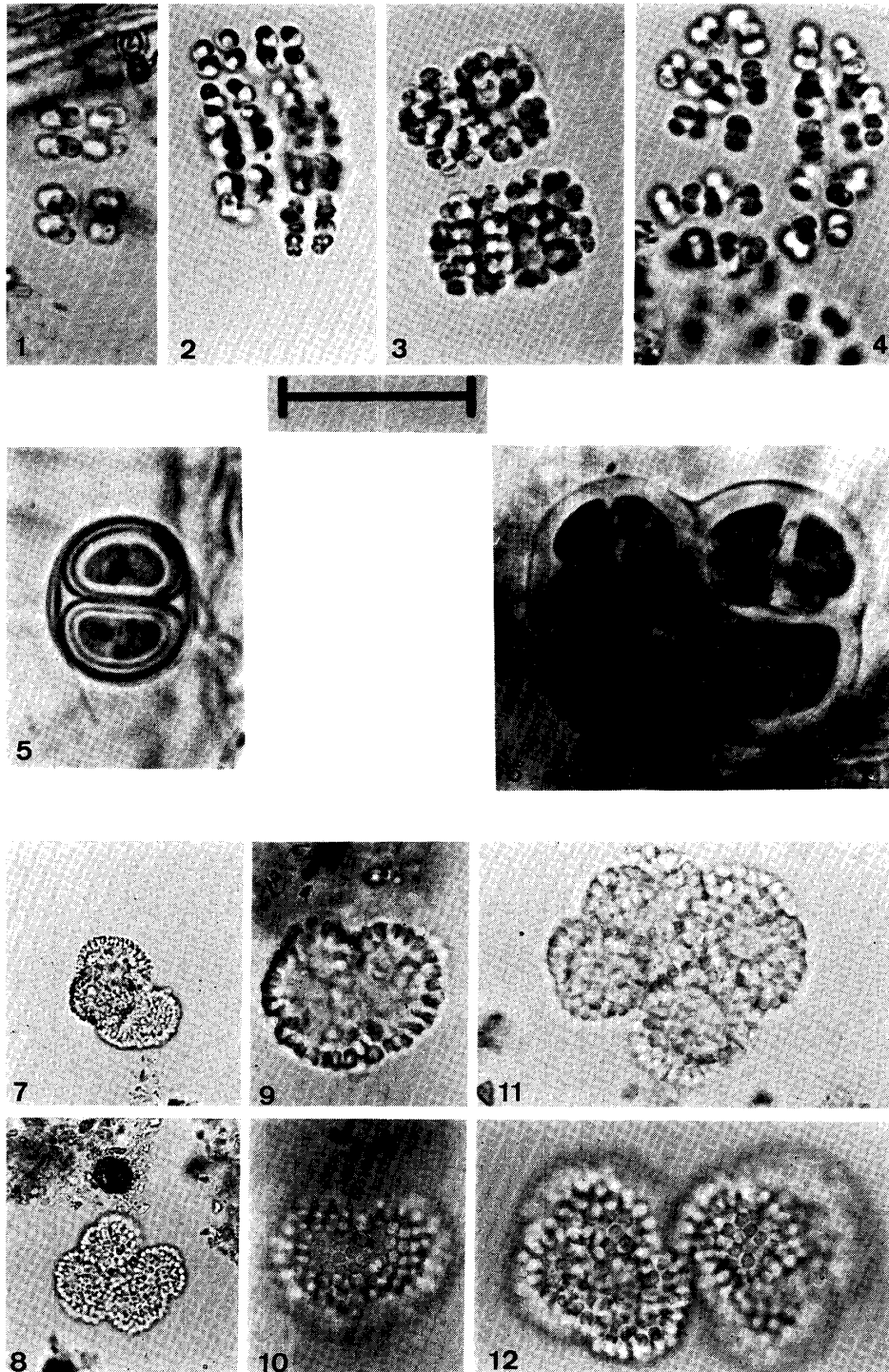
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Plates 1.

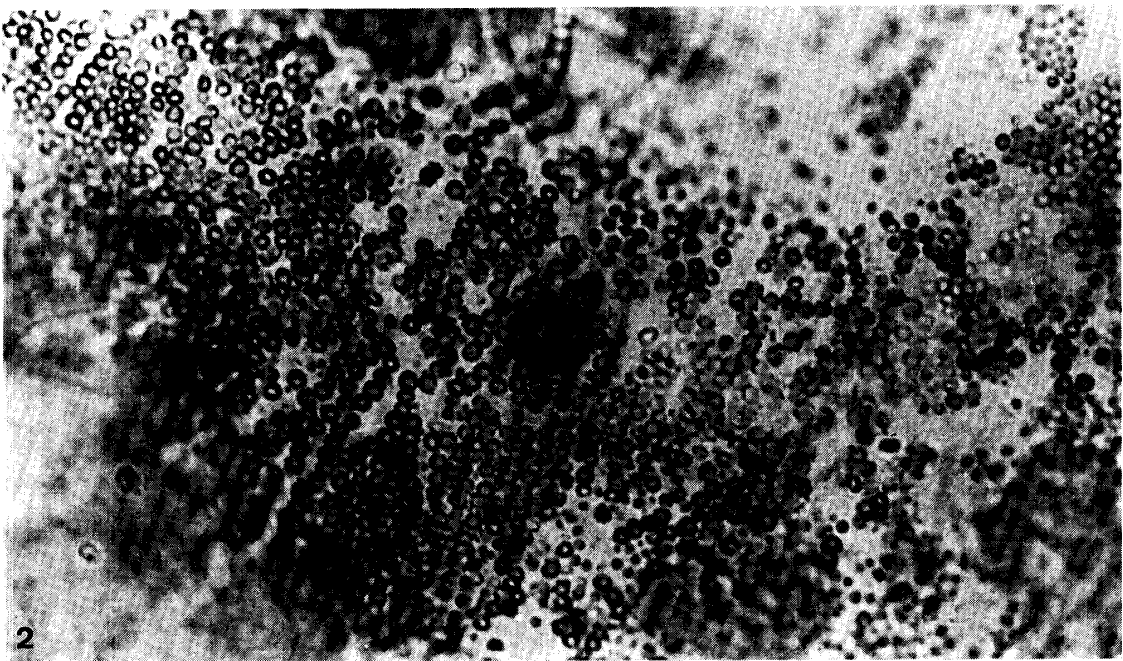
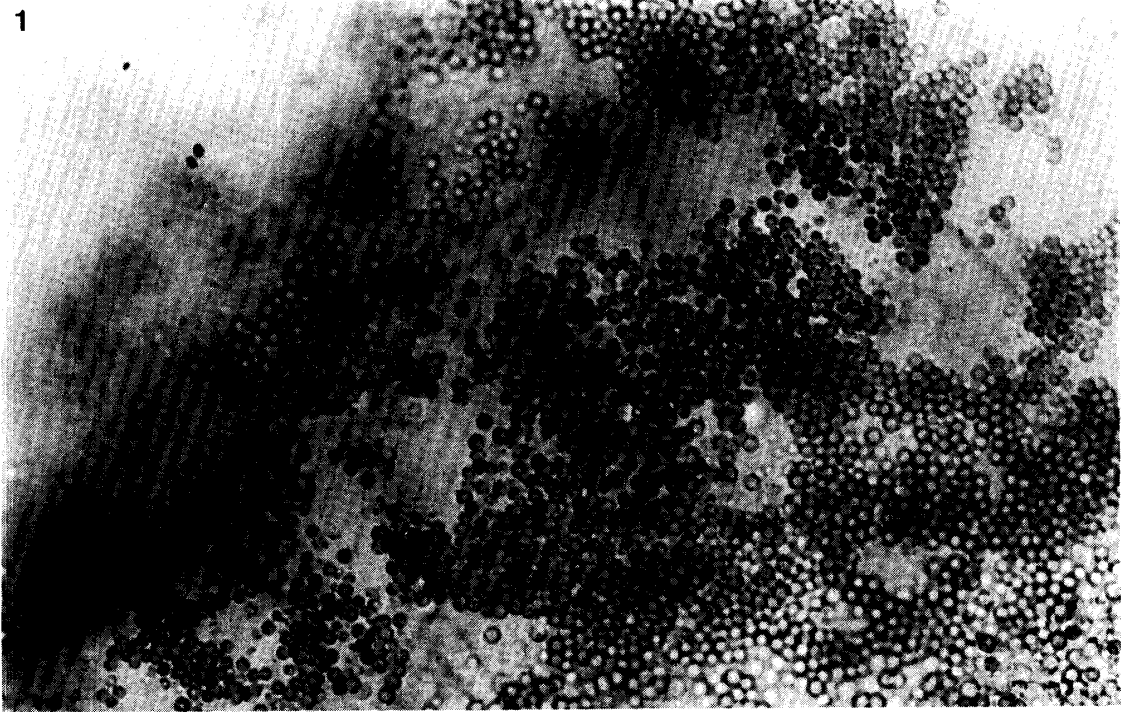
1- 2 = *Aphanothece* cf. *nidulans*

3- 4 = *Aphanothece* cf. *castagnei*



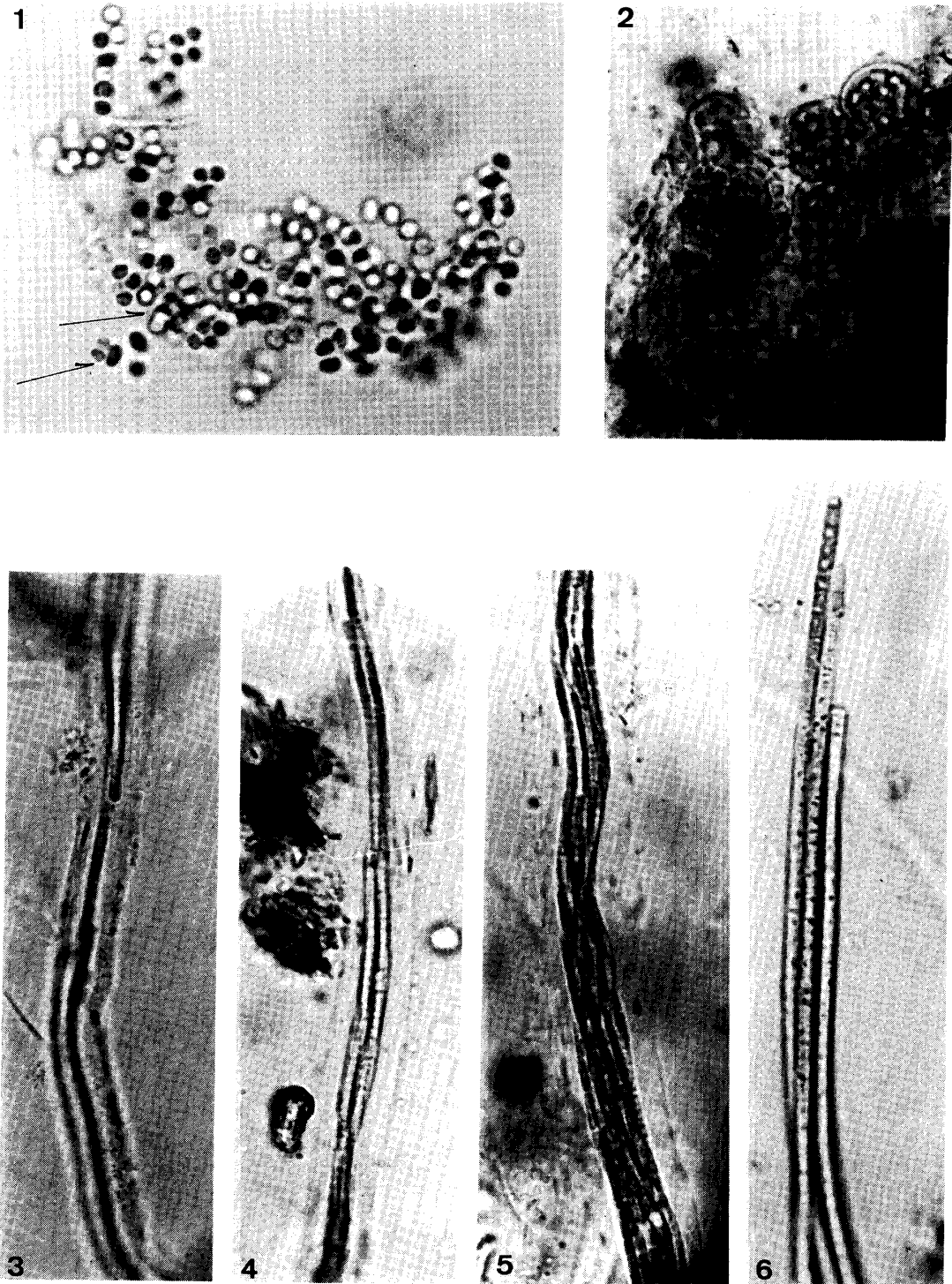
Plates 2.

- 1- 4 - *Eucapsis himalayensis*
 5 - *Chroococcus tenax*
 6 - *Chroococcus turicensis* (composed colony)
 7-12 - *Woronichinia kuselae*



Plates 3.

1- 2=*Chlorogloea simplex*

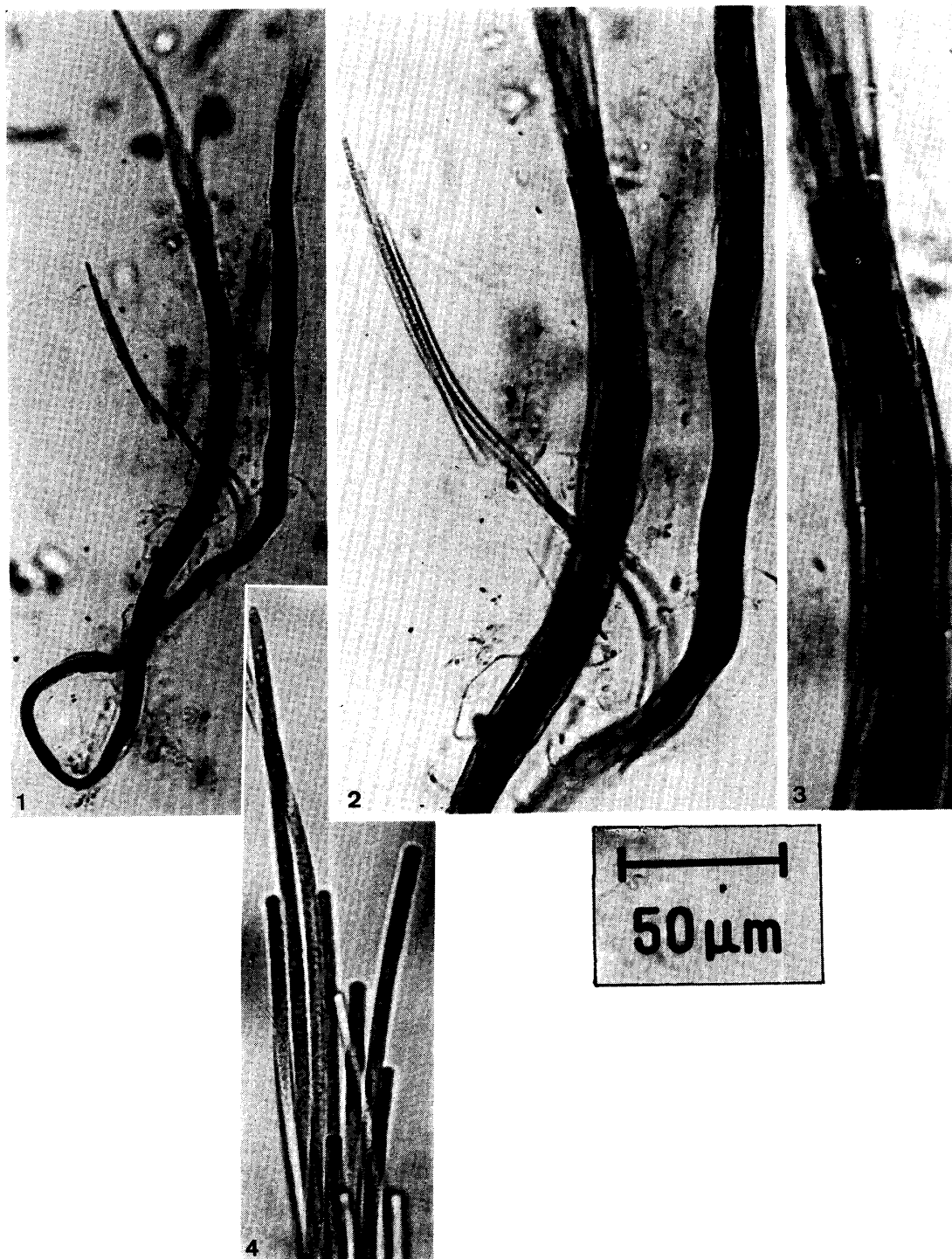


Plates 4.

1 - *Chlorogloea simplex* (young colony)

2 - *Enthophysalis rubra*

3- 6 - *Microcoleus* sp.



Plates 5.

1- 4 - *Microcoleus* sp.



Plates 6.

1- 3 = *Schizothrix radius-solis*

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