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The algae of Two Soil Types

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THE ALGAE OF TWO SOIL TYPES

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CHAPTER I

INTRODUCTION

The purpose of this investigation was to identify and describe the algal flora of two different soil types; a sandy soil, Plot I, and an alkali soil, Plot II.

The soil types are located near Beverly, Washington, in Grant County, approximately 40 miles east of Ellensburg, Washington. Each soil plot sampled was approximately 50 yards by 70 yards.

The loamy sand soil represents a common soil type along the eastern bank of the Columbia River and is an area commonly referred to as "sagebrush country." (See figure 1.)

The plot is about a half mile north of Beverly on the westerly facing slope above the Columbia River in Township 16 N., Range 23 E., Section 27 of the Beverly quadrangle.

The alkali soil is typical of the narrow strip of land in an old river bed that is now partially occupied by the intermittent Crab Creek. The soil plot is characterized by the white alkali patches and the preponderance of one grass,

Figure 1. An easterly view up the hill from the S.E. corner of the plot. The vegetation shown is predominantly Hop sage, Grayia spinosa, and Cheat grass, Bromus tectorum.

Distchilis spicata, saltgrass. (See figure 2.) The alkali plot is located in Township 16 N., Range 23 E., Section 35 (central portion) of the Beverly quadrangle. This station is approximately one mile east of Beverly and is accessible via Lower Crab Creek Road. The plot is about 100 yards south of the road and just above a pond located at the lower end of the alkali area.

Figure 2. A view of the N.E. section of the plot. The white areas are alkali patches. The ubiquitous grass is D. spicata. Lower Crab Creek Road is about 100 yards north of this area.

Lower Grant County, the general location of Beverly, is subject to a variable climate. The annual precipitation in this area is less than eight inches, mainly due to its being in the rain shadow of the Cascade Mountains. There are persistent and often times severe westerly winds in this area. The temperature variation is considerable with an extreme maximum of 113°F and a minimum of -16°F (21:1171).

A review of the published literature of soil algal studies of the State of Washington revealed that no formal studies of this nature had been done. There was only one study in which some soil samples were collected at a volcanic site near Spokane, Washington. These samples, along with many others from western states, were used in investigating the relationship of the algal and lichen floras to the nitrogen content of soils of volcanic and arid range origin. (16:661-663).

There has been a substantial amount of work done on aquatic algae, some of which is summarized by Prescott in his, "A Guide to the Literature on Ecology and the Life Histories of the Algae," (14:167-240). The soil algae, on the other hand, have been neglected evidenced by the relatively few published accounts on soil algae in this country (17:92-128).

One of the earliest soil algal investigators in the United States was Robbins (15:24-36). In his study he examined a limited variety of soils found in Colorado and identified 21 species of terrestrial algae.

Moore and Karrer (12:281-307) listed, in their study of algae at the Missouri Botanical Garden, 31 species living in the soil. Some of the algae were living at a considerable depth in the soil, apparently as saprophytes.

Probably the earliest study on the algae of the desert soils was that of Bonar and Goldsmith (2:324). In this investigation they examined the soils of the southwest, identified, and described a total of 14 genera of terrestrial algae.

Skinner (18:25-28) found that for certain green algae the soil was a satisfactory habitat. He inoculated partially heat-sterilized soils with some green algae and found that the algae increased as much as 500% when grown at room temper--atures in the dark.

From about 1940 to the present, most of the published work on soil algae in the United States has been conducted in the southwest. Booth (3:38-46) lists several blue-greens as dominant algal forms from the soils of old, eroded and abandoned fields. He also investigated, in eroded areas, the soil-stabilizing effectiveness of the soil algal flora.

Drouet (5:145-176) made an extensive study of the Myxophyceae of eastern California and western Nevada. This study was a compiling of data gathered by him and other investigators. Although this study included algae from diverse habitats, there were 25 species of soil algae.

The soil algae of Colorado were investigated by Durrell (6:322-328). He examined 223 different soil samples from throughout Colorado and identified 85 species, 40 genera: 21 genera of Chlorophyta and 17 genera of Cyanophyta. The habitats of the algae included cultivated land (dry and irrigated farm land), grasslands, and forest lands. Durrell made a comparison of his inventory of Colorado terrestrial algae with those of other observers of different countries and concluded that there was great similarity in the algal floras found in the soils. He noted from the knowledge of the size of these organisms, their tenacious hold on life, and the many ways that they have adapted to meet the rigorous environmental demands that it was not surprising to find comparable algal floras over widely separated geographical areas.

Death Valley, with its extremely low annual rainfall and summer ground temperatures often exceeding 130^{o}F, seems quite an adverse habitat for organisms. Yet, in 113 soil samples collected in Death Valley, Durrell (8:2680-273) identified 23 species of algae, 16 of which were blue-greens. An interesting observation was that many of the algae grew under transparent rocks of quartz and calcite. These algae were thus afforded some protection from dessication while receiving sufficient illumination. Many of the blue-greens had gelatinous sheaths which protected them from drying out to a certain extent (7:73-78).

The present study was limited to the following: 1) two different soil types, 2) only the top half-inch to inch of soil was sampled thus restricting the study to the surface algal flora, and 3) the soil algae of a grazed and ungrazed area.

The nature of the investigation was intended to be descriptive with an emphasis on the discovery and identification of the floristic composition of the soil algal flora of the two soil types.

CHAPTER II

PROCEDURES

1. Selection of the soil plots

The alkali soil was located with the aid of soil surveys of Central Washington and biotic indicators. The biotic indicator was saltgrass, *D. spicata*, which grows only in alkali or salty soils. A field test with hydrion paper indicated that the soil had a pH of 10.0.

The sandy soil, common in the area north of Beverly, had a pH of 7.0 when field tested with hydrion paper. This soil differed from the alkali soil in texture and also in that it supported quite a different macrovegetation from that of the alkali soil.

2. Sampling the soil sites

Two plots were staked out in the sandy soil, some distance apart, prior to the sampling. Since the total algal flora was important to the study it was felt that by sampling two comparable, though separate areas, the chances for the determination of the algal flora were greatly improved. In both plots five stations were originally sampled. These stations were determined by walking up the diagonals from each corner 10 to 15 paces and selecting an area four foot square. As each piece of sampling equipment was used, it was flamed with an alcohol lamp as a precaution against contamination. The soil within each subplot was sampled with a spatula, amalgamated in a petri-dish with a glass rod, and then a teaspoon of soil was placed on filter paper in a sterile petri-dish. The fifth sample was taken from the middle of the plot using the same sampling techniques. In the sampling of the second plot, attention was focused on the macrovegetation growing in and near the areas sampled. The results of this will be described fully in Chapter III. The initial sampling of these two plots was done on February 1, 1964. A later more extensive sampling was conducted on only one of the plots because the soil algal flora was found to be similar if not identical in both. The March 27, 1964, collecting included the five original stations and fifteen additional stations associated with the macrovegetation. The final pattern of sampling was a rough grid pattern.

On March 27, 1964, ten samples were collected from the alkali soil plot; four by walking up the diagonals from the corners with the other six being obtained randomly. On May 10, 1964, twenty additional samples were collected on a grid pattern. Each sample was collected within an imaginary grid of 12 yards by 14 yards. The same basic techniques used in the sampling of the sandy soil were employed in sampling the alkali soil.

3. Culturing the soil algae

The moist plate method of Willson and Forest (22:309-313) was adopted for culturing the soil algae. This technique was simply the moistening of the field-collected soil samples with a suitable liquid medium. They found that enriched medium caused more rapid growth than either cistern water or distilled water (22:309-313). The enriched solution, Modified Bristol's (1:623), with a minor element supplement (11:44) was selected.

The samples were cultured in the furnace room of the Science Building for want of a more suitable place. The cultures were flooded whenever they appeared to be drying out. They were illuminated twenty four hours a day under a bank of lights with four fluorescent tubes (Ken Rad 40W Cool White). The mean temperature for the total culturing period was about 27°C with a maximum of 32°C and a minimum of 20°C.

CHAPTER III

RESULTS

1. Description of soil plots

<u>Loamy sand soil--Plot I</u>. A variety of plants inhabit the area. The typical macrovegetation collected and classified consisted of 16 families and 27 species of angiosperms. The predominant vegetation of the area is low shrubs (*Artemisia*, *Purshia*, *Chrysothamnus*, *Grayia*, and *Salvia*) and grasses (*Bromus* and *Agropyron*). For a listing and pictoral discussion of the vegetation of Plot I see Appendix A.

The presence of the plant indicator, *Artemisia tridentata*, denotes a positive farming potentiality of the soil. The only apparent use of the land, however, seems to be grazing. Sheep were noted to have grazed the area early in the Spring of 1964.

Analysis of the soil of Plot I is summarized in Table I, on page 12.

The low conductivity reading of 0.10 reveals that the soil is within the range of normal soils from the standpoint of salinity. The pH of 7.2 is also within the limits of the desirable range for the growth of nearly all plants. The low salinity and pH indicate that this soil is well drained. The organic matter and clay percentage is quite low, typical of well drained desert soil, thus accounting for the low cation exchange capacity. The textural analysis classifies the soil as loamy sand soil (10). The depth of the soil in the plot is in excess of one meter.

Alkali soil--Plot II. The typical macrovegetation of this plot consisted of 6 families and 9 species of flowering plants. See Appendix A. In the alkali area the dominant plant was *D. spicata*, saltgrass, which grew in nearly pure stands over much of the ground surface. There were no living shrubs in the alkali soil. Several common species of the

TABLE I

ANALYSIS OF LOAMY SAND SOIL*																			
STL NO. 64	pH	OM%	Conductivity Mmhos/cm	Cation Exchange Capacity	Cations extracted by Ammonium Acetate				Soluble Cations		Exchangeable Cations				Mechanical Analysis				Textural Class
					Na	K	Ca	Mg	Na	K	Na	K	Sum of Ca	+ Mg	Sand %		Silt %	Clay %	
				Milliequivalents/100 gms Soil															
10912	7.2	0.9	.10	3.5	.07	.54	2.51	.33			.07	.54	2.51	.33	85.6		6.0	8.4	Loamy Sand

*This table is part of the soil analyses conducted by the Washington State University Soil Testing Laboratory at Pullman, Washington.

genus *Erigeron*, a compositae, was the dominant showy plant in the area.

The results of the analysis of the alkali soil is summarized in Table II. The conductivity reading of 12.0 denotes a salty soil, i.e. the soil contains a large amount of soluble salts. Soils this salty will support only a limited few species of plants. A pH of 9.9 indicates an alkaline condition. The percentage of organic matter is quite low but not unusually low for alkali soils. Textural analysis indicates a sandy loam soil. The cation exchange capacity is low due to the low percentage of clay and organic matter in the soil. The analysis also indicates that the soil is poorly drained (10). Whereas much of the surface of the sandy soil was loose, there was a hard crust over much of the alkali soil surface. This crust was due in part to the high concentration of salts which acted as a cementing agent.

TABLE II

ANALYSIS OF ALKALI SOIL

STL NO. 64	pH	OM%	Conductivity Mmhos/cm	Cation Exchange Capacity	Cations extracted by Ammonium Acetate Na	K	Ca	Mg	Soluble Cations Na	K	Exchangeable Cations NA	K	Sum of Ca + Mg	Mechanical Analysis Sand %	Silt %	Clay %	Textural Class
				Milliequivalents/100 gms Soil													
10911	9.9	0.2	12.0	3.5	4.6	1.3	17.6	4.8	3.4	.4	1.2	.9	1.4	55.6	40.0	4.4	Sandy loam

2. Description of the soil algal flora

The algae found growing in the soil samples collected were inconspicuous in the field. In fact, for much of the year there was little if any evidence suggesting the presence of algae. During the late winter and early spring, the moist soils had a green tinge. This color was not due entirely to algae, moss protonemata accounted for much of the coloration.

Table III lists that portion of the soil algal flora that has been identified from both soil types.

TABLE III

ALGAE IDENTIFIED FROM BOTH SOIL TYPES*	Loamy sand	Alkali
CYANOPHYTA		
<u>Anabaena torulosa</u> (Carm.) Lag.	X	X
<u>Anabaena variabilis</u> Kuetz.		X
<u>Borzia trilocularis</u> Cohn	X	
<u>Cylindrospermum lichenforme</u> (Bory) Kuetz	X	
<u>Cylindrospermum muscicola</u> Kuetz.	X	
<u>Lyngbya aestuarii</u> (Vauch.) Lieb.	X	
<u>Lyngbya</u> sp.		X
<u>Microcoleus lacustris</u> (Rab.) Far.		X
<u>Microcoleus vaginatus</u> (Vauch.) Gom. ...	X	X
<u>Nodularia Harveyana</u> (Thw.) Thur.		X
<u>Nodularia spumigena</u> Mert.		X
<u>Nostoc commune</u> Vauch.	X	X
<u>Nostoc ellipsosporum</u> (Desmaz.) Rab. ...	X	
<u>Nostoc humifusum</u> Carm.		X
<u>Nostoc Linckia</u> (Roth) Born. and Thur. .		X
<u>Nostoc muscorum</u> Ag.	X	X
<u>Nostoc sphaericum</u> Vauch.	X	
<u>Oscillatoria formosa</u> Bory..............		X
<u>Phormidium inundatum</u> Kuetz.		X
<u>Scytonema</u> sp.	X	
<u>Synechococcus aeruginosus</u> Naeg.	X	
CHLOROPHYTA		
<u>Chlamydomonas</u> like?	X	
<u>Chlorella vulgaris</u> Beyer.	X	
<u>Chlorococcum humicola</u> (Naeg.) Raben. ..	X	X
<u>Hormidium</u> sp.	X	
<u>Nannochloris</u> sp.	X	
<u>Oedocladium</u> sp.		X
<u>Pamellococcus</u> sp.	X	
<u>Protococcus viridis</u> Ag.	X	X
<u>Ulothrix flaccida</u> Kuetz.	X	
<u>Ulothrix variabilis</u> Kuetz.		X
CHRYSOPHYTA		
<u>Navicula</u> sp. 1	X	
<u>Navicula</u> sp. 2		X
<u>Navicula</u> sp. 3	X	X
<u>Pinnularia</u> sp.	X	

*Algae cultures are part of Central Washington State College collection.

In the loamy sand plot, 23 species of terrestrial algae were identified from 30 soil samples. Of these 23 species: 12 were blue-greens, 8 were greens and 3 were diatoms. No attempt was made to study the algae quantitately; however, it was noted that Nostoc was the most consistently occurring alga in the cultures. Since only the surface was sampled the algae listed refers to the surface algal flora only. In a cursory examination and culturing of sub-surface soil samples the algae identified were species which also occurred on the surface. The surface algal flora was much more luxuriant than that of the subsoil.

In the algal flora of the alkali soil the blue-greens out-number the other algae two to one. From the 30 soil samples collected there were 19 species identified. Of the 19 species there were 13 blue-greens, 4 greens and 2 diatoms. Anabaena variabilis grew in greenish-black expanses in the cultures of the soil from the white alkali patches. This alga was also the dominant in these cultures. It should be remembered, however, that the cultural conditions do not necessarily parallel those found in the field.

Another aspect of the algal flora of the alkali soil was the few species of Chlorophyta identified. Not all of the algae have been identified in the soil, but the paucity of green algal species is significant remembering that in the loamy sand soil there were 8 species of green algae as compared to only 4 species in the alkali soil.

In cultures of both soil types, Nostoc was the dominant alga. The other common algae of the soils were Microcoleus, Anabaena, Phormidium, Lyngbya, Chlorococcum, Protococcus, Navicula and Pinnularia. There were several algae that were found in only one soil and not the other. Scytonema, Cylindrospermum, Synechococcus and Borzia of the blue-greens were represented in only the loamy sand soil. Nodularia and Oedocladium were found only in the alkali soil.

During part of the sampling of the loamy sand soil, samples were collected in association with some of the macro-vegetation. Samples were taken near and under such shrubs as Artemisia, Grayia, Purshia, Chrysothamnus and Salvia; in grassy areas predominantly Bromus and Agropyron; and in balds, areas denuded of vegetation. Table IV summarizes the results of this study.

TABLE IV

COMPARISONS OF ALGAE FOUND IN THE LOAMY SAND SOIL PLOT

Algae Habitats:	1	2	3	4	5
Borzia trilocularis............	X		X		
Chlamydomonas like?............	X				
Chlorococcum humicola	X	X	X	X	X
Hormidium sp.	X		X		X
Microcoleus vaginatus	X		X		X
Navicula sp.	X	X	X	X	X
Nostoc sp.					X
Pamellococcus sp.	X	X	X	X	X
Pinnularia sp.	X	X	X	X	X
Protococcus viridis	X	X	X	X	X
Synechococcus aeruginosus	X		X		X

Plates 1 and 3 were from under and near shrubs.
Plates 2 and 4 were from the open balds.
Plate 5 was from a grassy area.

Similar if not identical algae were found in the grassy and shrubby areas. In the balds, however, very little, if any, algae were found.

CHAPTER IV

DISCUSSION

The decision to select two different soils such as a loamy sand soil and an alkali soil was deliberate. With such a difference in the soils it was hoped that there would be a discernable difference noted in the soil algal flora. The fact that there were several genera and species found only in one soil type and not the other seems to indicate that there might be a difference in the algal floras, just as in the macrofloras of the two soil types. It would be unwise, however, to explicitly say that there was a difference in the soil algal floras, due to the lack of sufficient data and failure to identify all the algae in the soils. Other variables which could influence the floristic composition of the soil algal floras were possibly grazing in the sandy soil plot and the early June flooding of a portion of the alkali soil plot by Crab Creek. The actual effect of the grazing on the algal flora is not known. The partial flooding of the alkali soil plot could account for part of the difference between algal floras by the introduction of new species hardy enough to live in a terrestial habitat as well as an aquatic one. Interesting studies could be conducted around these two variables.

Another factor which might be of significance was that by February there was no snow cover left in the area of the soil plots. Just how typical this occurrence is, is unknown; however, a few miles to the west of this area there were several inches of snow over much of the ground surface.

In comparing the algal flora of both soil plots with the published lists from investigations of xeric southwest soils, an obvious though not surprising similarity is noted. The common genera of the southwest desert soils are common in the arid soils studied near Beverly, Washington. The existence of algal crusts common in the southwest was not noted in the field. In some cultures a crust formed, which when drying, cracked and curled upwards.

The reasons that the balds were relatively devoid of algae, while the grassy and shrubby areas were not, can only be surmised. The surface of the balds appeared gravelly, indicating that the finer particles had been removed. (See Appendix A, Part II.) If a wind of sufficient velocity carried these small soil particles away, as is entirely possible, then the small algal species could have been just as easily removed along with the wind-blown soil surface. Brown, Larson, and Bold (4:583-585) have shown that wind is an agent of dissemination of algae. The algae in the grassy areas and shrubby areas receive some protection, and also since the soil surface is consolidated sufficiently to resist being blown away, the algal species appear more abundant in the soil surface of these areas.

This study indicates that there are no specific algae associated with a specific macrovegetation type as evidenced by the widespread distribution of the algae. The same species of algae were found growing in an area typically covered by *Bromus* as well as *Artemisia*. Since these data are imcomplete, an interesting study would be one in which an attempt was made to elucidate possible biotic relationships between members of the macroflora and the soil algal flora.

CHAPTER V

SUMMARY

In this investigation, a portion of the soil algal flora of an alkali soil and a loamy sand soil located in Grant County near Beverly, Washington, was identified and described. The sandy soil was a common soil north of Beverly, while the alkali soil was represented by a narrow strip of land extending along Crab Creek east of Beverly.

The typical macrovegetation of both soil types was identified. The common macroflora of the loamy sand soil included sixteen families and twenty seven species, whereas the typical macrovegetation of the alkali soil consisted of six families and nine species. The difference in the number and variety of plants between the two soils was due largely to the chemistry of the soils. The alkali soil supported only plants that were tolerant to high alkalinity and salinity. The other soil was nearly neutral, well within the range of most plants, thus accounting for the luxuriant macroflora.

That portion of the soil algal flora identified from both soil types included predominantly representatives of the Cyanophyta. Of the 23 species identified in the loamy sand soil, twelve were blue-greens, eight were greens, and three were diatoms. The nineteen species identified from the alkali soil included thirteen blue-greens, four greens, and two diatoms.

The soil algae identified in this study compared favorably to previous studies of soil algae of comparable areas, namely the xeric southwest part of the United States. The predominant soil algal genera of the southwest desert soils were found to be the dominant algal genera in the arid soils studied in this investigation. This supposts the evidence which suggests that in comparable soils there exists similar algal floras over widely separated geographical areas.

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APPENDIX A

Appendix A is a pictorial discussion of the typical macrovegetation and physiognomy of the loamy and alkali soils. The typical macroflora of both plots was collected, identified and submitted to the herbarium of Central Washington State College. Part I will describe the loamy sand soil area with Part I describing the alkali soil.

PART I

Loamy sand soil. The following table of the common macroflora of the loamy sand soil depicts a variety of plant life.

TABLE V

MACROVEGETATION OF THE LOAMY SAND SOIL PLOT

I. Boraginaceae
   Hackelia hispida
II. Chenopodiaceae
   Grayia spinosa
III. Compositae
   Artemisia tridentata
   Balsamorhiza deltoidea
   Chrysothamnus nauseosus
   Chrysothamnus viscidiflorus
   *Erigeron linearis**
IV. Cruciferae
   Erysimum occidentale

Table V (continued)

V. Gramineae
  Tribe Agrostidea
    Oryzopsis hymenoides
    Stipa comata
  Tribe Festuceae
    Bromus tectorum
    Poa marcida
  Tribe Hordeae
    Agropyron spicatum
    Sitanion sp.
VI. Labiatae
  Salvia dorii var. _cornosa_
VII. Liliaceae
  Allium cusickii
  Brodiaea Douglasii
VIII. Nyctaginaceae
  Abronia mellifera
IX. Onagraceae
  Oenothera pallida
X. Polemoniaceae
  Gilia sinuata
  Phlox longifolia
XI. Polygonaceae
  Eriogonum umbellatum
XII. Ranunculaceae
  Delphinium menziesii
XIII. Rosaceae
  Purshia tridentata
XIV. Santalaceae
  Commandra pallida
XV. Scrophulariaceae
  Penstemon speciosa
XVI. Umbelliferae
  Cymopterus terebinthinus var. _terebinthinus_

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*This plant grew in both soil plots.

Figure 2. Typical shrubby vegetation of Plot I. The gnarled shrub in the lower left corner is *Artemisia tridentata*, sagebrush. The other dominant shrub is *Chrysothamnus*, Rabbit brush.

Figure 3. The dominant shrub in Plot I: Grayia spinosa, Hop sage. The lighter patches behind the shrub are grassy areas predominantly Cheat grass, B. tectorum.

Figure 4. This low shrub is Chrysothamnus, Rabbitbrush. This shrub is commonly called sagebrush -- a misnomer as Artemisia is the true sagebrush.

Figure 5. The low shrub, <u>Eriogonum umbellatum</u>, commonly called sulfur eriogonum is a very showy plant with a yellow cluster type of inflorescence.

Notice the bald, the area devoid of any vegetation. These balds are quite common to the area. Notice also the texture of the soil, almost gravelly. The finer particles have been blown away by the prevalent winds of the area.

PART II

Alkali soil. The alkali soil area supported a sparse plant population. The typical macrovegetation of this area as compared to that growing in the sandy area was poor indeed. The following table summarizes the common macroflora of the alkali soil plot.

TABLE VI

MACROVEGETATION OF THE ALKALI SOIL PLOT

I. Compositae	IV. Juncaeae
Achillae millefolium	*Juncus balticus*
Erigeron compositus	V. Leguminosae
Erigeron linearis	*Astragalus* sp.
Erigeron poliospermus	VI. Malvacae
II. Cruciferae	*Sphaeralcea munroana*
Lepidium perfoliatum	
III. Gramineae	
Tribe Festuceae	
Distichlis spicata	

The following photographs illustrate that this area is characterized by the white alkali patches and the scarcity of vegetational variation. The overall topography is flat with shallow depressions being common. The common grass, *D. spicata* depicted in the pictures was used as a biotic indicator.

Figure 1. The central and western portions of the plot. The dark object in the upper left hand corner is a small pond. The small, low growing plants are _Astragalus_ sp.

Figure 2. A westerly view towards the Columbia River and Saddle Mountain. Notice the flat monotonous topography of the area and the sparsely covered white alkali patches.

Figure 3. The eastern half of the plot looking south towards Sentinel Mountain. The shrubs in the immediate background are dead as there were no living shrubs in the alkali area proper. Crab Creek is situated near the base of the mountain.

Figure 4. A close-up of an alkali patch showing the rhizopodal growth pattern of *D. spicata* in the N.E. corner of the plot.

APPENDIX B

Appendix B is a collection of the descriptions and drawings of the soil algae identified in this investigation. The descriptions are mainly the author's with Tilden (21), Prescott (13) and Geitler (9) being used as references. The drawings were done using a Bausch & Lomb camera lucida. Descriptions and drawings of the diatoms have been excluded.

LIST OF ALGAE IDENTIFIED, DESCRIBED AND DRAWN

PLATE

I. *Microcoleus lacustris* (Rab) Far.

Microcoleus vaginatus (Vauch) Gom.

II. *Phormidium inundatum* Keutz.

Nostoc ellipsosporum (Desmaz.) Raben.

III. *Nodularia Harveyana* Keutz.

Nostoc humifusum Carm.

Nostoc Linckia (Roth) Born. & Thur.

Anabaena variabilis Kuetz.

IV. *Lingbya aestuarii* (Mert.) Lieb.

Cylindrospermum muscicola Keutz.

Anabaena torulosa (Carm.) Lag.

V. *Cylindrospermum lichenforme* (Bory) Kuetz.

Nostoc sphaericum Vauch.

Nostoc commune Vauch.

VI. *Synechococcus aeruginosus* Naeg.

Nostoc muscorum Ag.

Nodualria spumigena Mert.

VII. *Oscillatoria formosa* Bory

Boriza trilocularis Cohn.

Scytonema sp.

Lyngbya sp.

VIII. *Chlorococcum humicola* (Naeg.) Raben.

Chlorella vulgaris Beyer.

Pamellacoccus sp.

Protococcus viridis Ag.

Ulothrix flaccida Kuetz.

IX. *Ulothrix variabilis* Kuetz.

Oedocladium sp.

X. *Hormidium* sp.

Nannochloris sp.

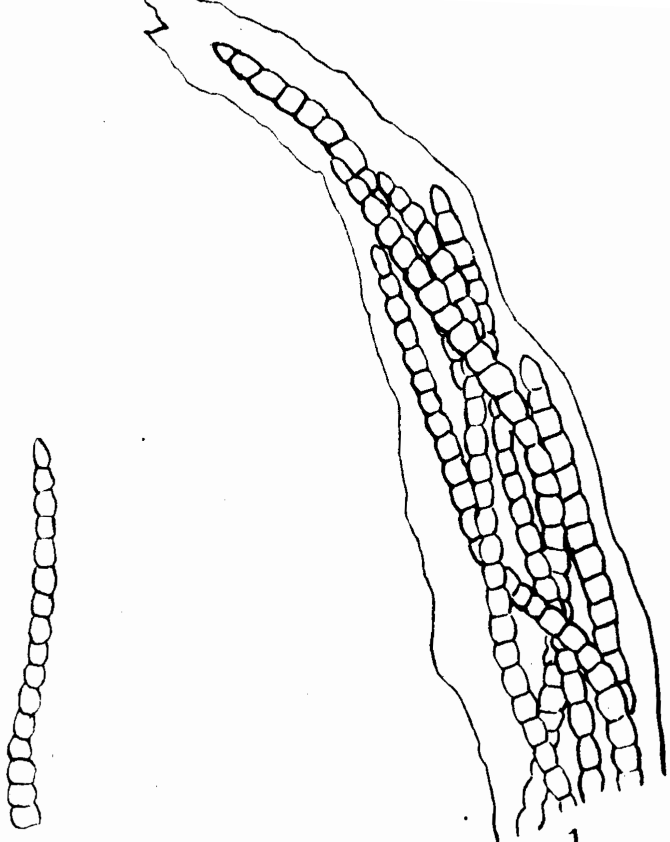
Plate I

1. *Microcoleus lacustris* (Rab.) Far. x645

Plant mass growing on damp alkaline soil. Sheaths colorless, enclosing several to many trichomes. Trichomes constricted at cross walls, cells distinctly cylindrical to barrel-shaped. Cells 4-5 microns wide and 4-8 microns long.

2. *Microcoleus vaginatus* (Vauch) Gom. x645

Many trichomes within a common colorless sheath, suggesting a rope. Trichomes not constricted at cross walls, cells somewhat granular. Cells, 3-5 microns wide; 1/2 to 2 times as long. Apical cell capitate with a calyptra. Plant mass growing in both loamv sand and alkali soil cultures. Trichomes frequently creep out of sheath and appeared as an *Oscillatoria*.



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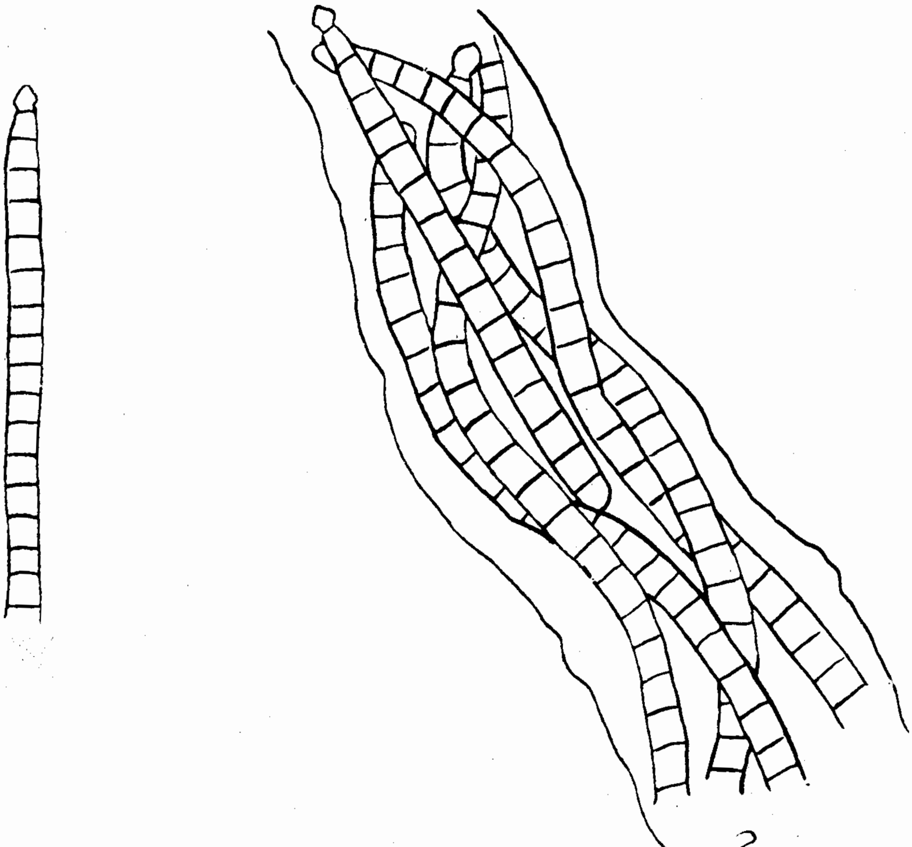

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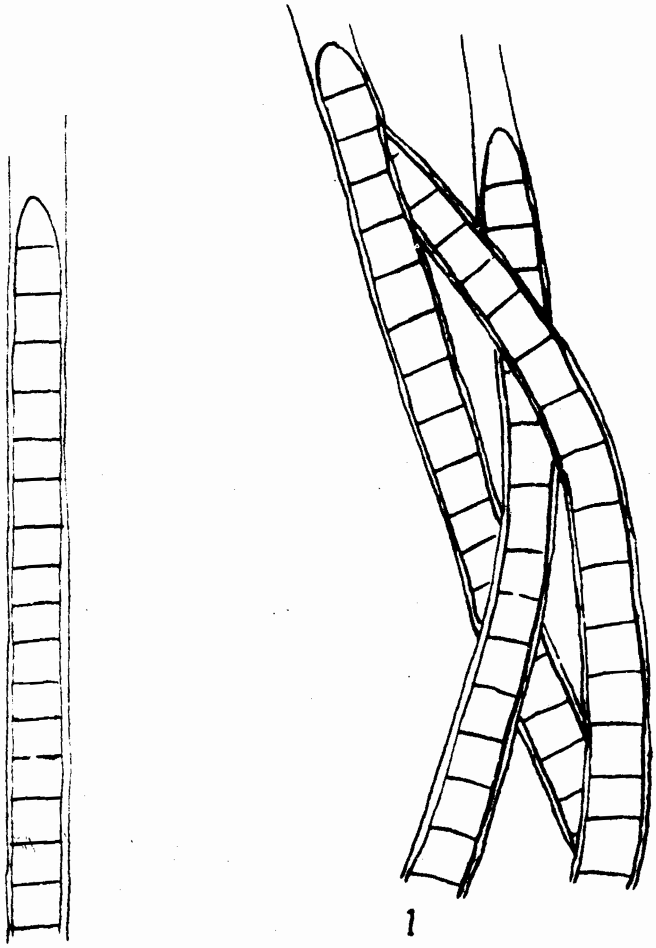
PLATE II

1. <u>Phormidium</u> <u>inundatum</u> Kuetz. x 645

Filaments intermingled with other algae and moss protonemata in alkaline soil. Trichomes enclosed within a thin, scarcely discernable sheath. Trichomes seemingly parallel, though may be bent or contorted. Apices somewhat tapered to form a conical apical cell. Cells squarish; 3-5 microns wide and 4-8 microns long. Trichomes not constricted at the cross walls.

2. <u>Nostoc</u> <u>ellipsosporum</u> (Desmaz.) Raben. x 645

Colony a large (1-2 cm) blackish-green, spherical mass growing among moss plants in sandy soil cultures. The trichomes are loosely entangled within the colony. The cells are 8-10 microns long, 3-4 microns wide and constricted at cross walls. Heterocysts; 6-14 microns long and 6-8 microns wide and appear intercalary. (No akinetes observed from collection--March 27, 1964 to August 7, 1964.)



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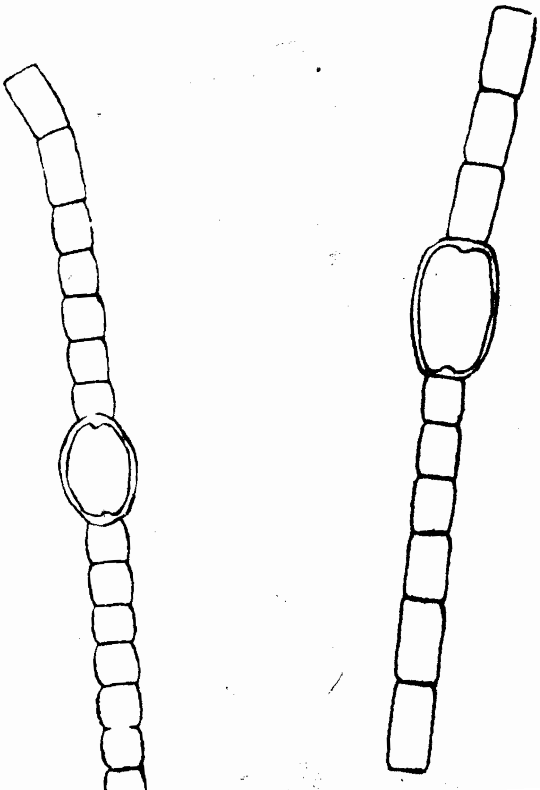


PLATE III

1. Nodularia Harveyana (Thw.) Thur. x 645

Filaments usually solitary, nearly straight, not entangled or coiled. Cells 2-4 microns wide and 2-2.5 microns quite compressed. Apical cells tapered. Heterocysts; 3-5 microns wide and 3-5 microns long, nearly quadrate. Akinetes nearly spherical or slightly compressed, about 6-8 microns in diameter. Alga found growing in alkaline cultures only.

2. Nostoc humifusum Carm. x 645

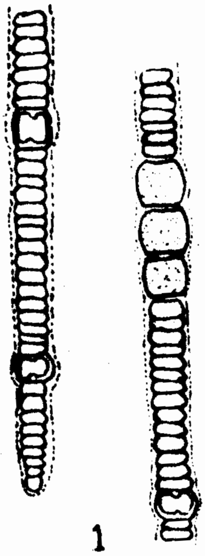
Plant mass mucus like, irregular in shape and variable in size. Colony sometimes an olive or brownish membraneous expanse covering the substrate (alkaline soil cultures). Cells somewhat globose of twice as long as the diameter. Cells 2.2-3 microns wide; 2-4.5 microns long. Trichomes entangled, twisted, and flexuous. Heterocysts 2.5-3 microns in diameter; spherical to oblong. (No akinetes observed.)

3. Nostoc Linckia (Roth) Born. & Thur. x 645

Colonies at first regular, later becoming irregular and tending to spread over substrate (alkaline soil cultures). Trichomes much entangled and twisted. Cells subglobose or barrel-shaped, 3-4.5 microns in diameter. Heterocysts nearly round to ovate; 5-7 microns in diameter. Akinetes rotund, or nearly so, 6-7 microns in width and 7-8 microns long, forming in catenate series.

4. Anabaena variabilis Kuetz. x 645

Plant mass dark to green to blackish flecks covering cultures from white alkali patches. Trichomes seemingly parallel and somewhat flexuous. Cells compressed to barrel-shape; 3.5-6 microns in diameter, 5-6 microns long and slightly constricted at the cross walls. Heterocysts 6 microns in diameter, 8 microns in length spherical to oval. Akinetes numerous in catenate series apparently remote from heterocysts. Akinetes 7-9 microns in diameter and 8-12 microns in length, thick walled.



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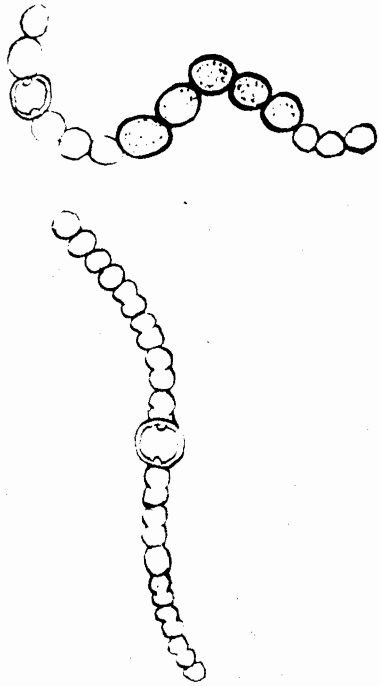

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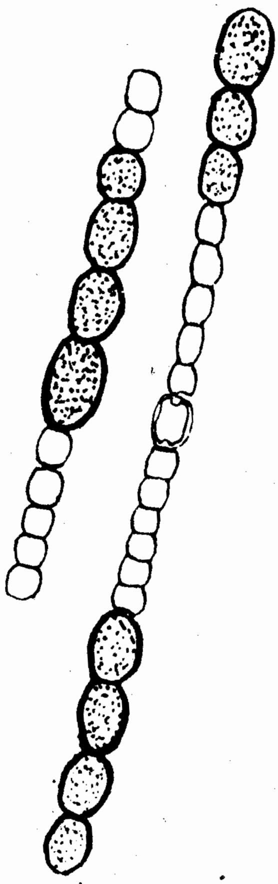

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PLATE IV

1. Lyngbya aestuarii (Mert.) Lieb. x 645

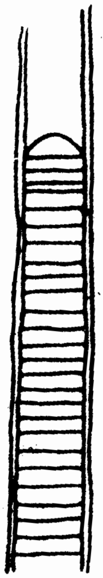
Found growing in sand cultures among moss protonemata. Formed a mat-like mass in association with moss. Trichomes were nearly straight--not coiled--but bent somewhat. Filaments 8-11 microns wide, cells 2-3.5 microns long, not constricted at cross walls. Sheath thick (1-1.5 microns thick), extending beyond trichome. The apices of trichomes slightly tapered; apical cells somewhat conical to truncate.

2. Cylindrospermum muscicola Kuetz. x 645

Plant mass a brownish-greenish membraneous growth covering the sandy substrate in culture. Cells barrel-shaped, 3-4 microns wide and 3-4 microns long. Heterocysts terminal, elongated; 4-4.5 microns wide, 6-8 microns long. Akinetes adjacent to heterocyst. Akinete with very thick wall, orange to brown in color. Akinetes 12-14 microns wide; 22-24 microns long.

3. Anabaena torulosa (Carm.) Lag. x 645

The plant mass a bluish-green gelatinous expanse covering the substrate. The trichomes somewhat straight, parallel in some cases--not coiled. Cells subspherical to barrel-shaped, 4-5 microns wide; 3-6 microns long. Apical cell is acutely conical. Heterocyst somewhat spherical, 4-5 microns in diameter. Akinetes 12-15 microns long, 6-8 microns wide and are typically on either side of the heterocyst. either solitary or in a series.



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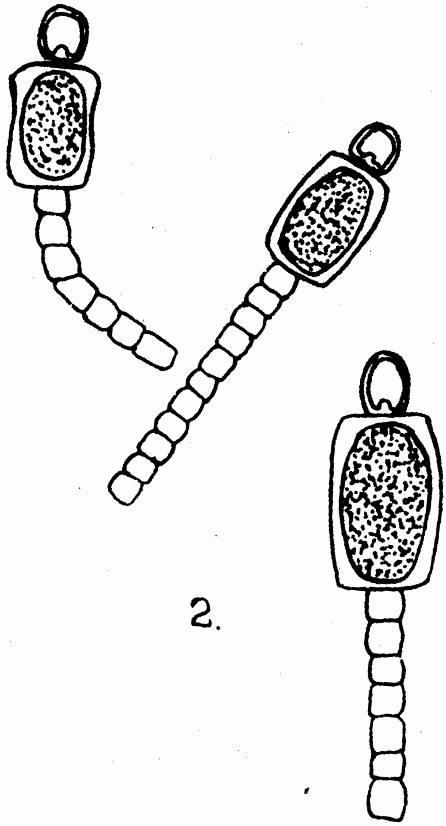

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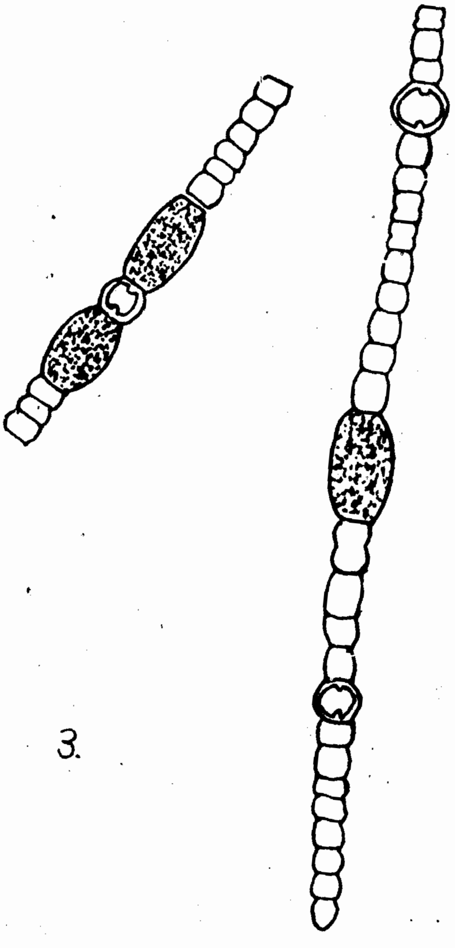

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PLATE V

1. Cylindrospermum lichenforme (Bory) Kuetz. x 645

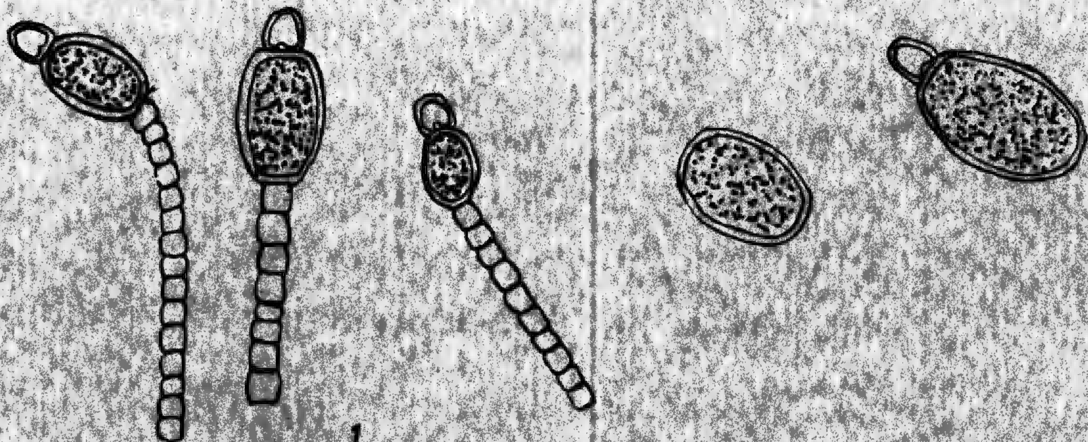
Plant mass found growing in sandy soil culture, a dark green to black amorphous mass spreading over the substrate (sandy soil cultures.) The trichomes entangled. Cells short, cylindric and constricted at cross walls; 3-3.5 microns long. Hetercysts terminal (one end only), somewhat elongate; 4-5 microns wide and 4-7 microns long. Akinete next to terminal heterocyst, 12-18 microns long, 8-12 microns wide. Akinete somewhat elongate to oblong.

2. Nostoc sphaericum Vauch. x 645

Colonies free, spherical and green, 1-3 mm in diameter, growing in sandy soil cultures. Colony surrounded by firm outer layer. Trichomes flexuous, densely entangled, 4-5 microns in diameter. Cells subspherical to barrel-shaped. Heterocysts 5-6 microns in diameter, somewhat spherical. Akinetes oval, 4-5 microns wide and 6-7 microns long.

3. Nostoc commune Vauch. x 645

Plant mass spreading over substrate (both sandy and alkali soil cultures) forming a leathery flattened black or dark green amorphous sheet. Trichomes densely entangled. Trichomes 4-6 microns in diameter, cells subspherical to barrel-shaped. Heterocysts 6-7 microns in diameter somewhat spherical. No akinetes observed.



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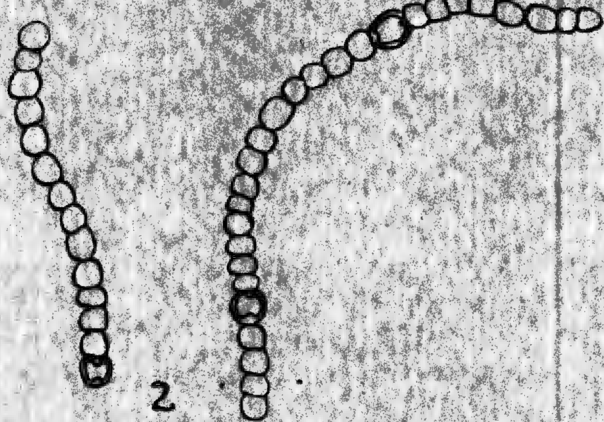

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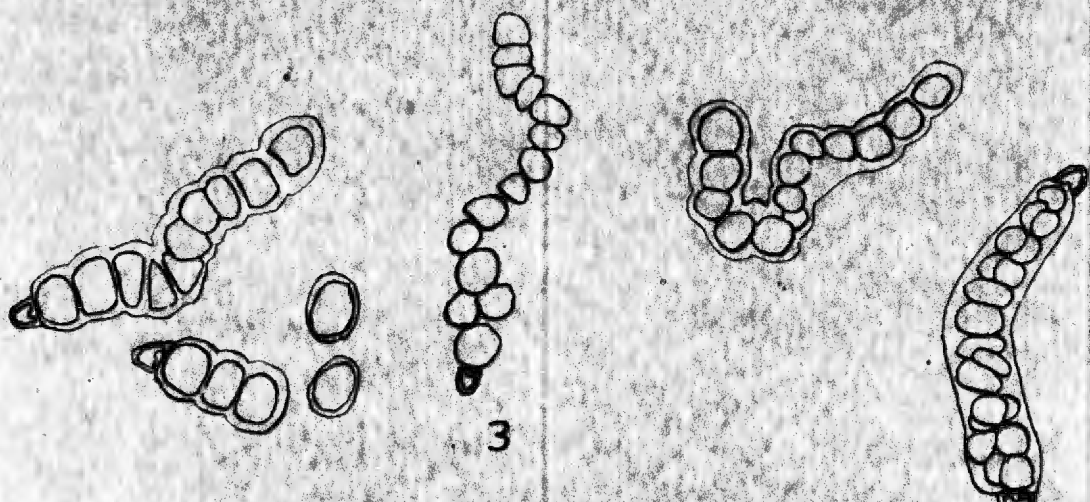

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PLATE VI

1. Synechococcus aeruginosus Naeg. x 645

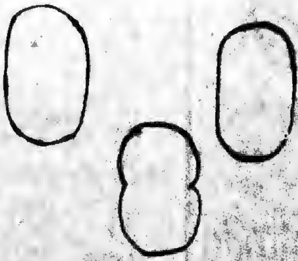
Alga cells in pairs or solitary among sand particles. Never a colony or a discrete plant mass formed in culture. Cells longer than wide, oblong 2 to 3 times their diameter. Cells 7 - 15 microns wide, 14 - 25 microns long, with the ends of the cells rounded.

2. Nostoc muscorum Ag. x 645

Plant mass a brownish, dull dark green, lumpy or tuberculose mass covering the substrate (found in sandy and alkali soil cultures). Trichomes much entangled. Cells variable in shape: some compressed, others nearly cylindrical, barrel-shaped or subglobose. Cells about 3 - 4 microns wide with length varying 5 - 7 microns. Heterocysts globose or slightly compressed 6 - 7 microns in diameter. Akinetes occur in series and are ovate; 8 - 12 microns long and 4 - 8 microns wide.

3. Nodularia spumigena Mert. x 645

Filaments usually entangled in a mass, sometimes solitary. Cells disc-shaped very much compressed and constricted at the cross walls; 6 - 8 microns wide and 3 - 5 microns long. Heterocysts intercalary somewhat compressed, 6 - 8 microns wide and 4 - 6 microns long. Akinetes intercalary though not necessarily near the heterocyst; 10 - 12 microns wide and 8 - 9 microns long.



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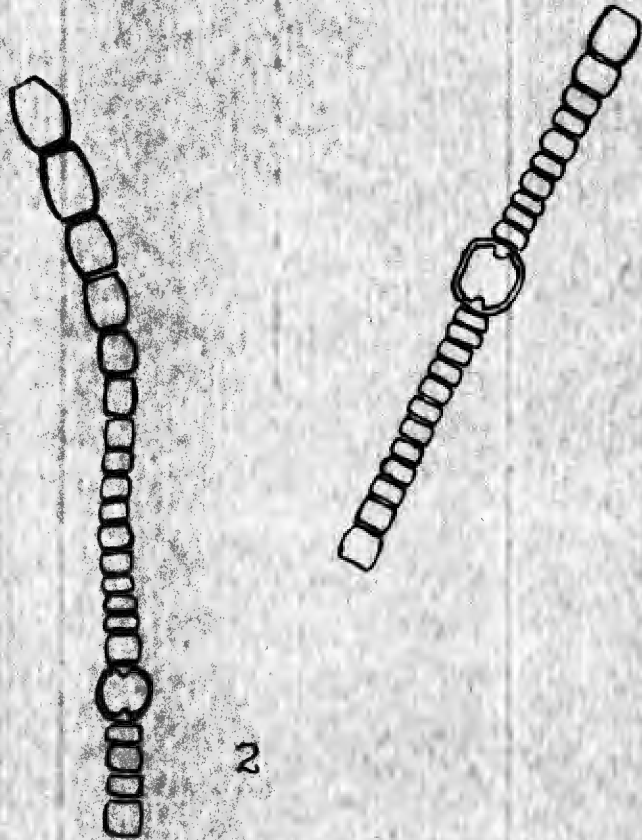

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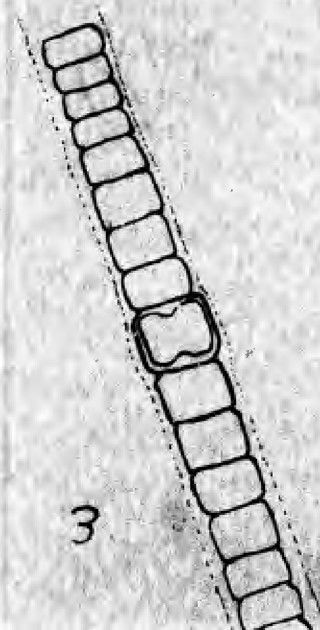

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PLATE VII

1. <u>Oscillatoria formosa</u> Bory x 645

A discrete plant mass was never observed, only individual trichomes were. Trichomes straight, apex bent slightly. Apical cell conical. Cells 4 - 6 microns wide, length 1 - 1 1/2 times width. Trichomes not constricted at cross walls, walls distinctly granulated.

2. <u>Borzia trilocularis</u> Cohn (after Geitler) x 645

Alga never appeared as a colony or as a discrete plant mass, rather as isolated or solitary trichomes. Trichomes typically 3 - 8 cells long. Terminal cells broadly rounded; cells somewhat compressed with slight constrictions at the cross walls. Trichomes a light bluish-green color. This alga was found only in the sandy soil cultures.

3. <u>Scytonema</u> sp. x 645

Alga growing in loamy sand culture only. Filaments sparingly falsely branched. Single trichome enclosed within a brown-colored sheath. Cells constricted at cross walls, barrel-shaped to subglobose; 5 - 8 microns wide and 5 - 7 microns long. Heterocysts appear to be terminal.

4. <u>Lyngbya</u> sp. x 645

Alga growing in alkaline cultures only. Trichomes enclosed within a firm thick sheath. Cells constricted at cross walls. Trichome 1.5 - 2 microns wide; cells longer than wide. Filament up to 3 microns wide.

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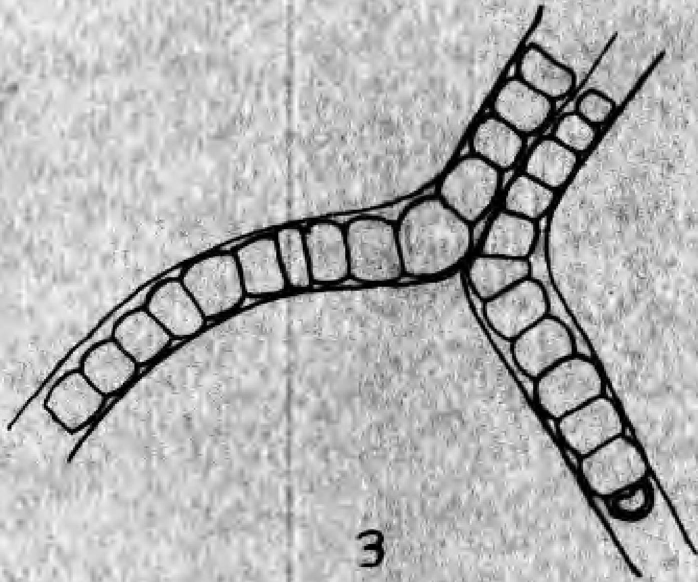

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PLATE VIII

1. Chlorococcum humicola (Naeg.) Raben. x 645

Without a doubt a very ubiquitous soil alga. Found in both types of soil cultures (sandy and alkali soils). Cells spherical, solitary or in small clumps, variable in size. Cells from 8 - 20 microns in diameter. Mature cells contain diffuse chloroplast and several pyrenoides, while young cells contain a parietal chloroplast and one pyrenoid. (Smith).

2. Chlorella vulgaris Beyer. x 645

Cells small and spherical, 5 - 8 microns in diameter. Chloroplast a parietal cup.

3. Pamellacoccus sp. x 645

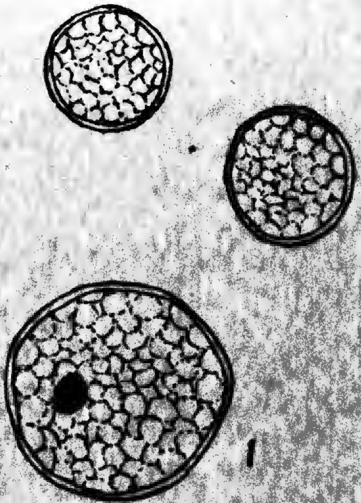
Cells vary from spherical to subelliposoidal and seemingly grow singly. Mature cells usually contain one or more (usually 2 or 3) discoid chloroplasts. Cell size varies as does the shape.

4. Protococcus viridis Ag. x 645

A very common alga, found growing in both types of soil cultures. Cells typically spherical and unicellular but may form an expanse of considerable size on substrate. The cells sometimes are mis-shapen (flattened) due to pressure exerted from within the cell mass. Cells typically 8 - 20 microns in diameter, with a parietal or lobed chloroplast.

5. Ulothrix flaccida Kuetz. x 645

Colony growing in sandy soil cultures. A pale green plant mass. Filaments are densely entangled and fragment easily. Filaments are 6 - 10 microns wide and the length of the cells is 1/2 - 2 times that of the width. Chloroplast appears as a plate or cup-shaped.



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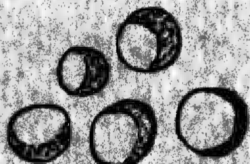

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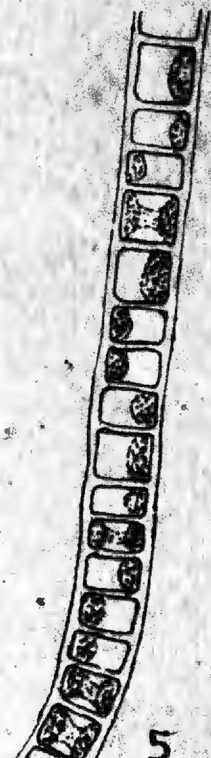

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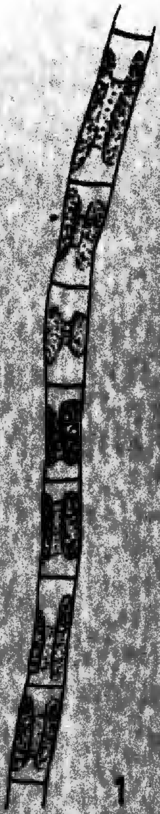
PLATE IX

1. Ulothrix variabilis Kuetz. x 645

Plant mass a light green, found growing in alkali soil cultures among moss protonemata. Filaments long and relatively slender interwoven among moss. Cells not constricted at cross walls. Cells 5 - 7 microns wide, 10 - 14 microns long. Chloroplast a folded parietal plate, 1/2 to 2/3 of the length of the cell.

2. Oedocladium sp. x 645

Alga found growing only in the alkali soil cultures. Colony a greenish mass covering a small area of substrate. Filaments much branched with rhizodal branches. The rhizodal branches are narrow and relatively colorless. Filaments composed of thick short cells. Chloroplast appears to fill cell.



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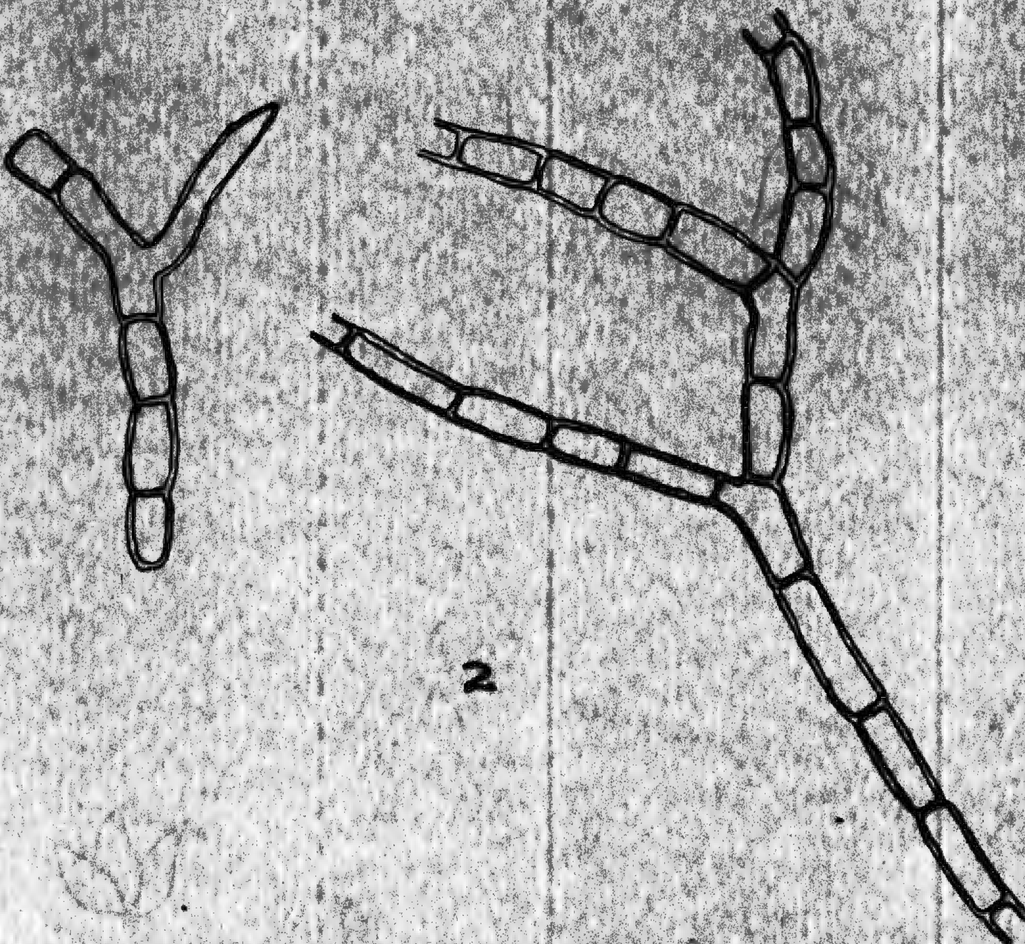

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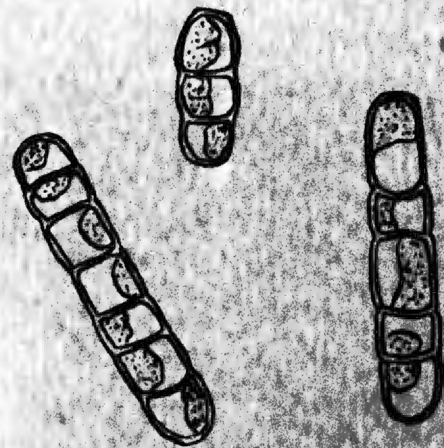
PLATE X

1. Hormidium sp. x 645

Simple unbranched filaments with parietal chloroplast, extending 1/2 or less the distance around the cell. Filaments fragment readily to form Sticchococcus-like sections.

2. Nannochloris sp. x 645

Solitary cells, subspherical to elongate with broadly rounded to squarish ends. Chloroplast located near one end. Reproduction is by transverse division at right angles to the long axis.



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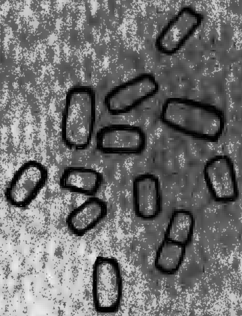

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