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The Algal Flora of Selected Wet Walls in Zion National Park, Utah, USA

by

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With 147 figures

Introduction

Large wet wall spring systems are common in the massive cliff country of southern Utah and northern Arizona of western North America. Such spring systems are formed when water percolates vertically through permeable sandstone layers until it contacts an impervious layer. The water then moves horizontally until it outcrops at the cliff face. Such wet walls or drip walls often create a weakness in the cliff face through freezing and thawing so that slumping of the rock is common to form a concave excavation. Such areas are usually referred to as hanging gardens. These gardens support unusual assemblages of vascular plants and animals (Woodbury et al. 1958, 1959). Likewise, the wet faces themselves often develop remarkable algal, moss, and liverwort communities.

The algal floras of such wet wall systems have been under study for some time (Rushforth et al. 1976; Rushforth et al. 1980; Clark and Rushforth in press; Johansen et al. 1981, 1982). In most cases we have studied, the moist wall is inhabited primarily by mucilage secreting green and bluegreen algae. As such species become established an abundance of secondary species colonize the mucilage. These include green and bluegreen algae and numerous diatom species as well as occasional Euglenophyta and chrysophytes.

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The present paper reports the findings of our studies on several additional wet wall and hanging garden systems. These occur in Zion National Park, Utah. Several algal taxa new to such habitats were discovered and are reported herein together with other species encountered.

Zion National Park, Utah was apparently first inhabited by humans around 500 A.D. These early inhabitants remained until about 1200 A.D. and then mysteriously left the area. Caucasians first were in the Zion area about 1776 and exploration of the area proceeded some 50 years later. This area was established as a National Park in 1919. Zion park is known for its deep cut gorges and straight colorful cliff faces. Hanging gardens and spring fed wet walls are common in the park. In addition, small streams cascade off of some of the tall mesas to form still other wet walls and create habitats suitable for algal growth.

Site Descriptions

All sites studied were located in the Navajo Sandstone Formation. This formation is a large aeolian sandstone of Triassic-Jurassic age common in much of the southwestern United States. It is famous for its vivid colors and immense relief. Hanging gardens and wet walls are common in this formation.

The first site studied (Figures 1-2) was located at Lower Emerald Pool. Three distinct subhabitats were sampled at this locality. A cascade spills here from the upper Emerald Pool stream and forms a splash zone a few meters wide. Stones and soil from this zone were sampled. We also sampled the attached algae on the large stone base of the waterfall. Finally, a true hanging garden has developed at this site and scrapings from the face of this garden were taken.

Our second study site was located at Weeping Rock (Figures 3-4). This area is a large wet hanging garden with water constantly dripping out of the sandstone and wetting the rock face. The sandstone of this locality is covered with dense growths of bacteria (Rushforth et al. 1980) and algae. The southern portion of this garden is open and receives rather direct sunlight part of the day. The northern part of the wall is in a depression and is more protected. Several subhabitats at Weeping Rock were sampled including the north wall, south wall, bacterial mats and small pools at the base of the wall.

The third site we studied was located in the Narrows region of Zion Canyon (Figures 5-6). Several small hanging gardens have formed on the cliffs above the Virgin River in this area. One is accessable by foot trail and is located 1/2 km from the parking area at the Temple of Sinawava. We sampled only the face of the hanging garden at this locality.

The last locality studied was located about 2 km above the exit of the Mt. Carmel tunnel. A trail leads to an overlook of the park at this locality, and the trail passes a large hanging garden. This garden is protected for the most part from direct sun light and the walls are quite wet. Thick mucilaginous mats have developed on the sandstone walls of this garden. Samples were obtained from these mats and from pool areas at the base of the wall.

Methods

Samples were obtained from all sites by scraping portions of visible algal or bacterial mats from the substrate and placing them in small vials. These were labeled and removed to the refrigerator in our laboratory for storage prior to study.

Samples were examined within 48 hours for nondiatom algae. Small subsamples were placed directly upon microscope slides and examined using Zeiss RA microscopes. Photomicrographs were made of each species using Nikon AFM equipment.

Upon completion of study of the samples for nondiatom algae, samples were prepared for diatom analysis. Samples were boiled for several minutes in concentrated nitric acid to remove organic matter. These were then rinsed several times in distilled water and finally a subsample was dried onto a microscope cover slip. These were mounted in Naphrax diatom mountant on standard microscope slides. All slides were examined using Zeiss RA microscopes and a Zeiss ICM 405 inverted microscope. Photomicrographs of each species were prepared.

In order to determine relative abundance of diatoms at each study site, a subsample of frustules from each subhabitat at each site was counted and these counts were then averaged for the entire site. If a diatom species comprised less than 1% of the total diatom flora from a site it

was designated as rare (R). Diatoms comprising between 1% and 5% of the flora were labeled infrequent (I), those between 5% and 15% common (C), between 15-25% abundant (A) and greater than 25% dominant (D).

Results

A diverse algal flora consisting of 27 species of Cyanophyta, 11 species of Chlorophyta and 76 species of Bacillariophyta was discovered in the hanging gardens, wet walls and associated habitats of Zion National Park. Several of these species are ubiquitous and found in a wide variety of terrestrial habitats in western North America. Others are restricted to hanging gardens or wet wall habitats.

Basically, more species occur in the wetter portions of the habitats studied. Generally the pattern of distribution is quite similar in most sites we studied. In moist areas, mucilage forming bluegreen, green algae or bacteria become established to form a suitable substrate for the establishment of a wide variety of other algal and bacterial species. This is particularly the case with the diatoms. Only rarely do diatoms form mats exclusive of Cyanophyta or Chlorophyta.

We are planning further research on hanging gardens to aid in understanding of these communities. We wish to study a single wall in detail and do quantitative and comparative ecologic studies along a moisture gradient. We would also like to study growth rates and successional patterns in these environments.

The species collected during our study are briefly described and discussed in the following section of this paper. A reference to a complete description for each diatom taxon is also given. Taxa treated herein are illustrated in photographs presented at the end of this work. A summary of the distribution of all algal species is given in Table 1.

DIVISION BACILLARIOPHYTA

Family Thalassiosiraceae

Cyclotella caspia Grunow (Fig. 8). Diameter 6-7 μm; striae 20 in 10 μm (Hustedt 1930B: 347). *C. caspia* was collected from the basal areas of

Table 1. Distribution of algal species collected from four hanging gardens in Zion National Park, Utah. X = present, relative abundance not estimated; R = rare; I = infrequent; C = common; A = abundant; D = dominant.

Species	Zion Narrows	Mt. Carmel	Emerald Pool	Weeping Rock
Schizophyta				
Thioploca ingrica				X
Cyanophyta				
Calothrix clavata				X
Calothrix parietana				X
Chamaesiphon incrustans			X	X
Chroococcus turgidus	X	X	X	X
Chroococcus varius				X
Gloeocapsa nigrescens	X	X		X
Gloeocapsa rupestris	X	X	X	X
Gloeothece palea				X
Gloeotheca rupestris	X	X		
Gomphosphaeria aponina	X			
Lyngbya limnetica				X
Merismopedia tenuissima	X			
Nostoc microscopicum		X		
Nostoc muscorum	X	X		
Nostoc paludosum	X	X	X	X
Oscillatoria agardhii			X	X
Oscillatoria angusta				X
Oxcillatoria geminata				X
Oscillatoria limnetica	X	X		X
Oscillatoria rubescens		X	X	
Oscillatoria subbrevis				X
Oscillatoria subbrevis f. minor				X
Scytonema alatum				X
Scytonema myochrous	X	X	X	X
Scytonema tolypothricoides	X			
Spirulina laxa				X
Spirulina subsalsa	X			
Chlorophyta				
Cladophora glomerata	X		X	X

Table 1. Continued

Cosmarium species	X			
Mougeotia species			X	
Oedogonium species				X
Oocystis species	X			X
Palmella miniata			X	
Spirogyra species				X
Stigeoclonium species			X	
Ulothrix cylindricum			X	
Ulothrix zonata			X	
Zygnema species			X	X
Bacillariophyta				
Achnanthes affinis	C	I		C
Achnanthes chilensis var. subaequalis	R			
Achnanthes coarctata			R	
Achnanthes deflexa		I	D	C
Achnanthes flexella	R	R		R
Achnanthes lanceolata			I	
Achnanthes lewisiana				R
Achnanthes linearis	C	C	I	
Achnanthes microcephala	I		R	R
Amphora coffeaeformis	R			
Amphora perpusilla	R	R	R	
Amphora veneta				R
Anomoeoneis vitrea	I		R	I
Caloneis bacillum				R
Cocconeis pediculus		R	I	
Cocconeis placentula var. euglypta	R	R	R	R
Cyclotella caspia	R			R
Cymbella affinis	R	R	I	C
Cymbella cistula			R	
Cymbella cymbiformis var. nonpunctata	R		C	C
Cymbella delicatula	I	C	C	I
Cymbella mexicana			R	R
Cymbella microcephala	C	D	I	I
Cymbella microcephala var. crassa	I	C	I	I
Cymbella minuta f. latens			R	
Cymbella minuta var.silesiaca	R		R	
Cymbella norvegica	R	I	R	R
Cymbella perpusilla		R		R

Table 1. Continued

Cymbella species 1		R		
Cymbella species 2		I	R	C
Denticula elegans	I			R
Denticula elegans f. valida	C	I	I	
Diatoma vulgare			R	
Epithemia argus var. longicornis		R	R	R
Epithemia argus var. protracta	R			R
Epithemia turgida		R		
Fragilaria brevistriata var. inflata	R			
Fragilaria pinnata	C		R	R
Fragilaria vaucheriae			C	R
Gomphonema angustatum	R			
Gomphonema dichotomum	C			C
Gomphonema intricatum				I
Gomphonema olivaceum				R
Gomphonema parvulum var. micropus			I	R
Hantzschia amphioxys			R	R
Mastogloia grevillei				R
Mastogloia smithii var. lacustris	R			R
Meridion circulare var. constrictum			R	
Navicula arvensis			R	
Navicula cryptocephala var. veneta			R	
Navicula excelsa	R			
Navicula gallica		R	R	
Navicula heufleri var. leptocephala		R	R	R
Navicula mutica				R
Navicula pupula	R	R		R
Navicula radiosa	R	R		R
Navicula subbacillum	I	A		R
Navicula wittrockii				R
Navicula species 1		I		I
Navicula species 2		R		R
Navicula species 3	R			R
Nitzschia angustata				R
Nitzschia communis			R	R
Nitzschia denticula	I	I	R	R
Nitzschia hantzschiana	R	I	R	R
Nitzschia inconspicua	C		R	I
Nitzschia microcephala	R			
Nitzschia paleacea				R

Table 1. Continued

Nitzschia romana	I			
Nitzschia species			R	
Pinnularia appendiculata	R			R
Pinnularia biceps var. minor			R	
Pinnularia species				R
Rhopalodia gibba		R		
Rhopalodia gibberula	R			R
Stephanodiscus carconensis		R		
Synedra pulchella	R			R

Weeping Rock and Zion Narrows. It was rare in both locations. Hustedt reported specimens with a diameter of 8-12 μm, making our specimens small. However, we have seen many small specimens of this diatom in collections from inland western United States.

Stephanodiscus carconensis (Eulenstein) Grunow (Fig. 7). Diameter 30 μm; costae 2 in 10 μm, composed of 6-7 rows of punctae at the periphery, narrowing to one row towards center; punctae 24 in 10 μm (VanLandingham 1964: 20). This *Stephanodiscus* was very rare in collections from the open wall area of the Mt. Carmel garden.

Family Fragilariaceae

Diatoma vulgare Bory (Fig. 14). Length 39 μm; width 11.5 μm; costae 7 in 10 μm; striae unresolved (Patrick and Reimer 1966: 109). *D. vulgare* was identified from a few specimens in collections from the splash zone at Emerald Pool.

Meridion circulare var. *constrictum* (Ralfs) Van Heurck (Fig. 13). Length 30 μm; width 5 μm; costae 4-5 in 10 μm; striae unresolved (Patrick and Reimer 1966: 114). *M. circulare* var. *constrictum* was rare in collections from Emerald Pool.

Fragilaria brevistriata var. *inflata* (Pant.) Hustedt (Fig. 11). Length 8.5-14 μm; width 3-4 μm; striae 11-14 in 10 μm (Patrick and Reimer 1966: 129). *F. brevistriata* var. *inflata* was collected from the wet wall of Zion Narrows.

Fragilaria pinnata Ehrenberg (Fig. 12). Length 6-19 μm; width 4-5 μm; striae 6-12 in 10 μm (Patrick and Reimer 1966: 127). *F. pinnata* was rare in collections from Weeping Rock, Emerald Pool, and common from Zion Narrows.

Fragilaria vaucheriae (Kütz.) Petersen (Fig. 9, 10). Length 21-45 μm; width 3-4 μm; striae 14-16 in 10 μm (Patrick and Reimer 1966: 120). *F. vaucheriae* was rare in collections from Weeping Rock and common in collections from Emerald Pool. Many of our specimens resembled *F. vaucheriae* var. *capitellata* in length and shape of the apices. However, we placed them in the nominate variety since their striae were coarse and they seemed to form an intergradional series according to shape and size.

Synedra pulchella Ralfs ex Kützing (Fig. 17). Length 60-100 μm; width 5-6 μm; striae 12-16 in 10 μm (Patrick and Reimer 1966: 146). *S. pulchella* was rare in collections from Zion Narrows and Weeping Rock.

Family Achnanthaceae

Cocconeis pediculus Ehrenberg (Fig. 15-16). Length 12-30 μm; width 7-25 μm; striae 17-20 in 10 μm on both valves (Patrick and Reimer 1966: 240). *C. pediculus* was rare from the northeast wall at the Mt. Carmel site, and infrequent in the splash zone and slick rock communities at Emerald Pool.

Cocconeis placentula var. *euglypta* (Ehr.) Cleve (Fig. 18, 19). Length 15-20 μm; width 10-12 μm; raphe valve striae 20-23 in 10 μm; rapheless valve striae 18-22 in 10 μm (Patrick and Reimer 1966: 241). *C. pacentula* var. *euglypta* was rare in samples from all sites.

Achnanthes affinis Grunow (Fig. 20, 21). Length 12-18 μm; width 2.5-3 μm; striae 26-28 in 10 μm near center, becoming finer at ends (Patrick and Reimer 1966: 254). *A. affinis* was common in collections from Weeping Rock and Zion Narrows and was infrequent from Mt. Carmel.

Achnanthes chilensis var. *subaequalis* Reimer. Length 13 μm; width 4 μm; striae 18 in 10 μm (Patrick and Reimer 1966: 276). *A. chilensis* var. *subaequalis* was identified from a single rapheless valve in a collection from the Zion Narrows wall. This is a new record for the state of Utah.

Achnanthes coarctata (Bréb. in W. Smith) Grunow. Length 33 μm; width 8 μm; rapheless valve striae 11-12 in 10 μm near center, becoming 14 in 10 μm near ends (Patrick and Reimer 1966: 277). *A. coarctata* was identified from a single rapheless valve collected from the splash zone at Emerald Pool.

Achnanthes deflexa Reimer (Fig. 22, 23). Length 12.5-24 μm; width 4-4.5 μm; striae 20-26 in 10 μm (Patrick and Reimer 1966: 256). *A. deflexa* was common in the wetter areas of Weeping Rock, dominant in the splash zone of Emerald Pool, and infrequent from Mt. Carmel. It is distinguished from our other *Achnanthes* by its deflected distal raphe ends, small or absent central area, and parallel striae.

Achnanthes flexella (Kütz.) Brun (Fig. 24, 25). Length 35-42 μm; width 15-17 μm; raphe valve striae 16-20 in 10 μm at center becoming 24-29 in 10 μm near ends; rapheless valve striae 24 becoming 27 in 10 μm (Patrick and Reimer 1966: 260). *A. flexella* was rare in collections from Mt. Carmel, Weeping Rock, and Zion Narrows.

Achnanthes lanceolata (Bréb.) Grunow (Fig. 26, 27). Length 13-27 μm; width 4.3-6 μm; striae 14-16 in 10 μm (Patrick and Reimer 1966: 269). *A. lanceolata* was found at Emerald Pool in the splash zone and wet wall communities.

Achnanthes lewisiana Patrick (Fig. 28). Length 10-14 μm; width 4-5μm; striae 13-15 in 10 μm (Patrick and Reimer 1966: 266). *A. lewisiana* was seen twice in collections from the base of Weeping Rock. Striae in our two specimens were coarser than those reported by other researchers.

Achnanthes linearis (W. Smith) Grunow (Fig. 29). Length 10-17 μm; width 2.5-3 μm; striae 24-32 in 10 μm on both valves (Patrick and Reimer 1966: 251). *A. linearis* was common in collections from Mt. Carmel and Zion Narrows and infrequent from Emerald Pool. This species is difficult to differentiate from *A. minutissima*. The majority of our specimens clearly showed coarser striae. However, it is possible that some specimens of *A. minutissima* were placed in *A. linearis* during this study.

Achnanthes microcephala (Kütz.) Grunow (Fig. 30). Length 10-24 μm; width 2.4-3 μm; striae 26-32 in 10 μm on both valves (Patrick and Reimer 1966: 250). *A. microcephala* was infrequent in collections from Zion Narrows and rare from Weeping Rock and Emerald Pool.

Mastogloia grevillei W. Smith (Fig. 33). Length 33-35 μm; width 11-12 μm; striae 9-10 in 10 μm; chambers 8 in 10 μm (Patrick and Reimer 1966: 298). *M. grevillei* was identified from two specimens in a collection from Weeping Rock.

Mastogloia smithii var. *lacustris* Grunow (Fig. 34, 35). Length 20-58 μm; width 7.5-13 μm wide; striae 15-18 in 10 μm; chambers 6 in 10 μm (Patrick and Reimer 1966: 300). *M. smithii* var. *lacustris* was rare in collections from Weeping Rock and Zion Narrows, preferring the drier portions of these sites. Some of our specimens were larger than usual for this taxon.

Anomoeoneis vitrea (Grun.) Ross (Fig. 32). Length 14-23 μm; width 4.5-5 μm; striae 28-32 in 10 μm (Patrick and Reimer 1966: 380). *A. vitrea* was infrequent in collections from the wet walls of Weeping Rock and Zion Narrows and rare at Emerald Pool.

Diploneis oblongella (Naeg. ex Kütz.) Ross (Fig. 31). Length 17-25 μm; width 7-8 μm; costae 18-20 in 10 μm (Patrick and Reimer 1966: 413). *D. oblongella* was rare in collections from Weeping Rock and the Narrows Garden.

Navicula arvensis Hustedt. Length 11 μm; width 3 μm; striae unresolved (Patrick and Reimer 1966: 483). *N. arvensis* was identified from a single specimen from the slickrock community at Emerald Pool.

Navicula cryptocephala var. *veneta* (Kütz.) Rabenhorst. Length 19 μm; width 6 μm; striae 14-16 in 10 μm (Patrick and Reimer 1966: 504). *N. cryptocephala* var. *veneta* was rare in the splash zone and slick rock communities at Emerald Pool.

Navicula excelsa Krasske (Fig. 38). Length 8.5 μm; width 4 μm; striae 16-20 in 10 μm (Hustedt 1961-1966: 164). *N. excelsa* was collected as a single specimen from the Zion Narrows garden. This taxon has been observed in other hanging gardens we have examined.

Navicula gallica (W. Smith) Lagerstedt. Length 11 μm; width 3.5 μm; striae 26 in 10 μm (Hustedt 1961-1966: 207). *N. gallica* was collected as four specimens from the wet walls of Emerald Pool and Mt. Carmel. This taxon is a common aerophile in western North America. We have

observed it in other hanging gardens as well as in caves in this region. Our specimens lacked raphes and had marginal spines.

Navicula heufleri var. *leptocephala* (Bréb. ex Grun.) Patrick (Fig. 39). Length 21-29 μm; width 5-6 μm; striae 12-16 μm (Patrick and Reimer 1966: 515). *N. heufleri* var. *leptocephala* was rare in Weeping Rock, Emerald Pool, and Mt. Carmel Garden samples. Our specimens resemble *N. graciloides* but are more finely striated and smaller than that taxon.

Navicula mutica Kützing (Fig. 40). Length 18-25 μm; width 6-7 μm; striae 18-20 in 10 μm (Hustedt 1961-1966: 583). *N. mutica* was rare in collections from Weeping Rock. This taxon is a common and widely distributed aerophile in western North America.

Navicula pupula Kützing (Fig. 41). Length 22-29 μm; width 7-9 μm; striae 14-18 in 10 μm at midvalve, becoming 25-26 in 10 μm near ends (Patrick and Reimer, 1966: 495). *N. pupula* was rare in collections from Weeping Rock, Zion Narrows and Mt. Carmel gardens.

Navicula radiosa Kützing (Fig. 36). Length 37-50 μm; width 6-10 μm; striae 10 in 10 μm near midvalve, becoming 14-16 in 10 μm at ends (Patrick and Reimer 1966: 509). *N. radiosa* was rare in collections from Weeping Rock, the Narrows and Mt. Carmel.

Navicula subbacillum Hustedt (Fig. 42, 43). Length 9-20 μm; width 4-5 μm; striae 20-24 in 10 μm (Hustedt 1961-1966: 117). *N. subbacillum* was rare at Weeping Rook, infrequent at Zion Narrows and abundant at Mt. Carmel. Many of our specimens were smaller than reported by other workers.

Navicula wittrockii (Lagst.) Cleve-Euler (Fig. 44). Length 26-27 μm; width 6-7 μm; striae 14 in 10 μm near midvalve, becoming 22 in 10 μm near ends (Hustedt 1961-1966: 124). *N. wittrockii* was identified from two specimens in a collection from Weeping Rock. This diatom resembles *N. bacillum* but differs in that it does not have the thickened striae at the poles.

Navicula species 1 (Fig. 45). Valve linear-lanceolate; 14-23 μm long, 3.5-4 μm wide; apices rostrate; axial area linear, narrow; proximal raphe ends close; central area small elliptical; striae 20 in 10 μm near midvalve, unresolved at the ends. This *Navicula* was infrequent in collections from Weeping Rock and Mt. Carmel Garden.

Navicula species 2 (Fig. 46, 47). Valve elliptical to lanceolate-elliptical, 11-16 μm long, 5-6 μm wide; apices rounded, slightly protracted; axial area broad, lanceolate; central area rounded, with one isolated puncta; striae radiate, 16-19 in 10 μm. This species was rare in samples from Weeping Rock and Mt. Carmel gardens. This organism appears to be allied with the *Navicula mutica* group.

Navicula species 3 (Fig. 37). Valve linear-elliptical with broadly rounded ends, 22-25 μm long by 6 μm wide; axial area narrow; central area elliptical; raphe enclosed in a silicious rib; striae radiate throughout, 20-22 in 10 μm at midvalve becoming up to 26 in 10 μm near ends. This organism was rare in collections from Weeping Rock and Zion Narrows. It closely resembles *N. bacillum* but is distinguished by its finer striae.

Caloneis bacillum (Grun.) Cleve (Fig. 48). Length 24-31 μm; width 5-6 μm; striae 21-22 in 10 μm (Patrick and Reimer 1966: 586). *C. bacillum* was identified from two specimens in a collection from Weeping Rock. The striae in our specimens were coarser than usual for this taxon.

Pinnularia appendiculata (Ag.) Cleve (Fig. 50, 51). Length 20-30 μm; width 4-5 μm; striae 16-22 in 10 μm (Patrick and Reimer 1966: 593). *P. appendiculata* was rare in samples from Weeping Rock and Zion Narrows. Our specimens closely resemble *P. subcapitata*. However they are separated on the basis of striation.

Pinnularia biceps var. *minor* (Boye Pet.) A. Cleve. Length 35 μm; width 8 μm; striae 12 in 10 μm (Cleve-Euler 1955: 63). *P. biceps* var. *minor* was identified from a single specimen in a collection from the splash zone at Emerald Pool. It is characterized by its uniquely shaped central area.

Pinnularia species (Fig. 49). Valve linear, with subrostrate apices, 33 μm long by 6 μm wide; axial area narrow, linear; central area a broad transverse fascia; striae radiate at midvalve, becoming convergent at ends, 21 in 10 μm. This *Pinnularia* was found only at the base of Weeping Rock. It is similar to some species of *Caloneis* and possibly belongs in that genus.

Cymbella affinis Kützing (Fig. 52, 53, 56). Length 24-40 μm; width 6.5-10 μm; dorsal striae 10-14 in 10 μm; ventral striae 12-15 in 10 μm (Patrick and Reimer 1975: 57). *C. affinis* was common in samples

from Weeping Rock, infrequent in samples from Emerald Pool and rare at the other two sites. This taxon showed some variability in valve shape. Specimens from Weeping Rock often had slightly concave ventral margins.

Cymbella cistula (Ehr.) Kirchner. Length 90-155 μm; width 19-25 μm; dorsal striae 7-8 in 10 μm at midvalve, becoming 10 in 10 μm near ends; ventral striae 8-9 in 10 μm at midvalve, becoming 12-13 in 10 μm near ends (Patrick and Reimer 1975: 62). *C. cistula* was rare and found only in collections from Emerald Pool. Its size and four distinct punctae in the central area separate it from our other *Cymbella* species.

Cymbella cymbiformis var. *nonpunctata* Fontell (Fig. 54, 56). Length 25-87 μm long; width 9-15 μm; dorsal striae 10-15 in 10 μm; ventral striae 11-16 in 10 μm (Patrick and Reimer 1975: 55). *C. cymbiformis* var. *nonpunctata* was the most abundant diatom in the Weeping Rock collections and was common in Emerald Pool. Our specimens have unusual axial areas and lack central areas, characteristics which may ultimately exclude our specimens from this taxon. About 4% of the frustules seen were large forms which exceeded the length range previously recorded for this taxon. The valve of these large forms was often curved transapically and swollen in the midregion. Their wide axial area, striae structure, and intergradation with smaller forms decided their placement in this taxon along with the more typical specimens.

Cymbella delicatula Kützing (Fig. 60, 63). Length 17-40 μm; width 5-8 μm; dorsal striae 14-16 in 10 μm at midvalve becoming 18-24 in 10 μm at ends; ventral striae 17-20 in 10 μm at midvalve becoming 23-24 at ends (Patrick and Reimer 1975: 28). *C. delicatula* was common in collections from Mt. Carmel and Emerald Pool and infrequent at the other two sites. This taxon occurs in most hanging gardens we have studied. Larger specimens have been designated in the past (Rushforth et al. 1976; Johansen et al. 1982) as *C. incerta* var. *naviculacea*. Such specimens do not fit either taxa well and we are currently studying a larger suite of frustules.

Cymbella mexicana (Ehr.) Cleve (Fig. 64). Length 79-110 μm; width 25-32 μm; striae 5-9 in 10 μm; punctae 10 in 10 μm (Patrick and Reimer 1975: 59). *C. mexicana* was rare in collections from the base of Weeping Rock and Emerald Pool.

Cymbella microcephala Grunow (Fig. 67-69). Length 12-24 μm; width 3-5 μm; striae 24-26 in 10 μm at midvalve, becoming 28 in 10 μm at ends (Patrick and Reimer 1975: 33). *C. microcephala* was dominant at the Mt. Carmel site, common at the Narrows and infrequent at Emerald Pool and Weeping Rock. Our specimens and others we have examined from hanging gardens are rostrate rather than subcapitate to capitate. It may be that they will prove to belong to a new taxon.

Cymbella microcephala var. *crassa* Reimer (Fig. 70, 71). Length 9-19 μm; width 3.5-4.5 μm; striae 16-22 (Patrick and Reimer 1975: 34). *C. microcephala* var. *crassa* was common at the Mt. Carmel site and infrequent at the others.

Cymbella minuta f. *latens* (Bleisch ex Rabh.) Reimer (Fig. 59). Length 19-23 μm; width 6.5-8 μm; striae 10-16 in 10 μm on both dorsal and ventral sides (Patrick and Reimer 1975: 49). *C. minuta* f. *latens* was rare in samples from the Emerald Pool splash zone.

Cymbella minuta var. *silesiaca* (Bleisch ex Rabh.) Reimer. Length 22-40 μm; width 8-9 μm; striae 12-15 in 10 μm at center becoming 16-18 in 10 μm near ends (Patrick and Reimer 1975: 49). *C. minuta* var. *silesiaca* was rare in collections from the splash zone and wet wall at Emerald Pool, and at Zion Narrows.

Cymbella norvegica Grunow (Fig. 66). Length 30-49 μm; width 8-9 in 10 μm; striae 10-18 in 10 μm (Patrick and Reimer 1975: 25). *C. norvegica* was infrequent in samples from Mt. Carmel and rare from all other sites. It is a common constituent of hanging garden floras.

Cymbella perpusilla A. Cleve (Fig. 65). Length 15-24 μm; width 4-6.5 μm; striae 10-14 in 10 μm (Hustedt 1930A: 361). *C. perpusilla* was rare at the base of Weeping Rock and open wall of Mt. Carmel.

Cymbella species 1 (Fig. 58). Valve lunate, 14 μm long by 5.5 μm wide; dorsal margin convex, ventral margin straight, somewhat swollen at midregion; axial area narrow; central area small, linear-elliptic; raphe arched; dorsal striae 11-13 in 10 μm; ventral striae 12-14 in 10 μm. This taxon was observed as a single specimen in a collection from Mt. Carmel.

Cymbella species 2 (Fig. 72). Valve nearly symmetrical, linear-elliptical to linear with acute apices, 15.5-40 μm long by 4-5.5 μm wide; axial area narrow; central area inconspicuous; proximal raphe ends de-

flected dorsally; striae radiate throughout, 19-24 in 10 μm. This taxon was common in collections from the base of Weeping Rock, infrequent from Mt. Carmel and rare from Emerald Pool.

Amphora coffeaeformis (Ag.) Kützing. Length 23-28 μm; width 3.5-5 μm; dorsal striae 20 in 10 μm at midvalve, becoming 28-30 in 10 μm near ends (Patrick and Reimer 1975: 78). *A. coffeaeformis* was rare in collections from Zion Narrows.

Amphora perpusilla (Grun.) Grunow (Fig. 74). Length 12 μm; width 4.5 μm; striae 18 in 10 μm (Patrick and Reimer 1975: 70). *A. perpusilla* was rare in collections from the Zion Narrows, Mt. Carmel and Emerald Pool.

Amphora veneta Kützing (Fig. 73). Length 21-30 μm; width 4-5 μm; striae 18-22 in 10 μm (Patrick and Reimer 1975: 72). *A. veneta* was very rare in collections from Weeping Rock.

Gomphonema angustatum (Kütz.) Rabenhorst (Fig. 76). Length 14-23 μm; width 4-5.5 μm; striae 12-16 in 10 μm (Patrick and Reimer 1975: 125. *G. angustatum* was rare in samples from the base of Zion Narrows drip wall.

Gomphonema dichotomum Kützing (Fig. 77, 78). Length 20-40 μm; width 6-7 μm; striae 10 in 10 μm at midvalve becoming 18 in 10 μm near ends (Patrick and Reimer 1975: 135). *G. dichotomum* was common in collections from the base of Weeping Rock and Zion Narrows. This taxon is easily confused with *G. intricatum* but is distinguished by its more linear shape and wider striae range.

Gomphonema intricatum Kützing (Fig. 79, 80). Length 33-44 μm; width 6-6.5 μm; striae 10-11 at midvalve becoming 12-16 near ends (Patrick and Reimer 1975: 134). *G. intricatum* was infrequent in collections from Weeping Rock.

Gomphonema olivaceum (Lyngb.) Kützing (Fig. 75). Length 15 μm; width 5 μm; striae 11-12 in 10 μm (Patrick and Reimer 1975: 139). *G. olivaceum* was identified from a single specimen in a sample from Weeping Rock drip wall.

Gomphonema parvulum var. *micropus* Cleve. Length 19-25 μm; width 5-8 μm; striae 14-16 in 10 μm (Hustedt 1930A: 373). *G. parvulum* var. *micropus* was infrequent in collections from Emerald Pool and rare from Weeping Rock.

Denticula elegans Kützing (Fig. 81). Length 17-25 μm; width 5-7 μm; costae 3-6 in 10 μm; alveoli rows 12-17 in 10 μm (Patrick and Reimer 1975: 170). *D. elegans* was rare in collections from Weeping Rock and infrequent from Zion Narrows.

Denticula elegans f. *valida* Pedicino (Fig. 82, 86). Length 15-46 μm; width 6-8 μm; costae 3-6 in 10 μm; alveoli rows 18-20 in 10 μm (Patrick and Reimer 1975: 171). *D. elegans* f. *valida* was common in collections from Zion Narrows and infrequent from Mt. Carmel and Emerald Pool. This taxon is an important aerophile in the arid intermountain west of North America.

Epithemia argus var. *longicornis* (Ehr.) Grunow (Fig. 92). Length 68-70 μm; width 13-18 μm; costae 2 in 10 μm; alveoli rows 10-12 in 10 μm; 4-6 alveoli between costae (Patrick and Reimer 1975: 177). *E. argus* var. *longicornis* was rare in collections from Weeping Rock, Mt. Carmel and Emerald Pool.

Epithemia argus var. *protracta* A. Mayer (Fig. 91). Length 49-68 μm; width 12-15 μm; costae 1-2 in 10 μm; alveoli rows 10-12 in 10 μm (Patrick and Reimer 1975: 177). *E. argus* var. *protracta* was rare in collections from Zion Narrows and the bacterial mats of Weeping Rock.

Epithemia turgida (Ehr.) Kützing (Fig. 93). Length 67-92 μm; width 12-14 μm; costae 2-4 in 10 μm; alveoli rows 10 in 10 μm; 2-4 alveoli between costae (Patrick and Reimer 1975: 182). *E. turgida* was rare in collections from Mt. Carmel.

Rhopalodia gibba (Ehr.) O. Müller. Length 80 μm; width 8 μm; costae 7-8 in 10 μm; alveoli rows 10-12 in 10 μm (Patrick and Reimer 1975: 189). *R. gibba* was rare in samples from Mt. Carmel.

Rhopalodia gibberula (Ehr.) O. Müller. Length 25-42 μm; width 7-10 μm; costae 3 in 10 μm; alveoli rows 14-17 in 10 μm (Patrick and Reimer 1975: 191). *R. gibberula* was rare in collections from the drip walls of Weeping Rock and Zion Narrows.

Hantzschia amphioxys (Ehr.) Grunow (Fig. 90). Length 40-42 μm; width 6-8 μm; fibulae 4-8 in 10 μm; striae 18-20 in 10 μm (Hustedt 1930A: 394). *H. amphioxys* was rare in collections from Weeping Rock and Emerald Pool. Capitate forms were observed but were retained in the nominate form rathe than forma *capitata* because of the intergradation between the two taxa.

Nitzschia angustata (W. Smith) Grunow. Length 35 μm; width 4 μm; striae 13 in 10 μm (Hustedt 1930A: 402). *N. angustata* was observed as a single specimen in a collection from the base of Weeping Rock.

Nitzschia communis Rabenhorst (Fig. 87). Length 28-35 μm; width 4-4.5 μm; fibulae 9-11 in 10 μm; striae unresolved (Hustedt 1930A: 417). *N. communis* was rare in collections from the splash zone at Emerald Pool and base of Weeping Rock.

Nitzschia denticula Grunow (Fig. 88). Length 28-45 μm; width 3.5-8 μm; fibulae 6 in 10 μm; striae 14-15 in 10 μm (Hustedt 1930A: 407). *N. denticula* was rare in collections from Weeping Rock and Emerald Pool and infrequent from Mt. Carmel and Zion Narrows.

Nitzschia hantzschiana Rabenhorst (Fig. 84). Length 15-35 μm; width 2.5-4 μm; fibulae 7-12 in 10 μm; striae 23-26 in 10 μm (Hustedt 1930A: 415). *N. hantzschiana* was infrequent in collections from Mt. Carmel and rare at all other sites. We have included *N. frustulum* var. *perpusilla* specimens in this taxon following the suggestion of Lange-Bertalot (1976).

Nitzschia inconspicua Grunow (Fig. 85). Length 9-12 μm; width 2-2.5 μm; fibulae 10-14; striae 22-28 in 10 μm (Lange-Bertalot 1976: 265). *N. inconspicua* was rare in samples from Emerald Pool, infrequent from Weeping Rock and common from Zion Narrows.

Nitzschia microcephala Grunow (Fig. 83). Length 13-16 μm; width 3 μm; fibulae 10 in 10 μm; striae 30 in 10 μm (Hustedt 1930A: 414). *N. microcephala* was rare in samples from Zion Narrows.

Nitzschia paleacea Grunow (Fig. 89). Length 24-30 μm; width 2.5-3 μm; fibulae 16-17 in 10 μm; striae unresolved (Hustedt 1930A: 416). *N. paleacea* was rare in collections from Weeping Rock.

Nitzschia romana (Fig. 95, 96). Length 13-32 μm; width 2.5-4 μm;

fibulae 10-12 in 10 μm; striae 24-26 in 10 μm (Hustedt 1930A: 415). *N. romana* was infrequent in collections from Zion Narrows.

Nitzschia species (Fig. 97). Valve lanceolate, 10.5 μm long by 2.5 μm wide, with rostrate apices; keel eccentric; pseudonodulus absent; fibulae 16 in 10 μm; striae 34-36 in 10 μm. This organism was rare in collections from Emerald Pool. It is in the *Nitzschiae lanceolatae* group, and bears a close resemblance to *N. fonticola.* Its striae are fine for that taxon.

DIVISION CYANOPHYTA

Family Chroococcaceae

Chroococcus turgidus (Kütz.) Naegeli (Fig. 98, 101). Plants unicellular or colonial; colonies 22.5-25 μm in diameter, containing 2-4 cells, occasionally more; colonial sheaths hyaline, slightly lamellate; cells ovoid if single, usually hemispherical, 5-10 μm in diameter. This taxon was found in collections from all sites. It was most abundant in the wet localities, especially at Mt. Carmel.

Chroococcus varius A. Braun in Rabenhorst (Fig. 103). Plant a small colony of 2-4 spherical cells; cells 2.5-4 μm in diameter; sheath thick, lamellate, colorless. *C. varius* was collected only from Weeping Rock where it was rare. Its small cell size and sheath characteristics separate it from *Chroococcus turgidus.*

Gloeocapsa nigrescens Naegeli in Rabenhorst (Fig. 99). Plant a small colony of 2-10 cells, 20-25 μm in diameter; cells spherical, 4-5 μm in diameter; sheath hyaline, somewhat lamellate. This taxon was collected at all localities except Emerald pool. It is most common in the more wet environments.

Gloeocapsa rupestris Kützing (Fig. 100, 102, 104). Plants colonial, often containing subfamilies of 2-12 cells; colonies 50-75 μm in diameter; colonial sheaths hyaline, lamellate; cells appearing rough, yellowish, 5-12.5 μm in diameter. *G. rupestris* was scattered in the mucilage of other algal species at all collecting localities. It was most abundant in areas with elevated moisture content.

Gloeothece palea (Kütz.) Rabenhorst (Fig. 106). Plant colonial, composed of subfamilies of 1-2 cylindrical cells; cells 2-2.5 μm in diameter

by 4-6 μm long; sheaths colorless; small colonies often aggregated to form large amorphous mass. *G. palea* was collected only from the wet wall at Weeping Rock where it was common.

Gloeothece rupestris (Lyngb.) Bornet in Wittrock and Nordstedt (Fig. 105). Plant colonial, containing up to 32 cells, 20-30 μm in diameter; cells elongate, 5 μm in diameter by 7-12.5 μm long. This taxon was collected only from the Mt. Carmel and the Narrows localities. Colonies were scattered in the mucilage of other species.

Gomphosphaeria aponina Kützing (Fig. 107). Plant colonial, containing about 20-30 cells; cells cordate, 2.5-3 μm in diameter by 5-8 μm long. *G. aponina* was collected only from the Zion Narrows garden where it occurred on the wet wall.

Merismopedia tenuissima Lemmermann. Plant a small rectangular colony of 16 cells, about 10 μm by 18 μm; cells 2-3 μm in diameter, usually hemispherical. This taxon was found only in collections from Zion Narrows. It was very rare.

Family Chamaesiphonaceae

Chamaesiphon incrustans Grunow in Rabenhorst (Fig. 108, 109). Plants epiphytic, often forming conspicuous dense growth on bacteria and filamentous algae, 3-6 μm in diameter, pale gray-green. *C. incrustans* was abundant on Weeping Rock and in the splash zone at Emerald Pool. It was most often found growing epiphytic on filaments of the bacterium *Thioploca ingrica*. *C. incrustans* was present but less common on filaments of *Cladophora glomerata*.

Family Oscilatoriaceae

Lyngbya limnetica Lemmermann (Fig. 116). Trichomes 2 μm wide, straight, not constricted at cross walls, not tapering; cells 6-10 μm long, pale grey-green, not granular; sheaths firm, colorless. This taxon was collected only from Weeping Rock. It was rare in our samples.

Oscillatoria agardhii Gomont (Fig. 113). Trichomes 4-5 μm wide, straight throughout length, tapering slightly at apex; apex usually

capitate; cells 4-5 μm wide, 3-7 μm long, not constricted at crosswalls; crosswalls granular. *O. agardhii* was collected only rarely at Weeping Rock and was common on the wet wall at Emerald Pool. This species was found as solitary filaments, never forming clumps. It was distinguished from other *Oscillatoria* species by trichome diameter and the lack of crosswall constrictions.

Oscillatoria angusta Koppe (Fig. 110). Trichomes solitary, light green, not tapering toward the apex, 1 μm in diameter; ends bluntly rounded; not constricted at the crosswalls, which are not discernable; cell contents homogenous. *O. angusta* was collected only from Weeping Rock. It was present in low numbers in all samples collected at that site.

Oscillatoria geminata Meneghini ex Gomont (Fig. 114). Trichomes solitary, light green, not tapering toward the apex; ends bluntly rounded; cells 2.5-3 μm wide, quadrate or shorter than long, constricted at the crosswalls; cell contents homogenous. *O. geminata* was collected from Weeping Rock where it was rare.

Oscillatoria limnetica Lemmermann (Fig. 111). Trichomes solitary, blue-green, not tapering toward the apex, straight or curved, 2-2.5 μm in diameter, not constricted at cross walls; cells 5-8 μm long. This taxon was found at all localities except Emerald Pool but was not present in high numbers.

Oscillatoria rubescens De Candolle ex Gomont (Fig. 117). Trichomes solitary, light blue-green or purplish, tapering slightly toward apex, mostly straight, 7-8 μm in diameter, not constricted at cross walls; cells 3-6 μm long, granular near cross walls; apical cell capitate. *O. rubescens* was rare in collections from Mt. Carmel and Emerald Pool.

Oscillatoria subbrevis Schmidle (Fig. 112). Trichomes solitary, pale grey-green, not tapering toward the apex; ends bluntly rounded; cells 5 μm wide by 2 μm long, not constricted at the crosswalls; cell contents occasionally granular, though not at crosswalls. *O. subbrevis* was collected in low numbers from the small pools and runoff at Weeping Rock.

Oscillatoria subbrevis f. *minor* Desikachary (Fig. 115). Cells 3.5-4 μm wide by 2-3(4) μm long; otherwise as in nominate. *O. subbrevis* f. *minor* was collected from the open part of the drip wall at Weeping Rock. It was growing among bacteria where it was rare.

Spirulina laxa G.M. Smith. Trichomes loosely spiralled, solitary or entangled to form a small aggregate, 2-2.5 μm in diameter; spirals 7-10 μm wide, about 20 μm long.

Discussion: *S. laxa* was collected only from Weeping Rock, where it was rare. Our specimens have wider spirals than normally recorded for this taxon.

Spirulina subsalsa Oersted ex Gomont (Fig. 119). Trichomes 2-2.5 μm in diameter, tightly coiled; spirals 2.5-5 μm wide, no space evident between turns. This taxon was rare in collections from the wall of the Zion Narrows garden.

Family Nostocaceae

Nostoc microscopicum Carmichael ex Born. & Flah. (Fig. 120, 121). Plant a colonial aggregate of few to many trichomes, microscopic; colonial mucilage soft, hyaline; cells truncate to globose, 5-8 μm in diameter, green to blue-green; heterocysts spherical, single or in a short series, 8-10 μm in diameter. This taxon was rare and found only in the Mt. Carmel garden. It was found only in the wet areas of the wall.

Nostoc muscorum Agardh ex Born. & Flah. (Fig. 118, 122, 123). Plant a colonial aggregate of many trichomes, microscopic to expanded and macroscopic, yellow-green to brown; individual trichomes ensheathed; cells globose to elliptical, 5-6 μm in diameter; heterocysts globose, singular, slightly larger than vegetative cells. *N. muscorum* was found only in the Mt. Carmel and Narrows gardens. It was not abundant and was observed growing on the wetter portions of the walls.

Nostoc paludosum Kützing ex Born. & Flah. (Fig. 124, 125). Plant colonial, microscopic, containing only 1-2 trichomes, hyaline to yellow; cells oblong to elliptic, 3-5 μm wide, 5-6 μm long; heterocysts about the same size and shape as vegetative cells. This *Nostoc* is common in terrestrial sites in western North America. It was found in all study sites in Zion Park mingled with other algal species.

Family Scytonemataceae

Scytonema alatum (Carm.) Borzi ex Born. & Flah. (Fig. 126, 127). Plant filamentous; filaments 45-65 μm in diameter; trichomes 8-10 μm in diameter; sheath broad with distinct "wings", ochrous; cells 8-10 μm wide, 10-13 μm long; crosswalls not or only slightly constricted; cell contents granular, green to ochrous. *S. alatum* was abundant on Weeping Rock but absent from other wet walls. It was distinguished from other *Scytonema* species by the large wing-like sheath.

Scytonema myochrous (Dillw.) Agardh ex Born. & Flah. (Fig. 128, 129). Plant filamentous; filaments 20-36 μm wide; trichomes 12.5-15 μm in diameter; sheaths thick, yellow to brown, lamellate; cells quadrate or barrel-shaped, compressed at branch ends. *S. myochrous* was found in all study sites. It is occasionally abundant forming mucilaginous mats on the walls. This taxon is a common aerophile in western North America.

Scytonema tolypothrichoides Kützing ex Born. & Flah. (Fig. 130, 132). Plant filamentous; filaments 12.5-15 μm in diameter; trichomes 7-10 μm in diameter; sheaths colorless to yellowish; cells 13-17.5 μm long, granular, light green. This species was rare and found only at the Zion Narrows garden.

Calothrix clavata West (Fig. 133). Plants filamentous, trichomes in small groups, not branched, tapering apically to a hair; cells granular, 5 μm wide by 3-7 μm long near base to 2 μm wide by 8 μm long near apex; heterocyst basal, homogenous, 5 μm wide; sheaths ochrous, persistant, and often devoid of cells. *C. clavata* was collected only from Weeping Rock, where it was rare. It was growing among bacteria.

Calothrix parietina (Naeg.) Thuret ex Born. & Flah. (Fig. 134). Plants filamentous, filaments 8-12 μm wide; trichomes tapering to a hair; cells granular, subquadrate to quadrate, 5-8 μm wide by 3-6 μm long; heterocyst basal, spherical, 7-10 μm in diameter; sheaths hyaline, not lamellate. This taxon was infrequent on the wet walls at Weeping Rock.

DIVISION CHLOROPHYTA

Family Palmellaceae

Palmella miniata Leiblein (Fig. 138, 140). Plant a single cell, or 2-7 cells grouped in loose matrix; cell ovoid, 7-25 μm wide, 25-37 μm long; chloroplast dark green, filling entire cell, fine granular. *P. miniata* was commonly seen, both as single cells and small colonies, in samples from the wet wall at Emerald Pool.

Family Oocystaceae

Oocystis species (Fig. 139). Plants unicellular or a small family of cells in old mother cell wall; cells 16-17 μm in diameter by 33-35 μm long, not nodulated at the poles. This taxon was rare in samples from Weeping Rock and the Narrows.

Family Ulotrichaceae

Ulothrix cylindricum Prescott. Plant filamentous, unbranched; cells 11-12.5 μm wide, 17-30 μm long; cell wall up to 1.5 μm thick, not constricted at the end walls. Chloroplast single, parietal. *U. cylindricum* was common only at the Emerald Pool site on the slick rock in association with *U. zonata*. The species was determined on the basis of size, thickness of the cell wall and amount of cell space occupied by the chloroplast.

Ulothrix zonata (Weber & Mohr) Kützing (Fig. 141). Plant filamentous, unbranched; cells 20-25 μm wide, 23-25 μm long; cell wall conspicuously thick, up to 2.5 μm; chloroplast single, parietal, taking up nearly half the cell. *U. zonata* was abundant in the samples from the slick rock at the Emerald Pool site in association with *U. cylindricum*. The species was easily distinguished on the basis of size and the thickened cell wall.

Family Chaetophoraceae

Stigeoclonium species (Fig. 145, 147). Plant filamentous, alternately branched; basal cells 7-10 μm wide, up to 20 μm long; branch cells

5 μm wide, up to 65 μm long; chloroplast parietal, nearly filling cell. This *Stigeoclonium* species was commonly found only in the splash zone at the Emerald Pool site on the protected sides of rocks. It appeared to be associated with *Cladophora glomerata*. The basal cells of the species resemble the description for *S. nanum* but the presence of long, empty branch cells prevented specific identification with that taxon.

Family Oedogoniaceae

Oedogonium species. Plants filamentous; vegetative cells cylindric, 10 μm in diameter, 60-75 μm long; chloroplast bright green, reticulate; sexual reproduction not observed. This *Oedogonium* was collected in rare numbers from the drip wall at Weeping Rock.

Family Zygnemataceae

Mougeotia species (Fig. 142). Plant filamentous, unbranched; cells 20 μ in diameter, 175-250 μm long, end walls plain; chloroplast plate-like or appearing reticulate, filling the cell. *Mougeotia* species was found only on the wet wall at Emerald Pool. Reproduction stages were not found.

Spirogyra species (Fig. 143). Plants filamentous; cells 37 μm wide by 50-105 μ long; chloroplasts bright green, one per cell, making 1-1.5 turns per cell; conjugation not observed. This *Spirogyra* was collected from the southern part of Weeping Rock, where it occurred in low numbers.

Zygnema species (Fig. 144). Plants filamentous, unbranched; cells 23-30 μm wide, (55)65-85(125) μm long; plastids variable, often not distinctly stellate; pyrenoids, when present, one per plastid. This *Zygnema* species was common at Weeping Rock and on the wet wall at Emerald Pool. It seemed to be present only on the wetter walls and associated with other filamentous Chlorophyta and Cyanophyta.

Family Desmidiaceae

Cosmarium species. Plant unicellular, 45 μm long by 18 μm wide; margins of semicells smooth, isthmus shallow. This *Cosmarium* is similar to *C. botrytis*. Two specimens were collected from the Zion Narrows locality.

Family Cladophoraceae

Cladophora glomerata (L.) Kützing (Fig. 146). Plant a branching filament; cells 27 μm in diameter by 250 μm long near branch tips, up to 70 μm in diameter by 1100 μm long near base of main thallus; branching alternate or more or less whorled. *C. glomerata* was found in samples from Weeping Rock, Emerald Pool and Zion Narrows. It was occasionally abundant in restricted areas.

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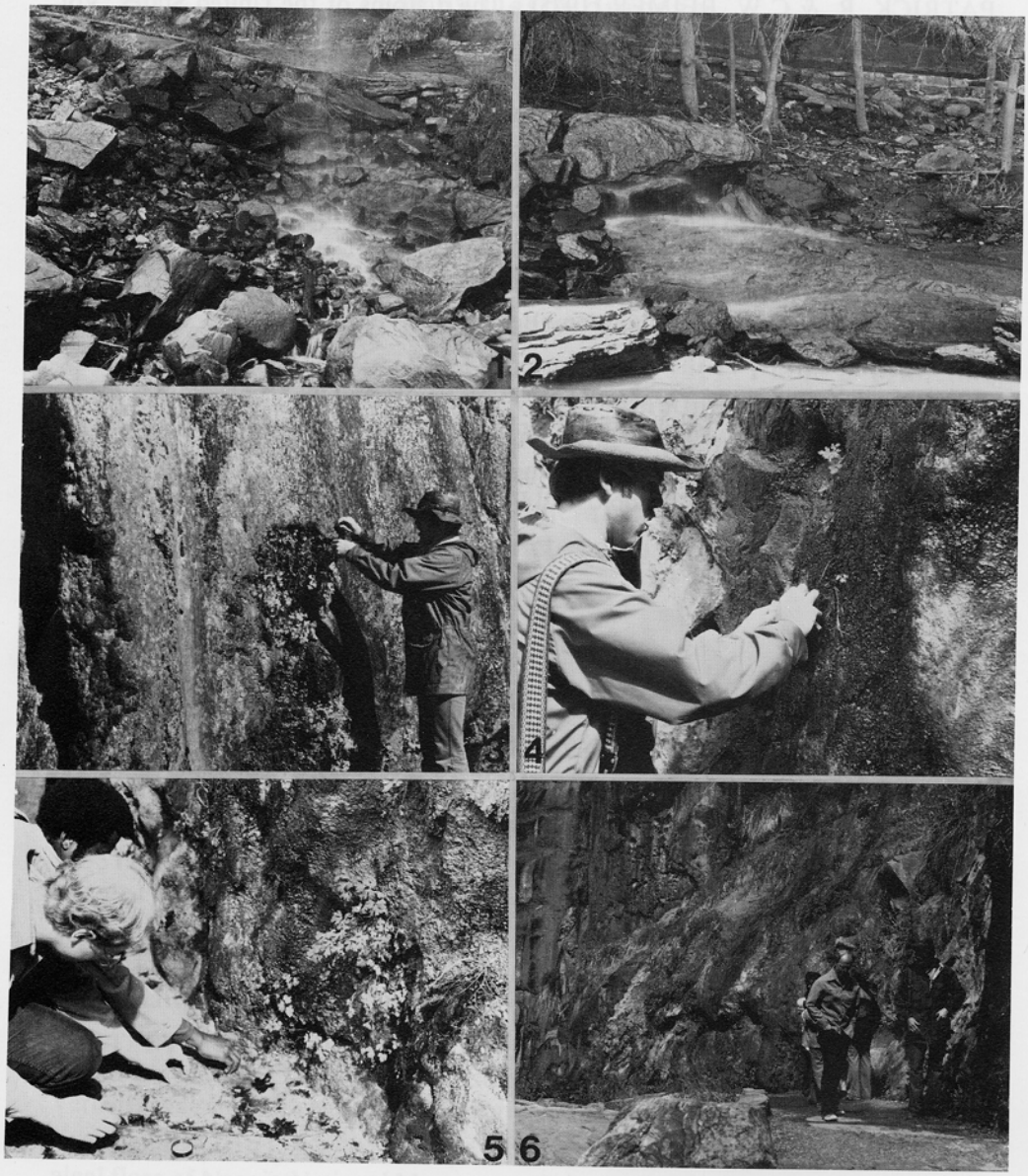

Figures 1-6. Collecting sites in Zion National Park. Figure 1. Stones and debris in splash zone, Emerald Pool. Figure 2. Slickrock splash zone, Emerald Pool. Figure 3. Collecting sample from Weeping Rock. The entire face of the rock here is covered by bacteria and algae. Figure 4. Closeup of blue-green algal mats on Weeping Rock. Figure 5. Wet wall in Zion Narrows. Figure 6. Large wet wall in Zion Narrows. Most of the rock wall in this figure is covered by algal mats.

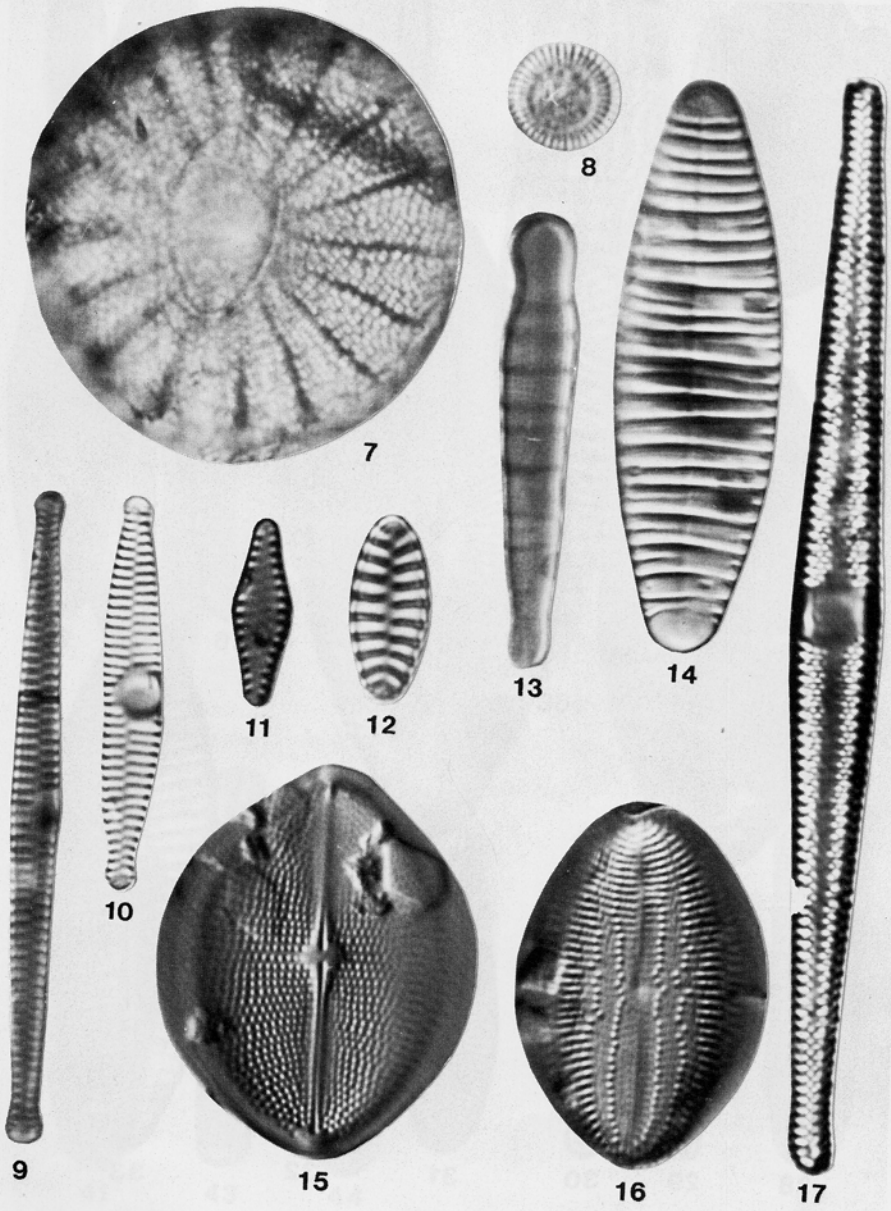

Fig. 7-17. Bacillariophyta. All micrographs at 2000×. Fig. 7. *Stephanodiscus carconensis*. Fig. 8. *Cyclotella caspia*. Fig. 9. *Fragilaria vaucheriae*. Fig. 10. *Fragilaria vaucheriae*. Fig. 11. *Fragilaria brevistriata* var. *inflata*. Fig. 12. *Fragilaria pinnata*. Fig. 13. *Meridion circulare* var. *constrictum*. Fig. 14. *Diatoma vulgare*. Fig. 15. *Cocconeis pediculus*, raphe valve. Fig. 16. *Cocconeis pediculus*, rapheless valve. Fig. 17. *Synedra pulchella*.

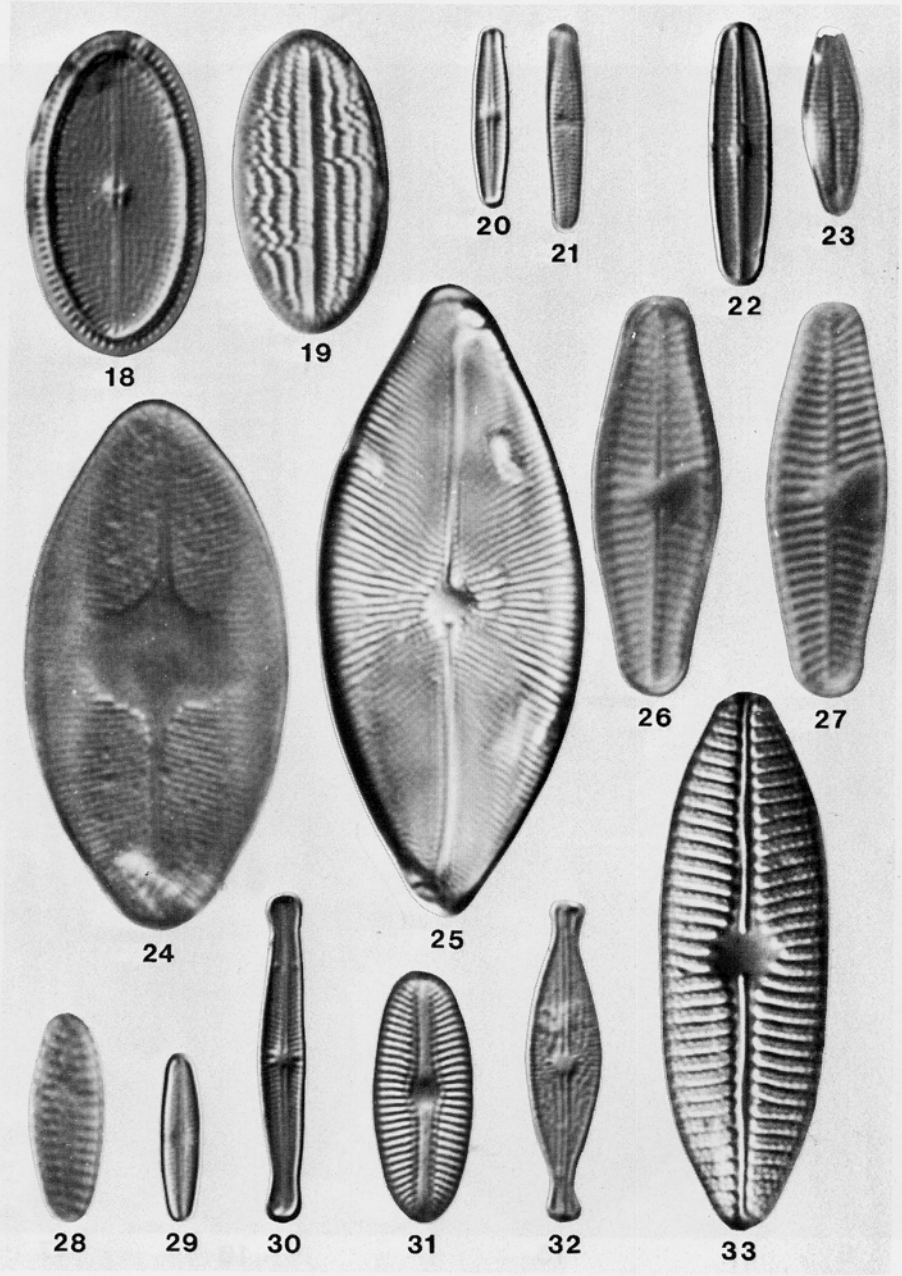

Fig. 18-33. Bacillariophyta. All micrographs at 2000×. Fig. 18. *Cocconeis placentula* var. *euglypta,* raphe valve. Fig. 19. *Cocconeis placentula* var. *euglypta* rapheless valve. Fig. 20. *Achnanthes affinis*, raphe valve. Fig. 21. *Achnanthes affinis,* rapheless valve. Fig. 22. *Achnanthes deflexa,* raphe valve. Fig. 23. *Achnanthes deflexa,* rapheless valve. Fig. 24. *Achnanthes flexella,* rapheless valve. Fig. 25. *Achnanthes flexella,* raphe valve. Fig. 26. *Achnanthes lanceolata,* raphe valve. Fig. 27. *Achnanthes lanceolata,* rapheless valve. Fig. 28. *Achnanthes lewisiana,* rapheless valve. Fig. 29. *Achnanthes linearis,* raphe valve. Fig. 30. *Achnanthes microcephala,* raphe valve. Fig. 31. *Diploneis oblongella.* Fig. 32. *Anomoeoneis vitrea.* Fig. 33. *Mastogloia grevillei.*

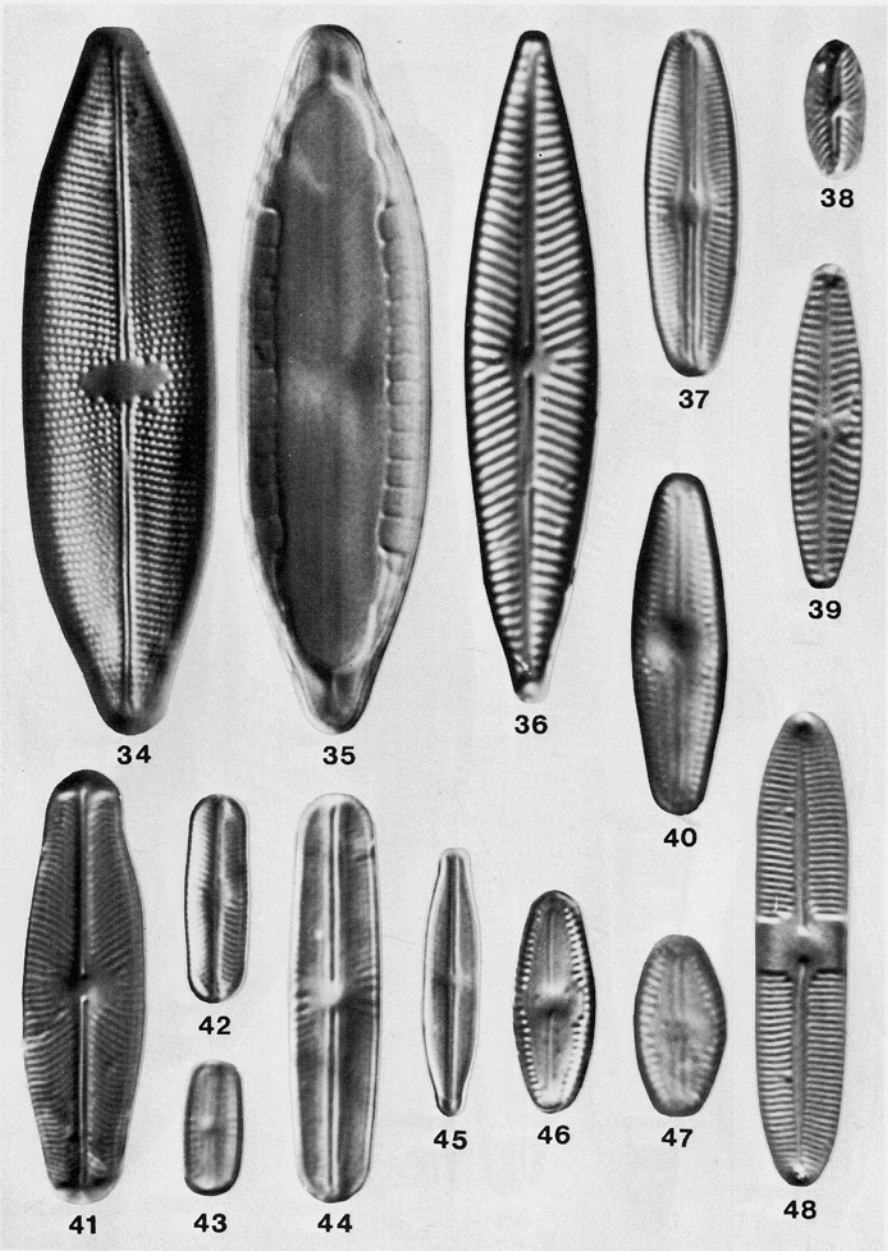

Fig. 34-48. Bacillariophyta. All micrographs at 2000×. Fig. 34. *Mastogloia smithii* var. *lacustris*. Fig. 35. *Mastogloia smithii* var. *lacustris*, showing internal chambers. Fig. 36. *Navicula radiosa*. Fig. 37. *Navicula* species 3. Fig. 38. *Navicula excelsa*. Fig. 39. *Navicula heufleri* var. *leptocephala*. Fig. 40. *Navicula mutica*. Fig. 41. *Navicula pupula*. Fig. 42. *Navicula subbacillum*. Fig. 43. *Navicula subbacillum*. Fig. 44. *Navicula wittrockii*. Fig. 45. *Navicula* species 1. Fig. 46. *Navicula* species 2. Fig. 47. *Navicula* species 2. Fig. 48. *Caloneis bacillum*.

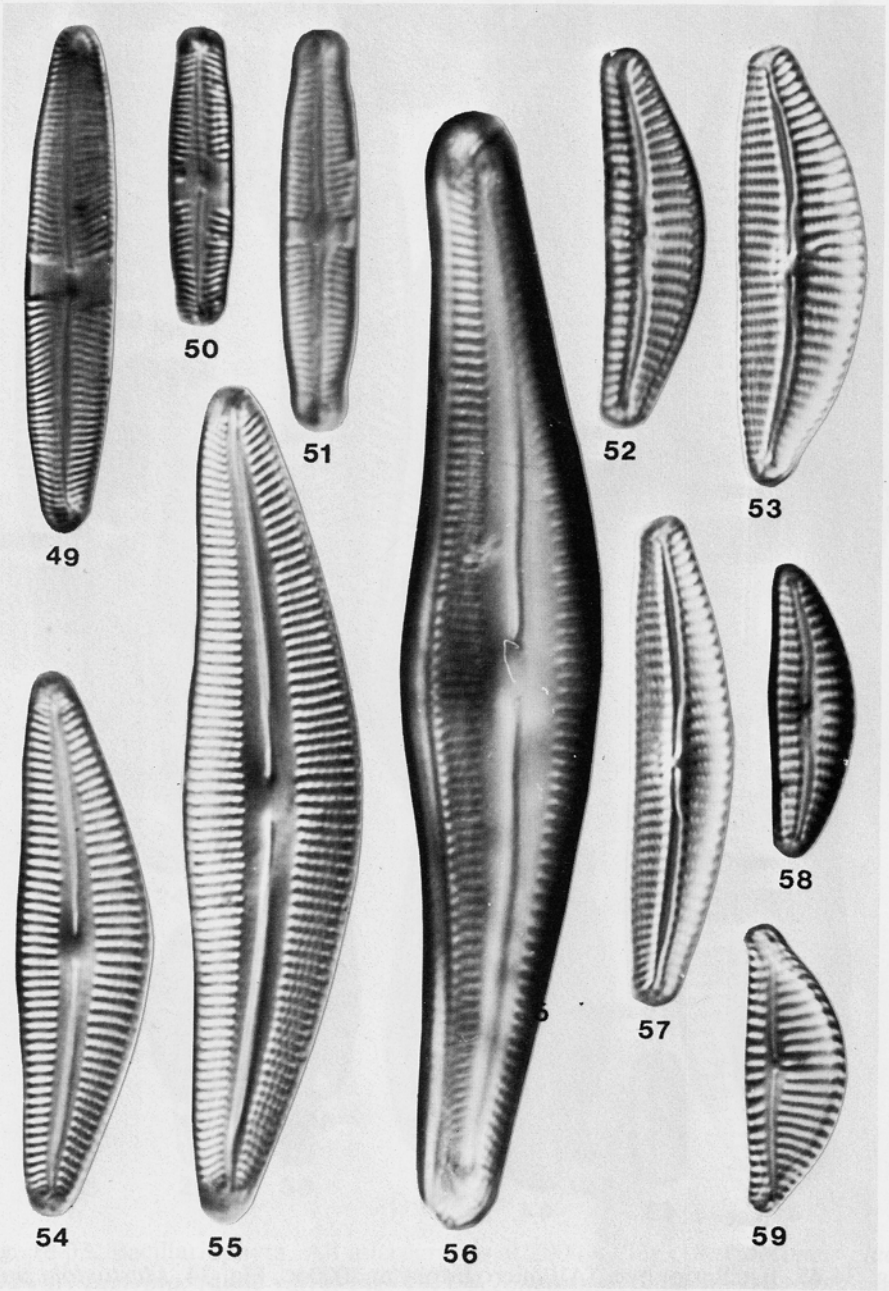

Fig. 49-59. Bacillariophyta. All micrographs at 2000×. Fig. 49. *Pinnularia* species. Fig. 50. *Pinnularia appendiculata*. Fig. 51. *Pinnularia appendiculata*. Fig. 52. *Cymbella affinis*. Fig. 53. *Cymbella affinis*. Fig. 54. *Cymbella cymbiformis* var. *nonpunctata*. Fig. 55. *Cymbella cymbiformis* var. *nonpunctata*. Fig. 56. *Cymbella cymbiformis* var. *nonpunctata*. Fig. 57. *Cymbella affinis*. Fig. 58. *Cymbella* species 1. Fig. 59. *Cymbella minuta* var. *latens*.

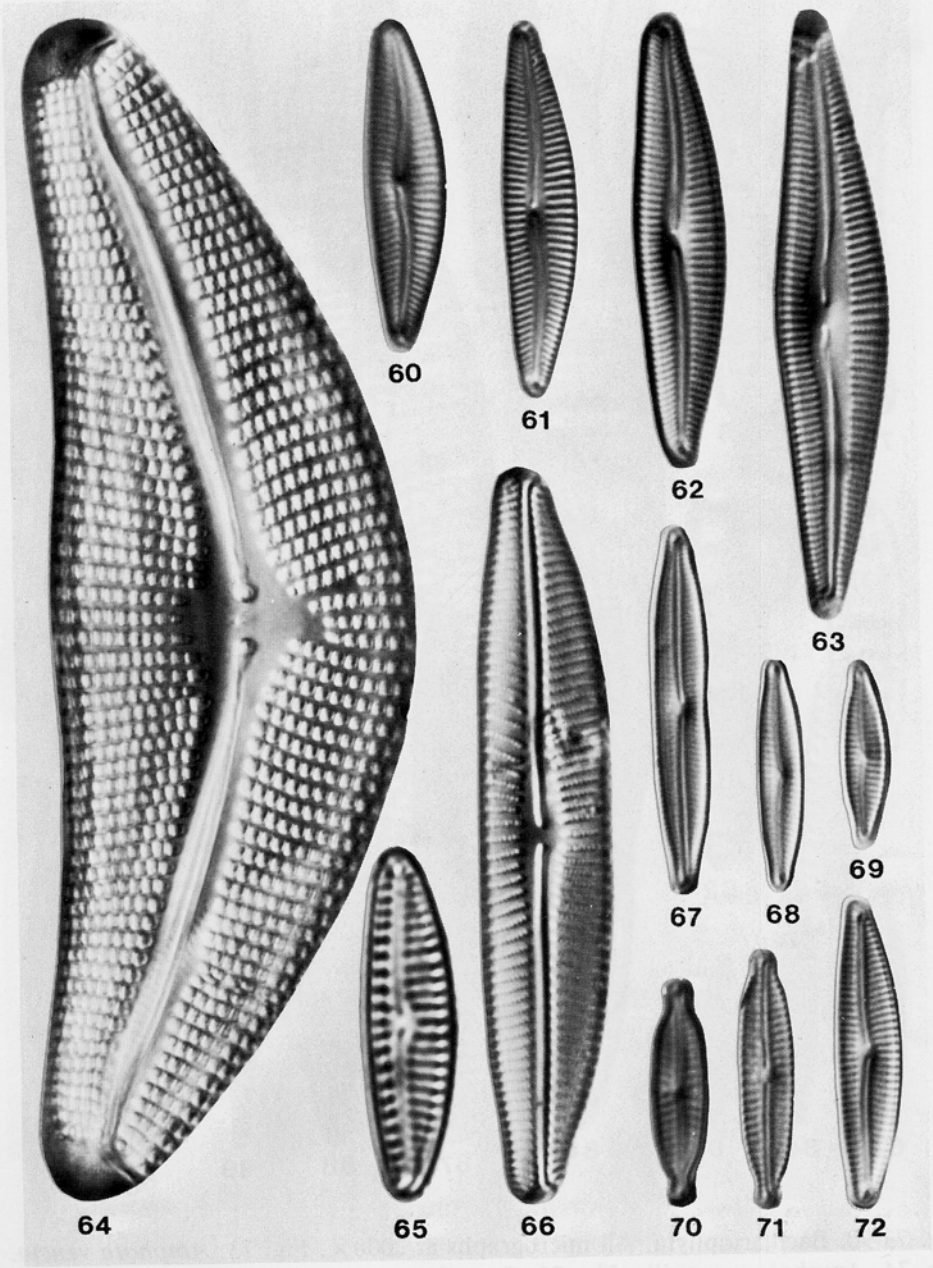

Fig. 60-72. Bacillariophyta. All micrographs at 2000× except where noted. Fig. 60. *Cymbella delicatula*. Fig. 61. *Cymbella delicatula*. Fig. 62. *Cymbella delicatula*. Fig. 63. *Cymbella delicatula*. Fig. 64. *Cymbella mexicana*, 1500×. Fig. 65. *Cymbella perpusilla*. Fig. 66. *Cymbella norvegica*. Fig. 67. *Cymbella microcephala*. Fig. 68. *Cymbella microcephala*. Fig. 69. *Cymbella microcephala*. Fig. 70. *Cymbella microcephala* var. *crassa*. Fig. 71. *Cymbella microcephala* var. *crassa*. Fig. 72. *Cymbella* species 2.

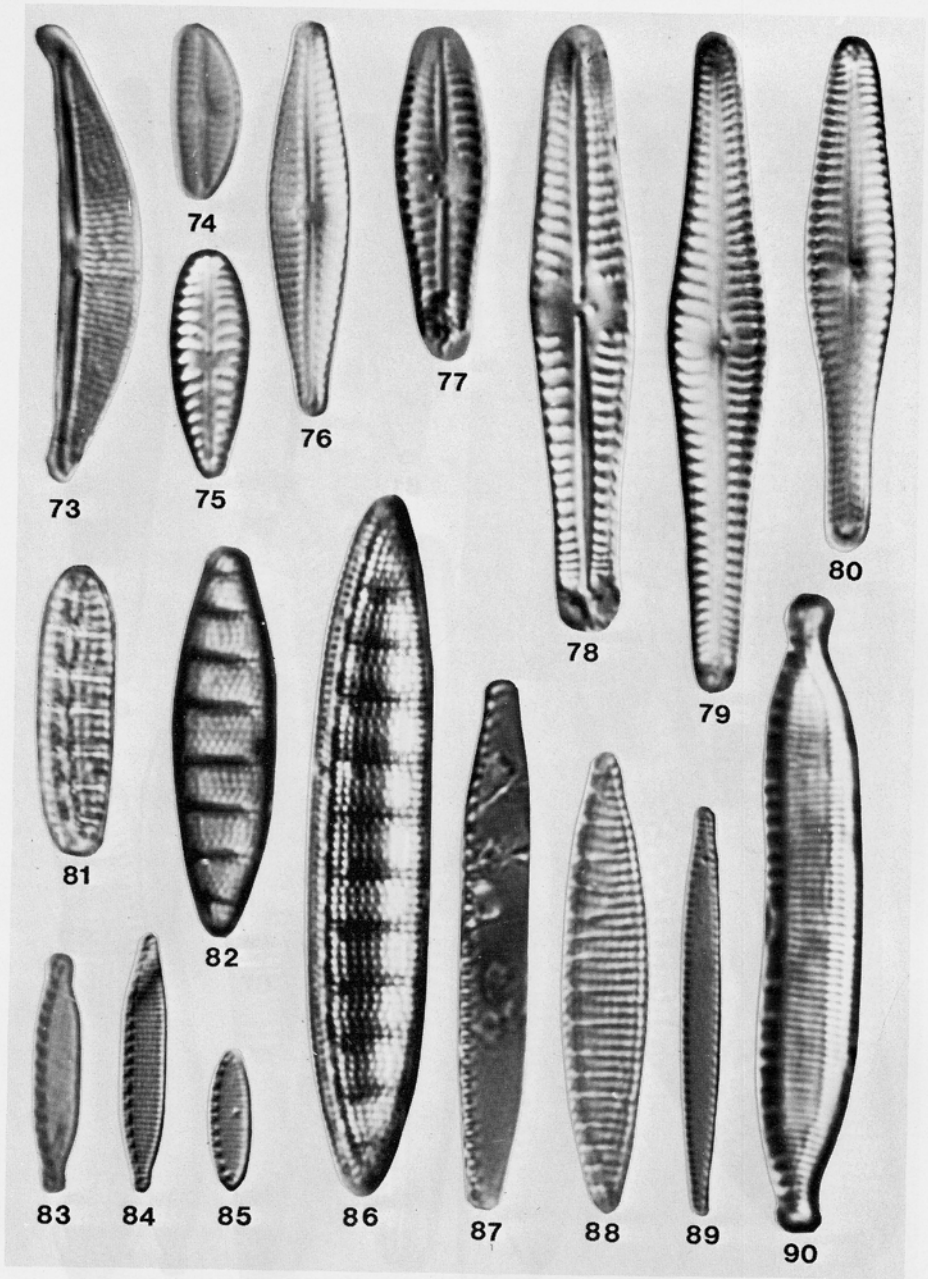

Fig. 73-90. Bacillariophyta. All micrographs at 2000×. Fig. 73. *Amphora veneta*. Fig. 74. *Amphora perpusilla*. Fig. 75. *Gomphonema olivaceum*. Fig. 76. *Gomphonema angustatum*. Fig. 77. *Gomphonema dichotomum*. Fig. 78. *Gomphonema dichotomum*. Fig. 79. *Gomphonema intricatum*. Fig. 80. *Gomphonema intricatum*. Fig. 81. *Denticula elegans*. Fig. 82. *Denticula elegans* f. *valida*. Fig. 83. *Nitzschia microcephala*. Fig. 84. *Nitzschia hantzschiana*. Fig. 85. *Nitzschia inconspicua*. Fig. 86. *Denticula elegans* f. *valida*. Fig. 87. *Nitzschia communis*. Fig. 88. *Nitzschia denticula*. Fig. 89. *Nitzschia paleacea*. Fig. 90. *Hantzschia amphioxys*.

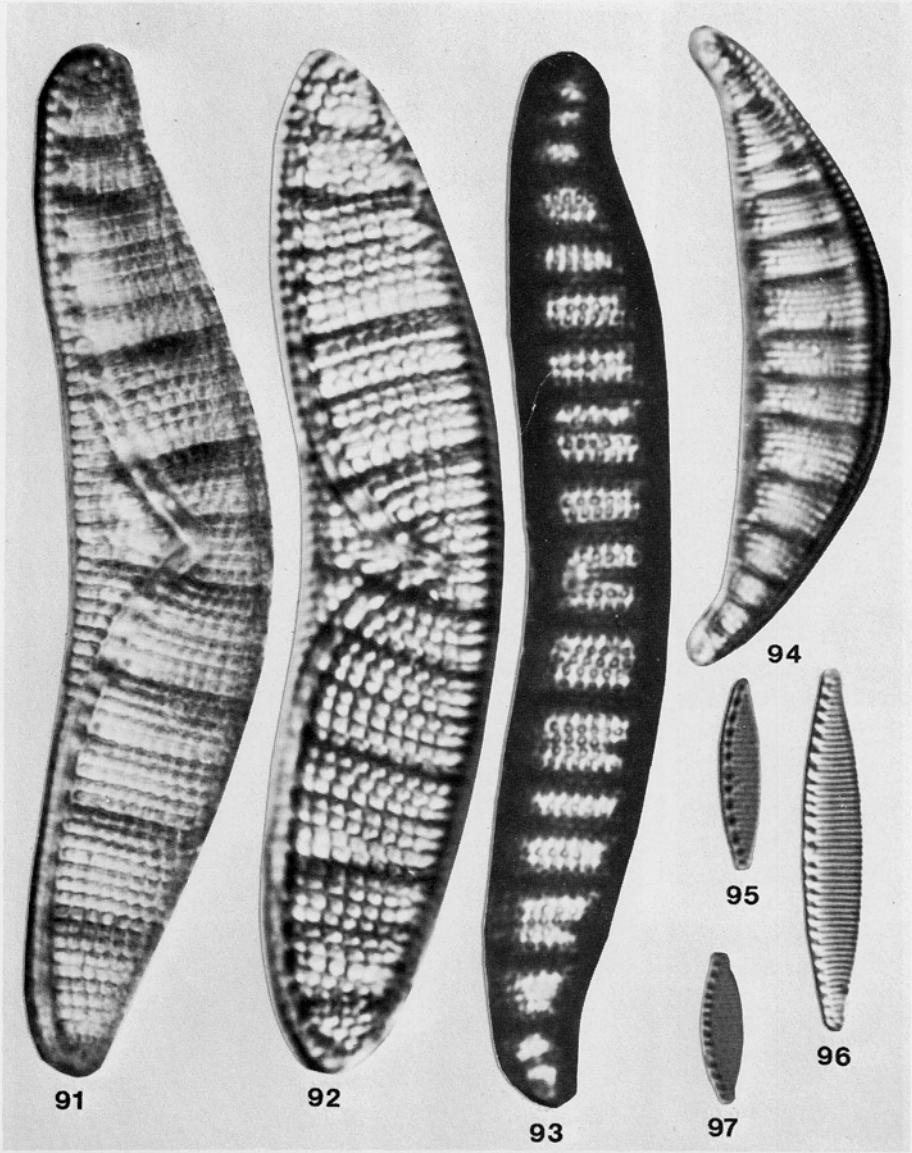

Fig. 91-97. Bacillariophyta. All micrographs at 2000× except where noted. Fig. 91. *Epithemia argus* var. *protracta*. Fig. 92. *Epithemia argus* var. *longicornis*. Fig. 93. Epithemia turgida, 1500×. Fig. 94. *Rhopalodia gibberula*. Fig. 95. *Nitzschia romana*. Fig. 96. *Nitzschia romana*. Fig. 97. *Nitzschia* species.

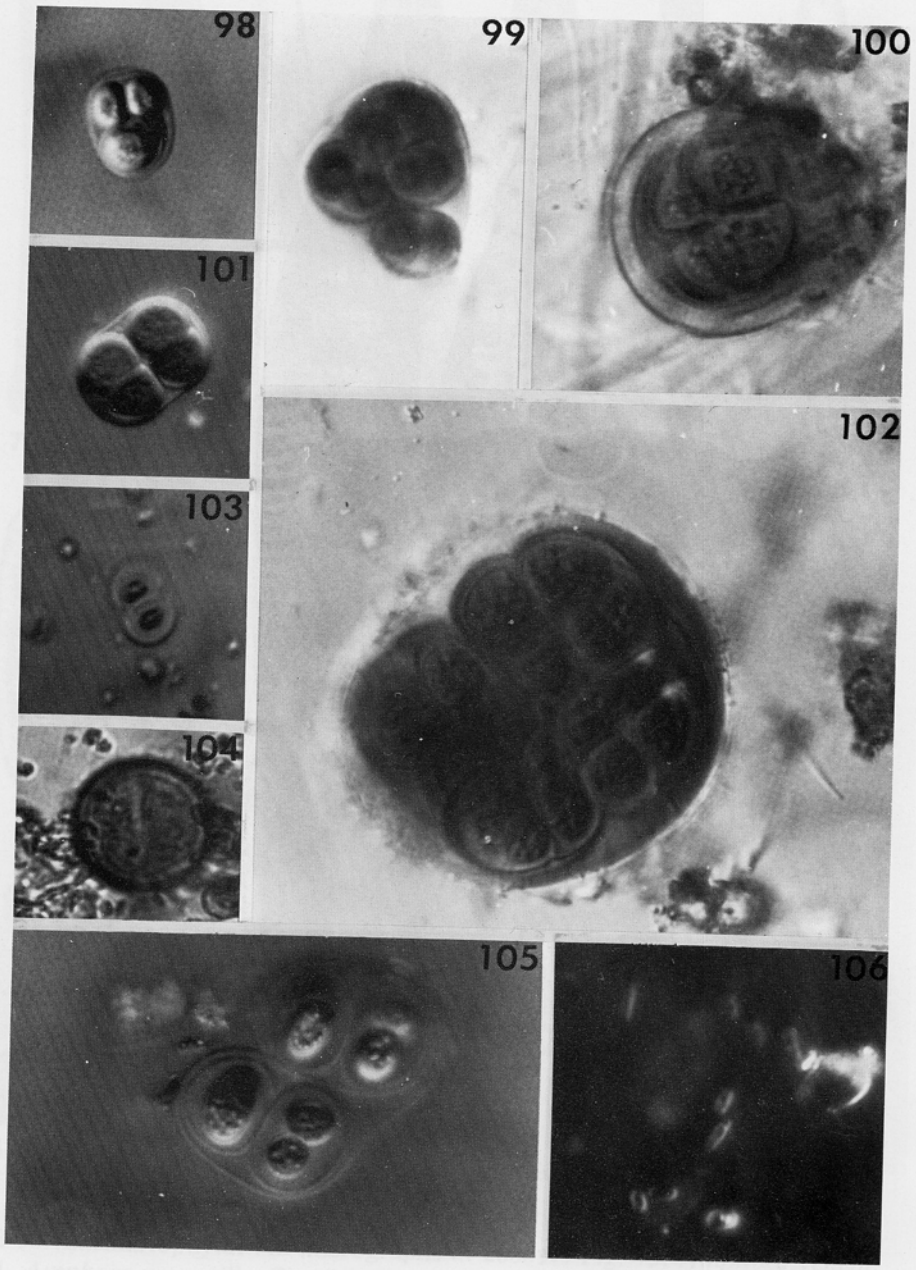

Fig. 98-106. Cyanophyta. Fig. 98. *Chroococcus turgidus*. Fig. 99. *Gloeocapsa nigrescens*. Fig. 100. *Gloeocapsa rupestris*. Fig. 101. *Chroococcus turgidus*. Fig. 102. *Gloeocapsa rupestris*. Fig. 103. *Chroococcus varius*. Fig. 104. *Gloeocapsa rupestris*. Fig. 105. *Gloeotheca rupestris*. Fig. 106. *Gloeotheca palea*.

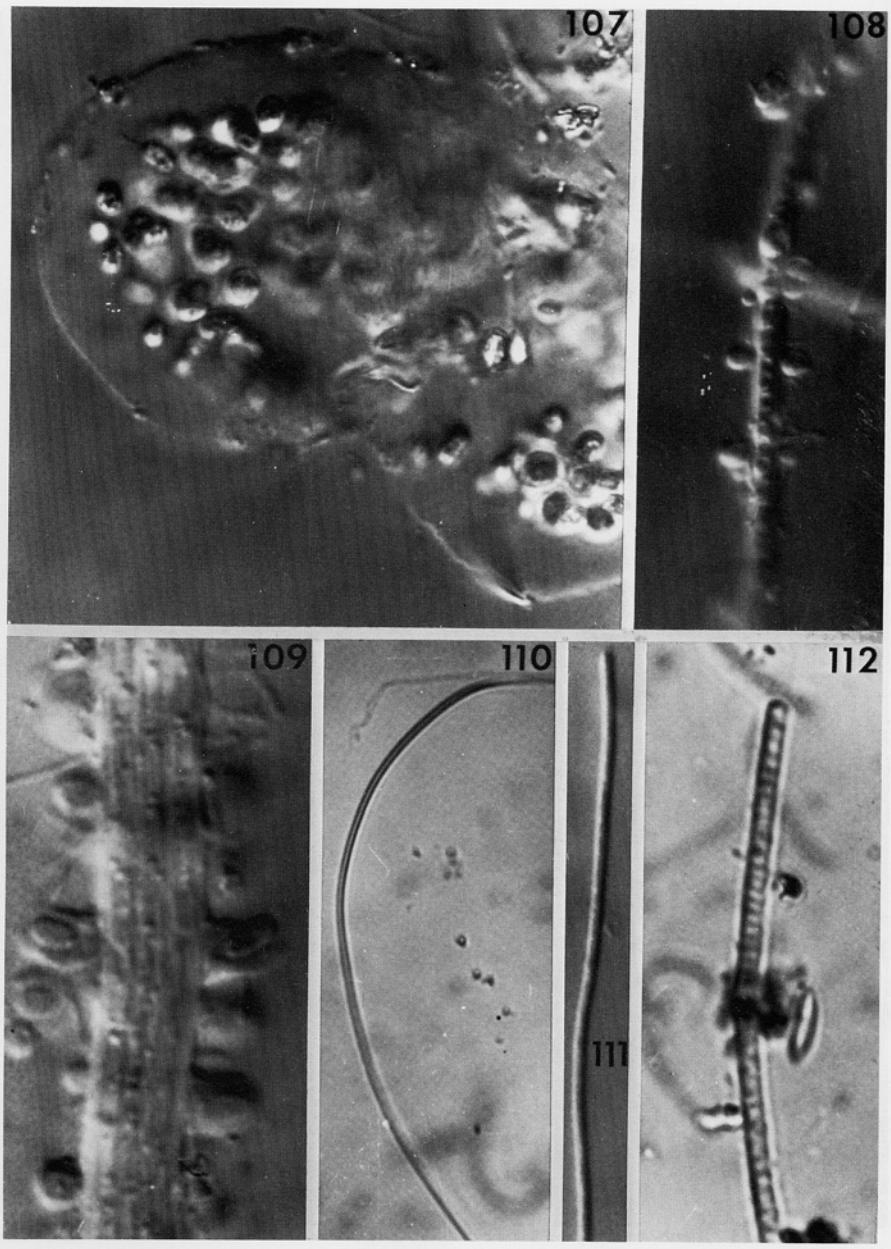

Fig. 107-112. Cyanophyta. Fig. 107. *Gomphosphaeria aponina*. Fig. 108. *Chamaesiphon incrustans*. Fig. 109. *Chamaesiphon incrustans*. Fig. 110. *Oscillatoria angusta*. Fig. 111. *Oscillatoria limnetica*. Fig. 112. *Oscillatoria subbrevis*.

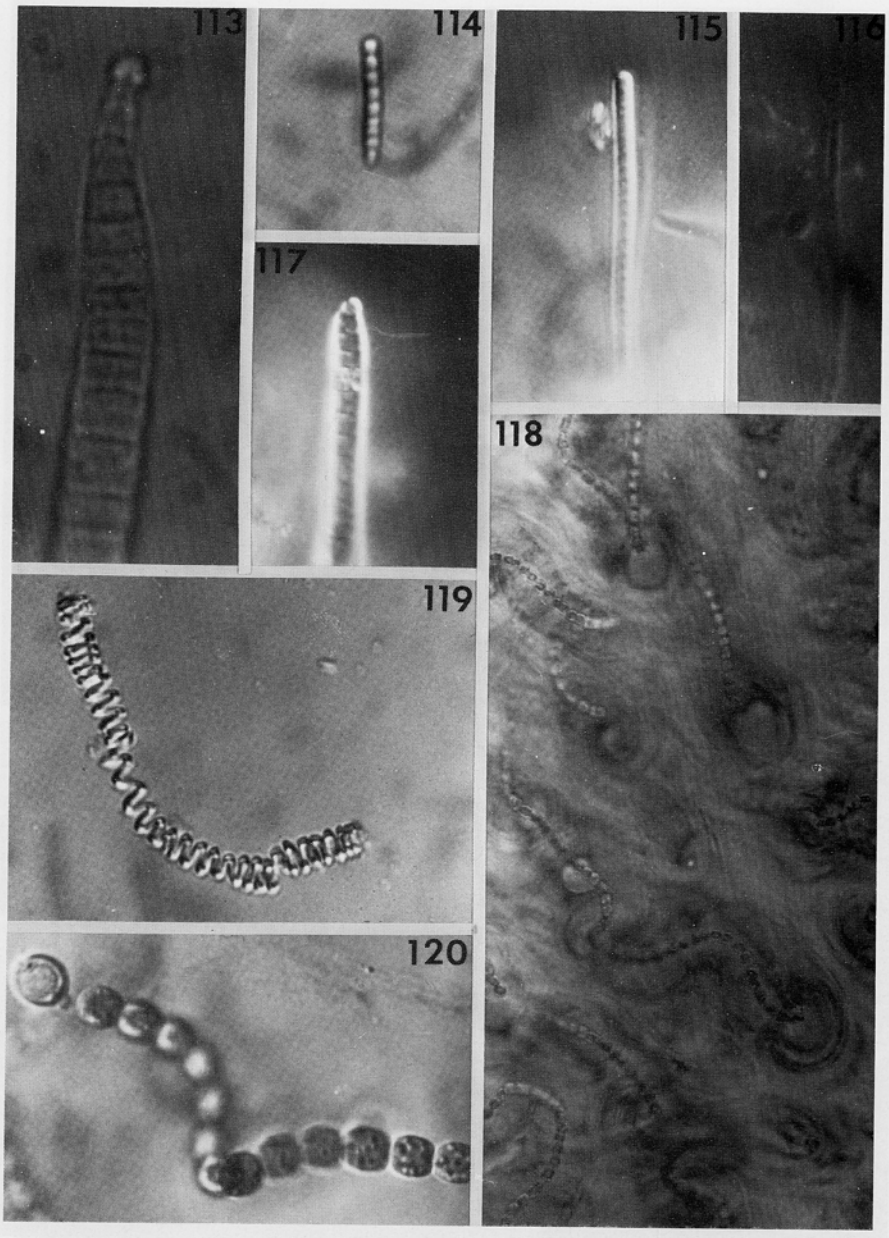

Fig. 113-120. Cyanophyta. Fig. 113. *Oscillatoria agardhii*. Fig. 114. *Oscillatoria geminata*. Fig. 115. *Oscillatoria subbrevis* f. *minor*. Fig. 116. *Lyngbya limnetica*. Fig. 117. *Oscillatoria rubescens*. Fig. 118. *Nostoc muscorum*. Fig. 119. *Spirulina subsalsa*. Fig. 120. *Nostoc microscopicum*.

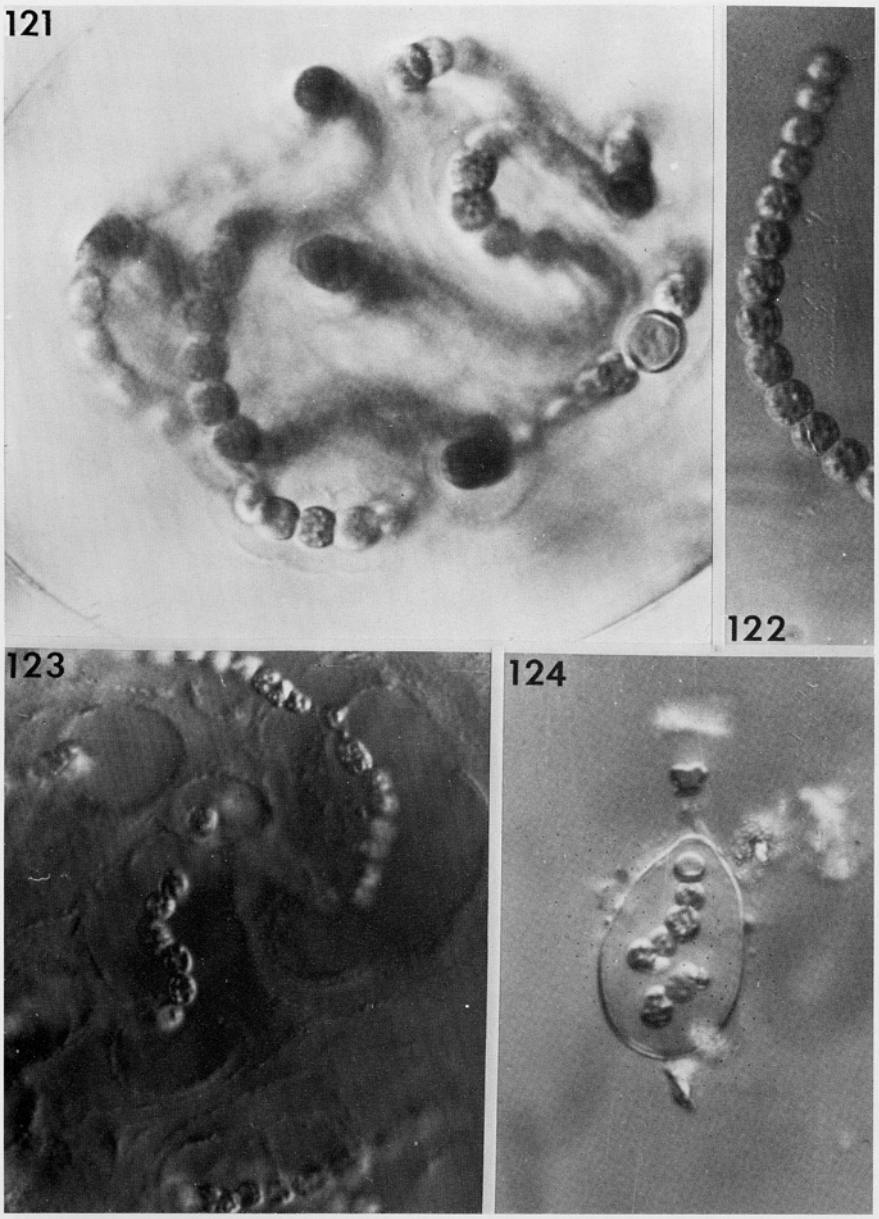

Fig. 121-124. Cyanophyta. Fig. 121. *Nostoc microscopicum*. Fig. 122. *Nostoc muscorum*. Fig. 123. *Nostoc muscorum*. Fig. 124. *Nostoc paludosum*.

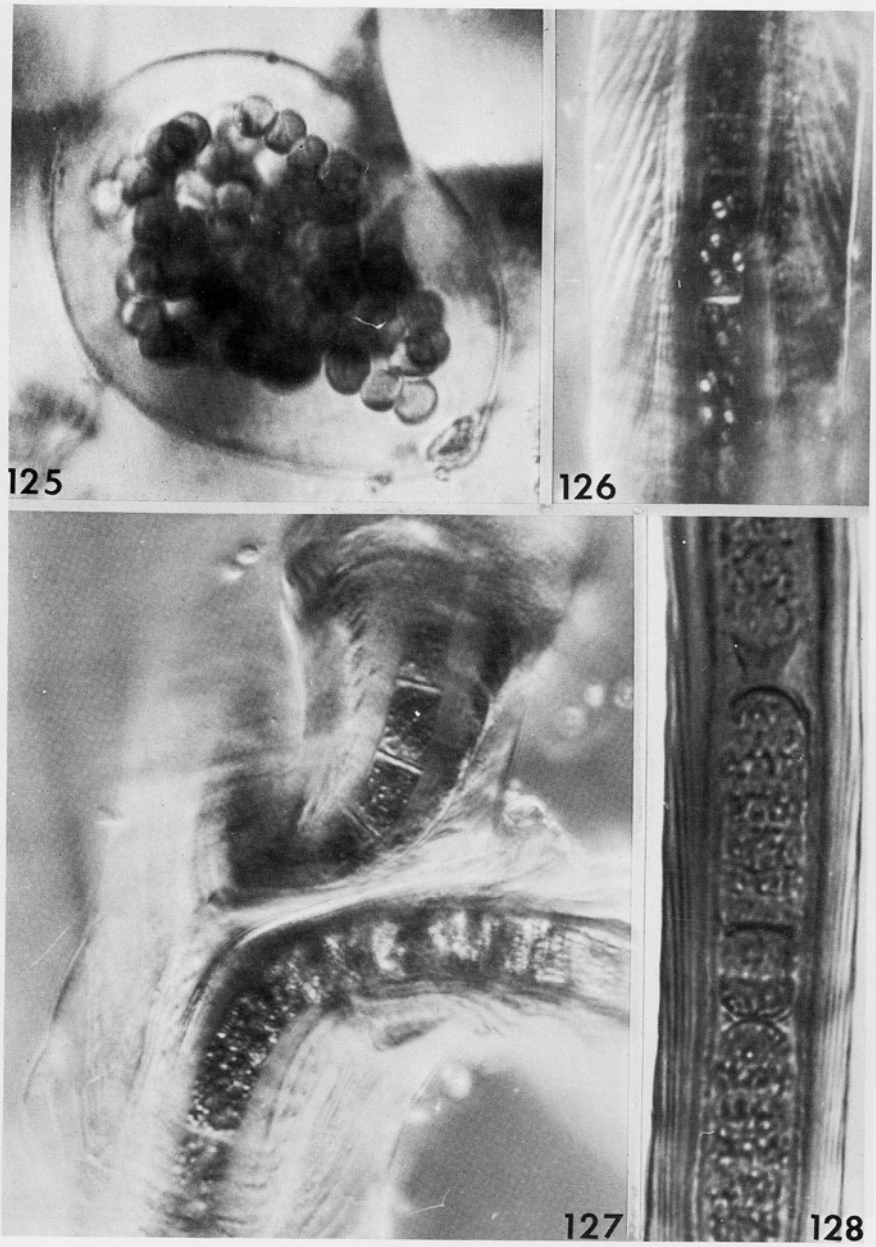

Fig. 125-128. Cyanophyta. Fig. 125. *Nostoc paludosum*. Fig. 126. *Scytonema alatum*. Fig. 127. *Scytonema alatum*. Fig. 128. *Scytonema myochrous*.

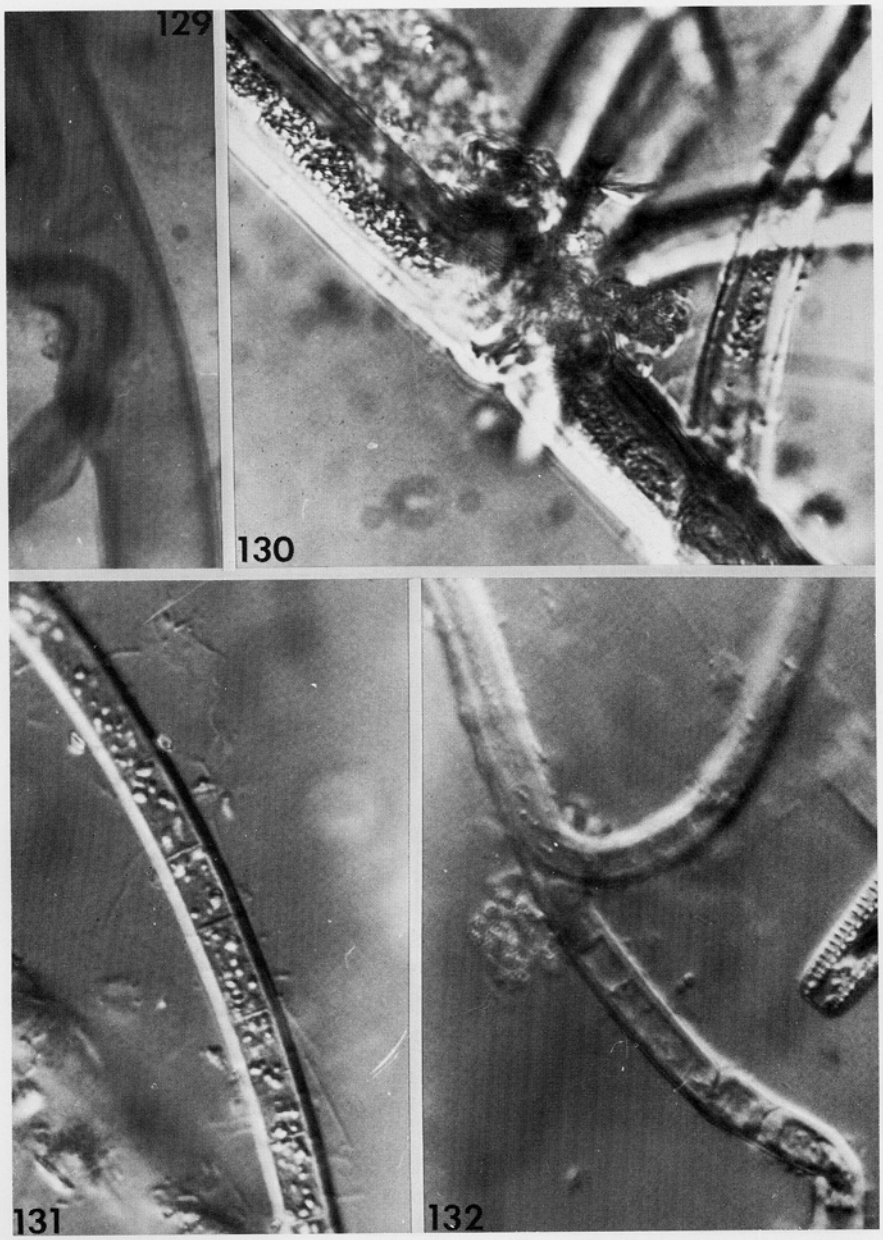

Fig. 129-132. Cyanophyta. Fig. 129. *Scytonema myochrous*. Fig. 130. *Scytonema tolypothrichoides*. Fig. 131. *Scytonema tolypothrichoides*. Fig. 132. *Scytonema tolypothrichoides*.

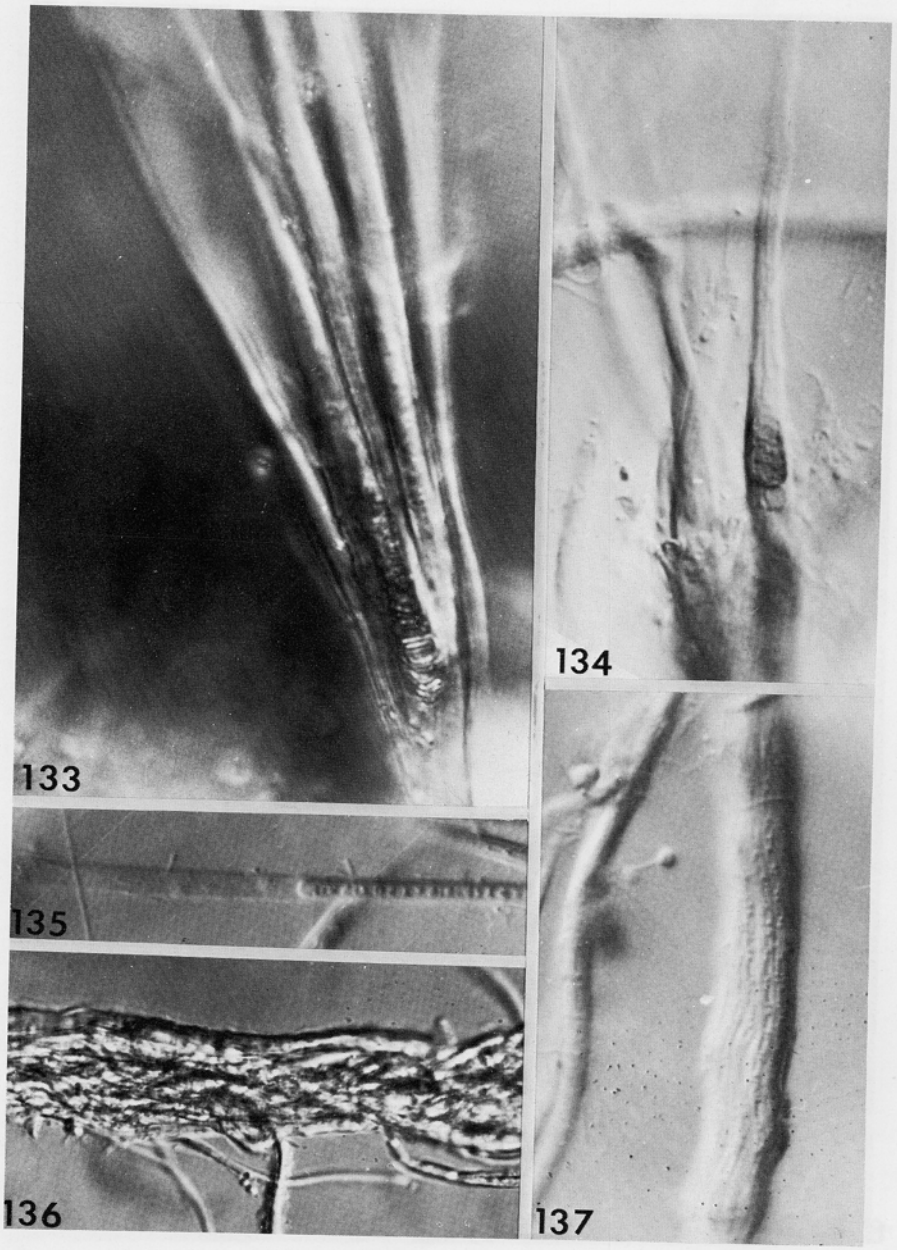

Fig. 133-137. Cyanophyta and Schizophyta. Fig. 133. *Calothrix clavata*. Fig. 134. *Calothrix parietina*. Fig. 135. *Bacterium*, Weeping Rock. Fig. 136. *Bacterium*, Weeping Rock. Fig. 137. *Thioploca ingrica* Weeping Rock.

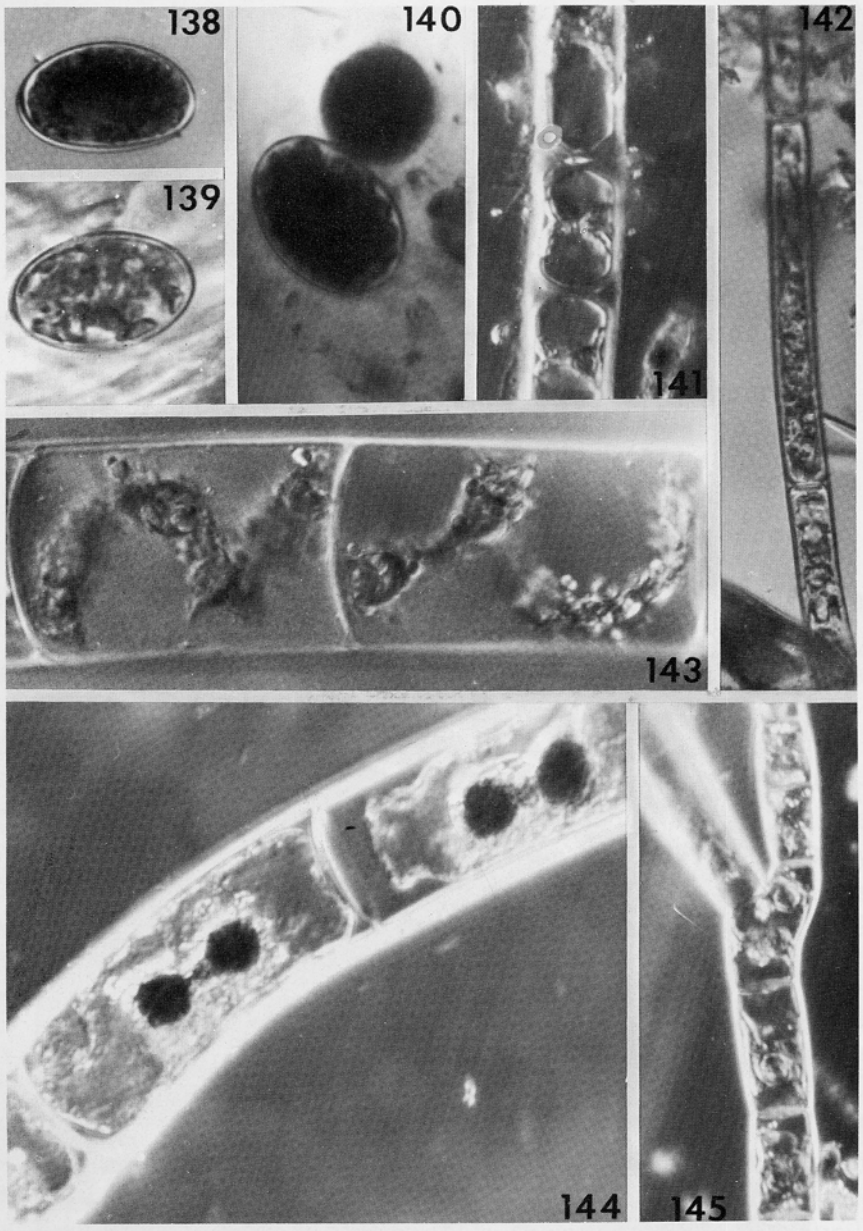

Fig. 138-145. Chlorophyta. Fig. 138. *Palmella miniata*. Fig. 139. *Oocystis* species. Fig. 140. *Palmella miniata*. Fig. 141. *Ulothrix zonata*. Fig. 142. *Mougeotia* species. Fig. 143. *Spirogyra* species. Fig. 144. *Zygnema* species. Fig. 145. *Stigeoclonium* species.

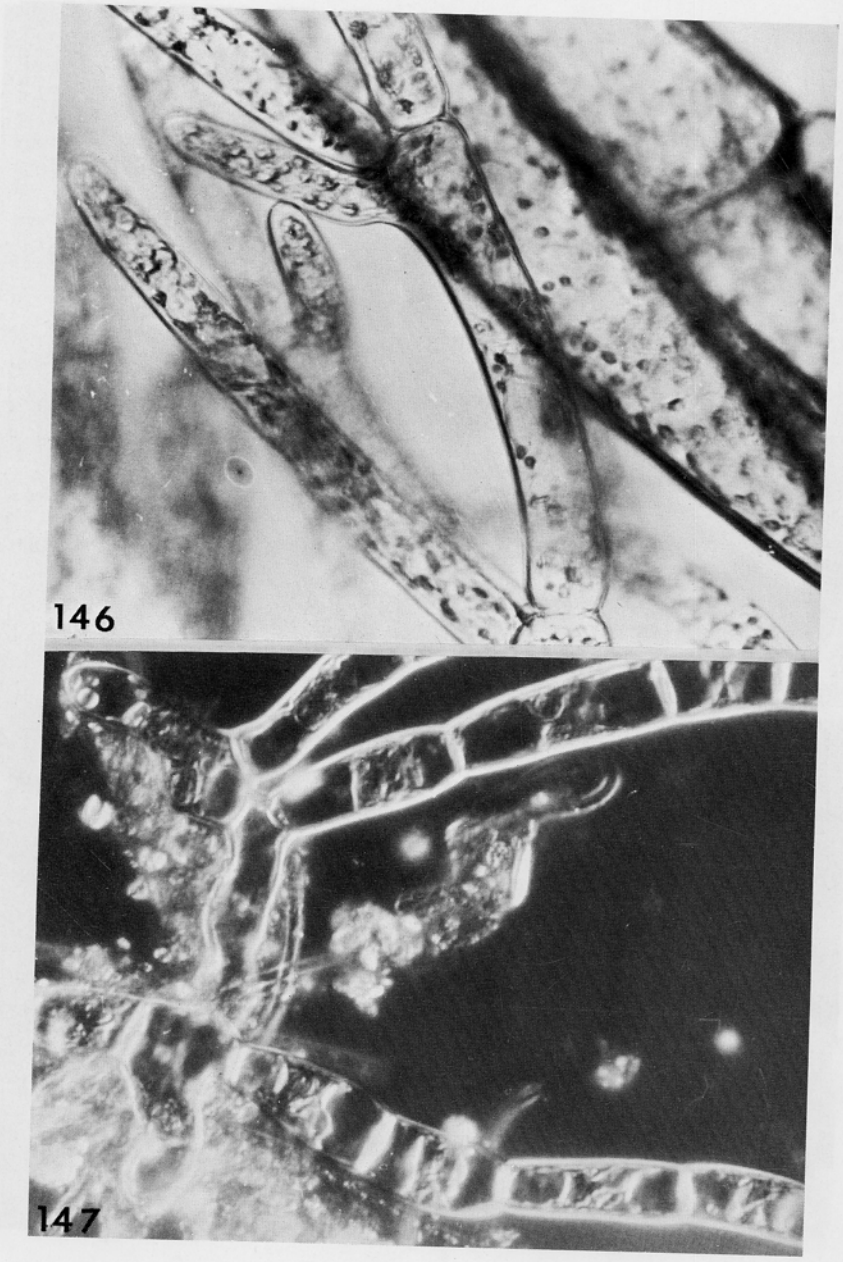

Fig. 146-147. Chlorophyta. Fig. 146. *Cladophora glomerata*. Fig. 147. *Stigeoclonium* species.