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ECO-TAXONOMIC DISTRIBUTION OF SOME COLONIAL CYANOPHYCOTA FROM NORTH-EAST PUNJAB, PAKISTAN

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Abstract

This study was carried out in four districts of Punjab i.e. Gujranwala, Gujrat, Narowal and Sialkot, which represents the north-east region of Pakistan. The sampling was performed randomly in different seasons of the year and 35 colonial species of cyanophycota belonging to 9 genera were identified. Most of the species were found abundantly in summer season and at alkaline pH greater than 7, which indicate that warmer conditions are required for optimal growth of colonial cyanophycota. Among 35 colonial cyanophycotes, Largest genus was found to be *Aphanocapsa* with its 8 species having variable pH and EC ranging from 7.68-8.9 and 75.3-144, followed by *Merismopedia* (7 spp.) having pH and EC ranging from 7.66-8.7 and 92.8-161, *Chroococcus* (5 spp.) having pH and EC ranging from 7.87-9.8 and 93.67-150.5, *Gloeocapsa* (4 spp.) having pH and EC ranging from 8.12-8.82 and 130.8-149.2, *Synechoccus* (3 spp.) having pH and EC ranging from 8.5-8.88 and 102.8-135 and *Microcystis* (3 spp.) having pH and EC ranging from 7.85-8.7 and 122.3-126, *Gloeothece* (2 spp.) having pH and EC ranging from 8.12-8.36 and 109.5-118.7, *Aphanothece* (2 spp.) having pH and EC ranging from 8.07-9.21 and 116.8-122.7 and *Eucapsis* (1 sp.) with pH and EC i.e., 8.3 and 12.02 respectively.

Key words: Eco-taxonomic, Colonial cyanophycota, North-East Punjab.

Introduction

Algae are the major producers in the aquatic ecosystem which continuously release oxygen in the atmosphere and an integral part of food chain. These freshwater algal blooms also help to mitigate atmospheric carbon dioxide as one of the largest sink of greenhouse gas (CO_2) which prevents drastic climatic changes and contribute in keeping the ecosystem intact. It also fix the nitrogen of the air into useable amino acids and participate in fertility of the soil by converting ammonium ions in the nitrites and nitrates as a chief components of this process. Moreover, one can obtain commercial benefits like alginates, carrageenan and agar. Algae can be used as food and fodder by consumers. Algae can utilize free atmospheric nitrogen and fix into amino acids, Ammonium ion or Nitrates (Naz & Shameel, 2003; Martin, 1989; Lee, 2008).

As far as, the habitat of colonial cyanophycotes is concerned, it is found that these species can easily be found at variable pH and EC which vary from species to species. Whilst the most of the species of colonial cyanophycotes are found to be present in summer seasons in warmer water with greater temperature and EC. But some species can also be found in winter season in their vegetative form. Light, temperature, salinity, pH, hardness, solubility of gases, electrical conductivity, density and concentration of different nutrients are the important factors for growth of algae (Soeder & Stengel, 1974; Sipaúba-Tavares *et al.*, 2010).

This study will help to maintain optimal conditions for the growth of colonial algae in order to take further benefits through biological techniques by producing biofuel which is the need of the day in order to reduce anthropogenic pressure on natural resources such like fossil fuel.

Study area: Four districts of North-east Punjab i.e., Gujranwala, Gujrat, Narowal and Sialkot were selected. The algal specimens were collected from different sites of these districts and geological position was recorded for each sample in these districts (Fig. 1). These sites included rain pools, road sides, ponds, fountain water tanks, permanent water reservoirs, rivers, rice fields, canals and irrigation channels. Sampling was done during different seasons of the year.

Materials and Methods

From the selected districts of the North-east Punjab, randomly samples were collected with the help of forceps and by hands etc. Some specimens were scraped from the surface of moist soil, walls of tube wells and other substrata. All the collected samples were preserved according to standard methods. Different ecological parameters such as pH and EC were noted in different seasons of the year. Each specimen bottle was numbered, dated with area code (Anon., 1985).

After the necessary collection, the samples were stained with 1% Iodine solution to make wall and other structures clearly visible. The stained material was examined under inverted microscope (Labomed TCM 400) and the size of specimens were measured with calibrated ocular microscope. The specimens were identified and classified with the help of literature (Prescott, 1962; Tiffany & Britton, 1952; Desikachary, 1959; Masud-ul-Hassan & Yunus, 1989; Shameel, 2012).

Results

Algal specimens were collected, identified and classified on the basis of their taxonomic features i.e. morphological and cytological features upto the species level in Table 2 (Shameel, 2012). Total 35 colonial algal species were found at variable pH and EC belonging to phylum Cyanophycota, class Chroocophyceae, order Chroococcales and Family Chroococcaceae containing 9 genera. First genus was *Aphanothece* having two species *A. saxicola* and *A. castagnei* growing on the substrata having pH (8.07 and 9.21respectively) and EC (116.8 and 122.7 respectively). Second genus was *Aphanocapsa* containing eight species which were *A. koordersii* (8.5pH and 107.8 EC), *A. pulchra* (8.57 pH and 137.3 EC), *A. Montana* (8.92 pH and 128.3 EC), *A. elachista* (8.57 pH and 144 EC), *A. roeseana* (8.6 pH and 141.5 EC), *A. muscicola* (8.22 pH and 109.7 EC), *A. banaresensis* (8.3pH and 128.7 EC) and *A. biformis* (7.68 pH and 75.3 EC). The third genus was *Gloeocapsa* containing 4 species which were *G. polydermatica*, *G. decorticans*, *G. compacta* and *G. nigrescens* having pH 8.8, 8.12, 8.82 and 8.17 and EC was 139.7, 149.2, 130.8 and 141.8 respectively. Fourth genus was *Synechococcus* containing 3 species which were *S. cedrosum* (8.5 pH and 135 EC), *S. elongates* (8.7 pH and 102.8 EC) and *S. aeruginosus* (8.88 pH and 110.2 EC). Fifth genus was *Gloeothece* containing two species *G. linearis* with 8.12 pH and 109.5 EC and *G. rhodochylamys* (8.36 pH and 118.7 EC). Next genus was *Merismopedia* which was classified into 7 species i.e., *M. convolute* (7.66 pH and 92.8 EC), *M. minima* (8.77 pH and 143.2 EC), *M. tenuissima* (8.57 pH and 161 EC), *M. punctata* (8.7 pH and 145 EC), *M. aeruginea* (8.45 pH and 127.3 EC), *M. glauca* (8.38 pH and 138 EC) and *M. elegans* (8.48 pH and 150.6 EC). Seventh genus was *Eucapsis* containing only one species *E. minuta* having 8.3 pH and 120.2 EC. Eighth genus was *Chroococcus* containing five species which were *C. gomontii*, *C. varius*, *C. minor*, *C. hansgirgi* and *C. turgidus* having 8.28, 8.62, 7.87, 9 and 8.75 pH and EC was 116.5, 118, 93.67, 137.67 and 150.5 EC respectively. The last genus was *Microcystis* containing 3 species *M. robusta* (8.32 pH and 122.3 EC), *M. aeruginosa* (8.7 pH and 126 EC) and *M. pulverea* (7.85 pH and 126 EC). All the thirty-five colonial cyanophycote species were drawn with the help of Camera Lucida and shown from Figs. 2–36 respectively for colonial members i.e. *Aphanothece saxicola* to *Microcystis pulverea* (Table 1) also *Synechococcus elongates* and *Merismopedia convoluta* were found in all the districts under study while *Merismopedia punctata* and *Chroococcus turgidus* were found only in Gujranwala district. *Eucapsis minuta* was found in Narowal and Sialkot districts. The most diverse genus was *Aphanocapsa* containing 8 species while the *Merismopedia* was represented by 7 species. Both of these genera were found in the whole study area from most of the water bodies. These were found in almost all kinds of freshwaters. The least diverse genus was *Eucapsis* containing only one genus i.e. *E. minuta* and was present only in the District Narowal. Gujranwala was found to contain highest algal diversity with 26 species out of 35 while lowest algal diversity was found in Gujrat with only 20 species out of 35, while 21 and 24 species were present in Narowal and Sialkot districts respectively (Table 1).

Fig. 1. Geographical positions of sampling units in four districts (A-D) of North East Punjab, Pakistan.
(A: Gujranwala, B: Gujrat, C: Narowal, D: Sialkot)

Table 1. Ecological distribution of colonial algae in different districts of Punjab, Pakistan.

Sr. No.	Algal species	Gujranwala	Gujrat	Narowal	Sialkot	pH	EC (µs)
1.	*Aphanothece saxicola* Nägeli	-	+	+	+	8.07 ± 0.08	116.8 ± 1.4
2.	*A. castagnei* (Brebisson) Rabenhorst	+	-	-	+	9.21 ± 0.25	122.7 ± 1.32
3.	*Aphanocapsa koordersi* Strom	+	-	+	+	8.5 ± 0.55	107.8 ± 1.53
4.	*A. pulchra* (Kützing) Rabenhorst	+	+	-	-	8.57 ± 0.28	137.3 ± 1.25
5.	*A. montana* Cramer	+	+	+	-	8.92 ± 0.55	128.3 ± 1.55
6.	*A. elachista* West G.S. West	+	+	-	+	8.57 ± 0.42	144 ± 1.38
7.	*A. roeseana* de Bary	+	+	-	+	8.6 ± 0.27	141.5 ± 1.42
8.	*A. muscicola* (Menegh) Wille	+	-	+	-	8.22 ± 0.56	109.7 ± 1.80
9.	*A. banaresensis* Bharardwaja	+	-	+	+	8.3 ± 0.27	128.7 ± 1.78
10.	*A. biformis* A. Brebisson	+	-	+	-	7.68 ± 0.26	75.3 ± 1.27
11.	*Gloeocapsa polydermatica* Kützing	+	+	+	-	8.8 ± 0.186	139.7 ± 1.17
12.	*G. decorticans* (A. Br.) Richter	+	-	+	+	8.12 ± 0.22	149.2 ± 1.02
13.	*G. compacta* Kützing	-	+	+	-	8.82 ± 0.14	130.8 ± 1.35
14.	*G. nigrescens* Nägeli	+	-	+	-	8.17 ± 0.38	141.8 ±1.95
15.	*Synechococcus cedrosum* Sauvageau	+	-	-	+	8.5 ± 0.49	135 ± 1.21
16.	*S. elongates* Nägeli	+	+	+	+	8.7 ± 0.75	102.8 ± 1.33
17.	*S. aeruginosus* Nägeli	+	+	-	+	8.88 ± 0.66	110.2 ± 1.20
18.	*Gloeothece linearis* Nägeli	-	+	+	+	8.12 ± 0.38	109.5 ± 1.19
19.	*G. rhodochylamys* Skuja	+	-	+	+	8.36 ± 0.43	118.7 ± 1.48
20.	*Merismopedia convoluta* Brebisson	+	+	+	+	7.66 ± 0.31	92.8 ± 1.95
21.	*M. minima* Breck	-	+	-	+	8.77 ± 0.18	143.2 ± 1.32
22.	*M. tenuissima* Lemmermann	-	+	-	+	8.57 ± 0.24	161 ± 1.28
23.	*M. punctata* Meyen	+	-	-	-	8.7 ± 0.33	145 ± 1.59
24.	*M. aeruginea* Brebisson	+	+	-	-	8.45 ± 0.13	127.3 ± 1.84
25.	*M. glauca* (Ehrenb.) Nägeli	-	+	+	+	8.38 ± 0.16	138 ± 1
26.	*M. elegans* A. Braun	+	-	+	+	8.48 ± 0.29	150.6 ± 1.31
27.	*Eucapsis minuta* Fritsch	-	-	+	+	8.3 ± 0.26	120.2 ± 1.67
28.	*Chroococcus gomontii* Nyguard	+	-	-	+	8.28 ± 0.27	116.5 ± 1.11
29.	*C. varius* A. Braun	+	+	-	+	8.62 ± 0.37	118 ± 1.78
30.	*C. minor* (Kützing) Nägeli	-	+	-	+	7.87 ± 0.33	93.67 ± 1.88
31.	*C. hansgirgi* Schmidle	+	+	+	+	9 ± 0.49	137.67 ± 1.41
32.	*C. turgidus* (Kützing) Nägeli	+	-	-	-	8.75 ± 0.22	150.5 ± 1.29
33.	*Microcystis robusta* (Clark) Nyguard	+	-	+	+	8.32 ± 0.35	122.3 ± 1.96
34.	*M. aeruginosa* Kützing	-	+	+	-	8.7 ± 0.20	126 ± 1.88
35.	*M. pulverea* (Wood) Forti	+	+	+	+	7.85 ± 0.45	126 ± 1.13

Discussion

Six morphological parameters and three ecological factors were studied and 35 species were identified. These morphological characters were shape of the colony, shape of the individual cell, Cell size, Mucilage of the colony, Mucilage of the individual cells and color of the thallus. While the ecological factors were pH, EC and season in which sampling was done. It was noted that individual cells of first two genera i.e. *Aphanothece* and *Aphanocapsa* were non-enveloped while cells of all other genera were enveloped similarly in *Aphanothece*, *Synechococcus* and *Gloeothece*, cell division occured in one plane which might be transverse (*Synechococcus*) or right angle (*Gloeothece*) while in *Aphanocapsa* and *Merismopedia* cell division occurs in two planes. In both these genera it is differentiated that individual cells non-enveloped in first and enveloped at the later while in rest of the genera, cell division occurs in three planes.

Two species *Synechococcus elongates* and *Synechococcus aeruginosus* were found at maximum pH i.e. 10.2. It was also found that at this pH the EC was low i.e., 85.5. So, it was found that high pH, low EC and high temperature of summer favored the growth of these species. On the other hand *Aphanocapsa biformis* shows minimum pH i.e., 7.2 and 47 EC and also show minimum growth. It was true only for filamentous algae but not for colonial algae. It was found that summer season conditions i.e. high temperature, high light intensity etc., favored the growth of algae but under certain conditions. This was found not favorable for colonial algae which require low pH, Low EC, high light intensity and high temperature. Kalin *et al*., (2001) also studied the relationships of the phytoplankton assemblages with the environmental data set and found close association among the algal flora and water quality parameters. Similarly, Munir *et al*., (2013) found a significant relation between distribution of algae along with temperature whereas negative relation was found between pH and EC along with distribution. Devika *et al*., (2006) also recorded high population during summer and suggested that this might be due to physical rather than chemical conditions in which the water temperature and transparency had a direct relationship with phytoplankton population. Water temperature influences aquatic weed algal blooms and surrounding air temperature (Gupta & Sharma, 1993). The higher range of pH indicates higher productivity of water (Khan & Khan, 1985). Similar kind of results were found by Khalid *et al*., (2014) found that blue green algae bred in summer season with high temperature which favored the growth of algae especially Cyanophycota.

Table 2. Taxonomic characteristics of some colonial cyanophycota of North East Punjab, Pakistan.

Sr. No.	Name of species	Thallus Color	SC	Colony shape	MC	MIC	DC (μ)	Season
1.	*Aphanothece saxicola* Nägeli	Colorless or Yellowish	Cylindrical	Spherical	Present	Absent	1-2	Summer,winter
	A. castagnei (Brebisson) Rabenhorst	Colorless or Yellowish	Ellipsoidal to Cylindrical	No definite shape	Present	Absent	2-4	Summer
2.	*Aphanocapsa koordersi* Strom	Blue green to dull green	Spherical	Circular	Present	Absent	2-3	Summer
	A. pulchra (Kützing) Rabenhorst	Blue-green	Orbicular	Circular	Present	Absent	4-5	Spring
	A. montana Cramer	Blue-green or Olive-green	Orbicular	No definite shape	Present	Absent	3-4	Summer
	A. elachista West G.S. West	Color-less	Ellipsoidal	Globular or ellipsoidal	Present	Absent	1-2	Summer, Winter
	A. roeseana de Bary	Brownish green	Oval	Globular	Present	Absent	5-8	Summer, Autumn
	A. muscicola (Menegh) Wille	Blue-green	Spherical	Spherical or ellipsoidal	Present	Absent	2-3	Summer, Spring
	A. banaresensis Bharardwaja	Colorless	Oval/Spherical	Circular	Present	Absent	4-6	Summer
	A. biformis A. Brebisson	Olive green	Spherical	Circular	Present	Absent	4-7	Summer, Winter
3.	*Gloeocapsa polydermatica* Kützing	Blue-green	Spherical	Circular	Present	Absent	3-5	Summer, Spring
	G. decorticans (A. Br.) Richter	Blue-green	Oval/Spherical	Oval	Present	Absent	19-21	Summer, Winter
	G. compacta Kützing	Reddish Brown	Spherical	No definite shape	Absent	Present	12-14	Summer, Winter
	G. nigrescens Nägeli	Blackish	Spherical	Oval	Absent	Present	2-3	Summer
4.	*Synechococcus cedrosum* Sauvageau	Blue-green	Ellipsoidal/elongated	Oval or ellipsoidal	Absent	Present	3-4	Summer
	S. elongates Nägeli	Light Blue-green	Cylindrical	No definite shape	Absent	Present	1.4-2	Summer
	S. aeruginosus Nägeli	Pale Blue-green	Cylindrical	No definite shape	Absent	Present	5-6	Summer
5.	*Gloeothece linearis* Nägeli	Hyaline or Yellowish	Cylindrical/Vermiform	Elongate-bulbous	Present	Present	1-3	Summer, Spring
	G. rhodochylamys Skuja	Blue-green, red or purple	Ellipsoidal to short cylindrical	More or less rounded	Present	Present	2-3	Summer
6.	*Merismopedia convoluta* Brebisson	Blue-green or Olive green or Yellowish	Spherical to oblongate	Convolute	Present	Present	4-5	Summer, Winter
	M. minima Breck	Pale Blue-green	Oval	Ractangular	Present	Present	0.5-0.6	Summer
	M. tenuissima Lemmermann	Pale Blue-green	Sub-spherical	Ractangular	Present	Present	1-2.4	Summer, Winter
	M. punctata Meyen	Pale Blue-green	Spherical	Ractangular	Present	Present	23-24	Summer, Winter
	M. aeruginea Brebisson	Blue-green	Spherical	Ractangular	Present	Present	5	Summer
	M. glauca (Ehrenb.) Nägeli	Pale Blue-green	Oval/ Spherical	Ractangular	Present	Present	3-6	All Seasons
	M. elegans A. Braun	Dark Blue	Spherical/Oblongate	Ractangular	Present	Present	5-7	Summer
7.	*Eucapsis minuta* Fritsch	Colorless	Spherical	Ractangular	Present	Present	1-1.5	Spring
8.	*Chroococcus gomontii* Nyguard	Colorless	Rounded	Circular	Present	Present	7-9	Summer
	C. varius A. Braun	Dirty Olive green or Brownish	Globular	Oval	Present	Present	2-4	Summer
	C. minor (Kützing) Nägeli	Dirty Blue-green	Spherical	Oval	Present	Present	3-4	Summer, Winter
	C. hansgirgi Schmidle	Hyaline	Spherical/Oblongate	Oval	Present	Present	8-12	Summer, Winter
	C. turgidus (Kützing) Nägeli	Colorless	Spherical/Ellipsoidal	Oval	Present	Present	8-32	Summer, Winter
9.	*Microcystis robusta* (Clark) Nyguard	Blue-green	Spherical/Elongated	Round to elongate	Present	Absent	7-9	Summer, Spring
	M. aeruginosa Kützing	Hyaline	Spherical	Ovate or Spherical	Present	Present	3-4.5	Summer, Spring, Winter
	M. pulverea (Wood) Forti	Blue-green or Olive green	Spherical/Ellipsoidal	Rounded to ellipsoidal	Present	Present	2-3.4	Summer

MC= Mucilage around Colony; MIC = Mucilage around individual cell; SC= Shape of cell; DC = Diameter of Cell; EC= Electrical Conductivity

Diagrammatic representation of some colonial cyanophycotes of North-East Punjab, Pakistan

I

Fig. 2. *A. saxicola*

II

Fig. 3. *A. castagnei*

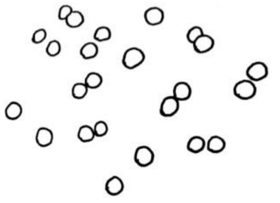

Fig. 4. *A. koordersii*

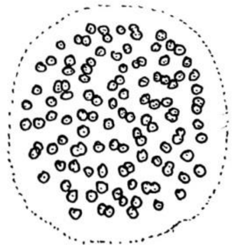

Fig. 5. *A. pulchra*

Fig. 6. *A. Montana*

Fig. 7. *A. elachista*

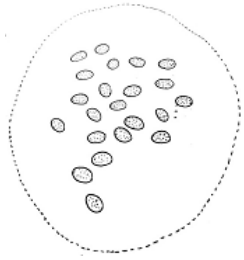

Fig. 8. *A. roeseana*

Fig. 9. *A. muscicola*

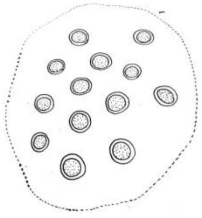

Fig. 10. *A.banaresensis*

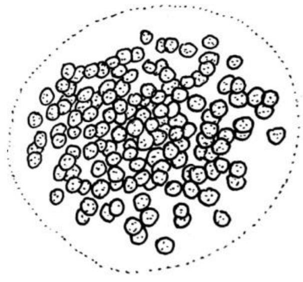

Fig. 11. *A. biformis*

Fig. 12. *G. polydermatica*

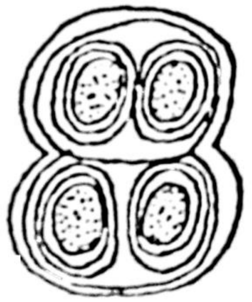

Fig. 13. *G.decorticans*

Fig. 14. *G. compacta*

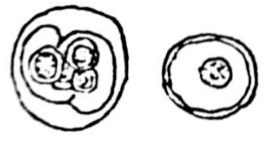

Fig. 15.*G. nigrescence*

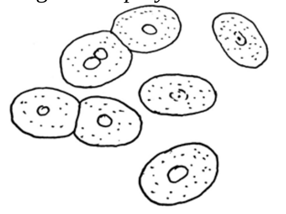

Fig. 16. *S. cedrosum*

Fig. 17. *S. elongates*

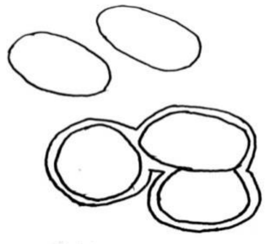

Fig. 18. *S.aeruginosus*

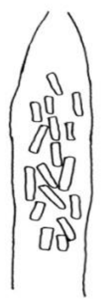

Fig. 19. *G. linearis*

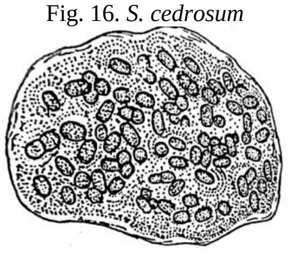

Fig. 20. *G. rhodochylamys*

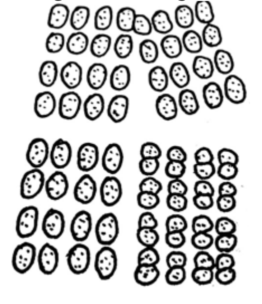

Fig. 21. *M. convolute*

Fig. 22. *M. minima*

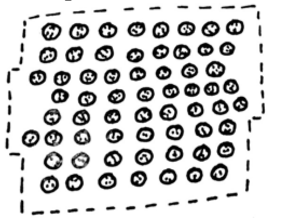

Fig. 23. *M. tennuissima*

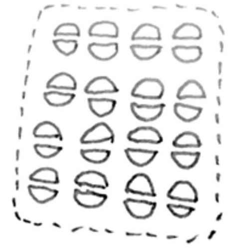

Fig. 24. *M. punctate*

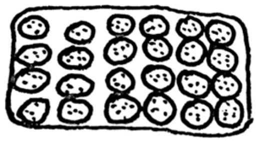

Fig. 25. *M. aeruginea*

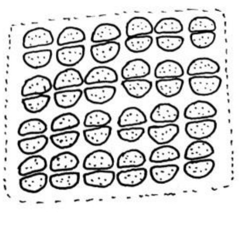

Fig. 26. *M. glauca*

Fig. 27. *M. elegans*

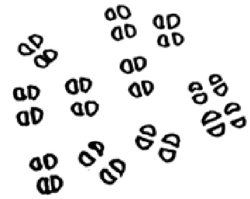

Fig. 28. *E. minuta*

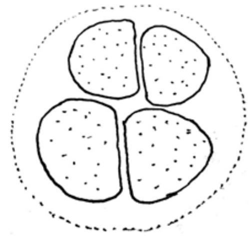

Fig. 29. *C. gomontii*

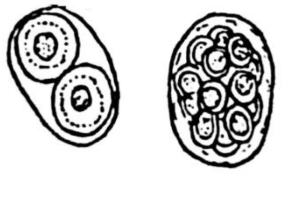

Fig. 30. *C. varius*

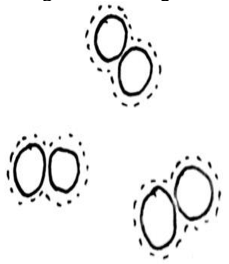

Fig. 31. *C. minor*

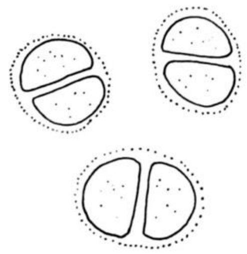

Fig. 32. *C. hansgirgi*

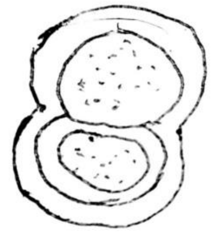

Fig. 33. *C. turgidus*

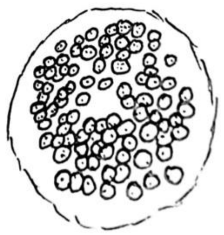

Fig. 34. *Microcystis robusta*

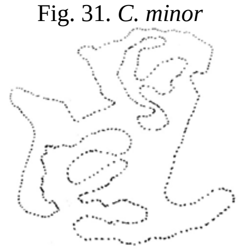

Fig. 35. *M. aeruginosa*

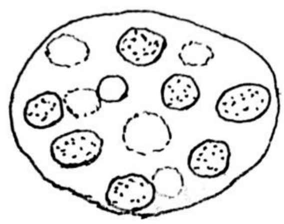

Fig. 36. *M. pulverea*

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