SMITHSONIAN MISCELLANEOUS COLLECTIONS
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THE SNOW AND ICE ALGAE OF ALASKA

(WITH 6 PLATES)

BY
ERZSÉBET KOL
Department of General Botany of
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THE SNOW AND ICE ALGAE OF ALASKA[1]

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Department of General Botany of Franz Joseph University, Kolozsvár, Hungary

(With 6 Plates)

INTRODUCTION

Up to the present time little has been known of the microorganisms of the snowfields and icefields of Alaska. The microorganism causing "red snow" was mentioned by Saunders (1901, p. 409) under the name *Sphaerella lacustris* (Girod.) Wittr. as being present in Yukatat Bay and on Muir Glacier, on the snow above Orca, Prince William Sound, and, according to Setchell (1903, p. 203) it is reported under the name *S. nivalis* (Bauer) Sommerf. from Unalaska. This red snow is probably due to organisms of the *Chlamydomonas nivalis* group which cause the red coloring of snowfields the world over.

In the summer of 1936 I was able to study the organisms of the snowfields and icefields in Alaska. As there had been no earlier study in this area, I endeavored to search the snowfields in widely separated mountain ranges for cryoplankton. I carried out researches in the mountain ranges on the coast and also in the interior of the Alaskan peninsula, I collected snow and ice algae on the Alaskan Range, and on the Wrangell Mountains in the interior, on the Chugatch Mountains and on the Coast Range, as shown by the accompanying map (fig. 1). It is most desirable that, at some future time, this research should be continued in the northern part of the Territory, because conditions in Alaska are exceptionally favorable for the growth of organisms in snow and ice, and there is much valuable information to be obtained there by biologists.

The developmental cycle of the snow-inhabiting organisms is not exactly known, nor do we even know what role these organisms play

[1] Owing to the impossibility of communicating with the author because of war conditions, the final revision of the manuscript and the reading of the proof was very kindly done by Prof. William Randolph Taylor, of the Department of Botany, University of Michigan.—Editor.

[2] Holder of the Crusade International Fellowship of the American Association of University Women for the academic year 1935-36. The Alaskan work was conducted under a grant from the Smithsonian Institution, for which the writer is deeply grateful.

in the biological cycle of areas covered by snow or ice, nor yet what higher organisms they may serve as exclusive food. Heretofore it has been necessary to conduct in the field such investigations as were possible, because the organisms could not be cultivated in warm lowland laboratories, and research in the field in areas of permanent snow and ice is handicapped by the difficulties of transporting necessary apparatus. However, a laboratory established at an altitude of 11,382 feet in the Jungfrau Pass, Switzerland, will be very helpful to study of the cryovegetation, and if other laboratories in like situations of extreme environmental conditions can be provided such studies will be made much more profitable.

In order to avoid repetition I append a list of the localities at which cryobiological samples were collected, and shall refer to them by number alone in the systematic portion of this paper.

A. Catalog of Alaskan Collections, 1936, by E. Kol

ALASKAN RANGE

Mount McKinley National Park: Head of the Savage River at an Altitude of About 4,500 Feet, July 21

1. The upper snowfield, snow surface with pH = 6.
2. Another part of the same snowfield, pH = 5.8.
3. A lower snowfield beside a brook, pH = 6.5.
4. Snowfield in the first little valley, surface pH = 6.5, but pH at a depth of 20 cm. = 5.5.

Teklanika Glacier, Teklanika Valley at an Altitude of About 4,500 Feet. July 24

14. From the ice surface, pH = 7.5.
15. From another part of the glacier.
16. From yet another part of the glacier, pH = 5.5.

WRANGELL MOUNTAINS

Kennicott Glacier. July 31

19. From the surface of the glacier, pH = 5.5.
20. From another part of the glacier.
21. From the pure ice.

22–24. From yet other parts of the glacier.

CHUGATCH MOUNTAINS

Worthington Glacier at About 2,070 Feet Altitude. August 2

28. From the ice of the glacier, pH = 5.0.
29. From another part of the glacier.
30. Dust from the same glacier.
31. Mud from the glacier.


MAP OF
ALASKA
Siberia
St. Lawrence I.
Bering Sea
Juneau
Ketchikan

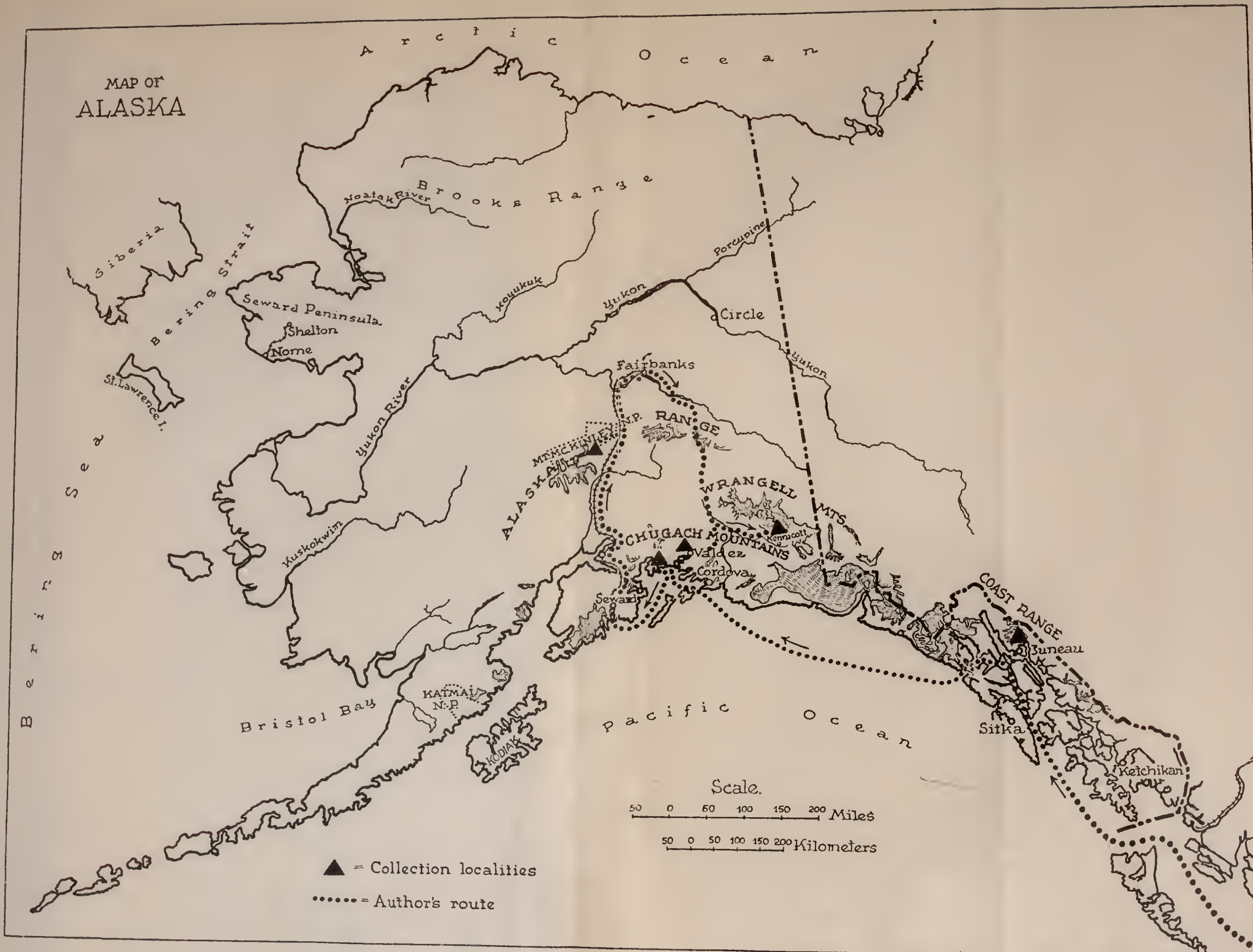

FIG. 1.—Map of Alaska showing author's route.

THOMPSON PASS, AT AN ALTITUDE OF 2,722 FEET. AUGUST 6

35. Red snow, pH = 5.0.
36. Red snow from another little snowfield.
37. From yet another snowfield.
43. Snow from the Pass.
44. From a small snowfield at the side of the Pass.
45. From a neighboring snowfield.
46. From a lower snowfield.
47. From a small neighboring snowfield.
48. From a red snowfield in the Pass, pH = 5.0.

COLUMBIA GLACIER. AUGUST 5

38. From the ice, pH = 5.0.
39. From another part of the glacier.

VALDEZ GLACIER. AUGUST 6

52. From the ice, pH = 5.0.

COAST RANGE

MENDENHALL GLACIER. AUGUST 12

53. From the ice, pH = 5.0.
54. From another part of the glacier.

ROBERTS PEAK, ALTITUDE 3,810 FEET. AUGUST 15

60. From a little snowfield on the ascent to the peak above Juneau, pH = 5.5.
61. From a neighboring snowfield.

GASTINEAU PEAK, ALTITUDE 3,666 FEET. AUGUST 15

62. From a lower snowfield, pH = 5.0.
63. Snow from the side of the peak.
64. Snow fleas from another snowfield, altitude 2,500 feet.
65. Same, preserved in methyl alcohol.
66. Same, preserved in formalin.
67. From another snowfield.

B. Catalog of Alaskan Collections, 1936, by H. J. Liek

MOUNT McKINLEY NATIONAL PARK

MULDROW GLACIER. JULY 22

12. From the ice of the glacier.

TOKLAT GLACIER. SEPTEMBER 4

70, 71. From the ice face.
72. From the ice of the glacier.
73–75. Snow from the glacier.

EAST FORK GLACIER. AUGUST 22

76. From ice of the glacier.
77. From the surface of the glacier.

In the course of these studies part of the research was carried out in Alaska on living material, part was carried out on living material which I brought away with me, and part was based on material preserved in formalin. For 4 years I maintained my cultures of living material, but they were ultimately lost in October 1940 on the removal of the Franz Joseph University to Kolozsvár, so that now only the preserved material remains. This, in small glass tubes in 4 to 5 percent formalin, is in duplicate, one set being in the possession of the Smithsonian Institution in Washington, the other in the department of general botany of the Franz Joseph University in Kolozsvár, Hungary.

I am deeply grateful to the Smithsonian Institution and its Secretary, Dr. C. G. Abbot, for enabling me to carry out my investigations. I am also indebted to Prof. I. Györffy, and to all who have helped with the research. For the collections from glaciers in Mount McKinley National Park, I must thank the Superintendent, Harry J. Liek.

CRYOENVIRONMENTS

The development of phytoplankton of fresh water is influenced by the chemical and physical character of the water, and in the same way the comparable factors in what may be termed the cryoenvironment of snow and ice act as the controlling factors in the development of the vegetation there, which we may call the cryovegetation. As we understand it today, the snow- and ice-inhabiting organisms, the cryobionts, live very close to the surface and so the changes that take place on the surface of the snow and ice fields are those which exert the chief influence on these organisms.

The minute particles falling from decomposing and shattered rock, and the wind-borne dust, dissolve slowly in the moisture more or less continuously present on the surface, which is always rich enough in oxygen. This water then serves as the mineral source for the microorganisms. It thus becomes clear that the vegetation is influenced by the chemical nature of the rocks that form the surrounding mountain slopes. Consequently, snowfields and glaciers lying among mountains composed of acid rocks will have a different vegetation from those which are surrounded by limestone. On the basis of my European experience I have divided the cryoenvironments into silicotroph and calcitroph types (Kol 1933, p. 283).

Changes in the pH of the surface snow and ice influence the composition of the vegetation on its surface, just as does the salt content. Therefore an attempt was made to obtain data to show the extent of the influence of this factor, together with the other observations, during the study of the cryoenvironments of Alaska.

TABLE 1.—*Result of measurements of pH*

(The values in this table are mean results of repeated measurements, which were made with a Hellige comparator.)

	Surface of snow	Surface of ice	At depth of 1 foot	Water	Date 1936
Alaskan Range:					
Mount McKinley National Park					
Head of the Savage River,					
snowfield: a..........	5.8	...	...	...	July 21
b..........	6.0	...	...	...	
c..........	6.5	...	...	...	
d..........	6.0	...	...	...	
e..........	6.5	...	5.5	...	
f..........	5.8	...	...	...	
g..........	6.0	...	5.5	...	
Melted water of the snowfield..	...	...	...	6.5	
Teklanika Glacier	5.5	7.0	...	...	July 24
Water flowing on the surface of the ice	...	...	...	7.0	
Wrangell Mountains:					
Kennicott Glacier: a............	5.5	4.5	...	...	July 31
b............	...	5.0	...	...	
Stream at side of the glacier...	...	...	...	8.0	
Melted water of the glacier....	...	...	...	6.0	
Chugatch Mountains:					
Worthington Glacier	...	5.0	...	...	Aug. 2
Melted water of the glacier....	...	...	...	6.0	
Stream at side of glacier.......	...	...	...	6.0	
Columbia Glacier: a............	...	5.0	...	...	Aug. 5
b............	...	5.0	...	...	
Melted water of the glacier....	...	...	...	5.5	
Glacier stream	...	...	...	7.0	
Thompson Pass, red snowfield: a..................	5.0	...	...	...	Aug. 6
b..................	5.0	...	5.0	...	
c..................	5.2	...	...	...	
Melted water of the snowfield..	...	...	...	6.0	
Valdez Glacier	...	5.0	...	...	
Coast Range:					
Mendenhall Glacier: a..........	...	5.0	...	...	Aug. 12
b..........	...	5.0	...	...	
Melted water of glacier........	...	...	...	5.5	
Glacier stream	...	...	...	7.5	
Roberts Peak, snowfield: a......	4.5	...	...	...	Aug. 15
b......	5.0	...	...	...	
Gastineau Peak, snowfield: a....	5.0	...	...	...	
b....	5.0	...	...	...	
Melted water of snowfields....	...	...	...	5.2	

It can be clearly seen from table 1 that the plants of the Alaska snowfields are mostly of the silicotroph type, which appears as a vegetation of red or pink snow. The pH of the field surface may differ from that found deeper in the mass, where it becomes more acid. When the reaction at the surface is pH 6.5, at a depth of 1 foot it may be 5.5, and to this depth the effect of the solution of mineral particles progressively decreases. Calcitroph snowfields were not met in Alaska, and their characteristic vegetation of green snow seems not to have been reported from America. There were some fields with a pH of 6.5 or 6.0, such as those at the head of the Savage River, but their microvegetation at the time of my visit was very poor. These fields showed only a few specimens of *Raphidonema* and of *Scotiella nivalis;* because of their location and the many rock fragments on their surfaces (pl. 2, fig. 4) they were unsuitable for development of a mass vegetation. The icefields throughout showed a pH of 5.0, except that of the Teklanika Glacier, which gave pH 7.0.

It is also possible to divide the cryoenvironments according to their physical character, and I recognize the following: 1, snow; 2, firn[3]; 3, snow over glacier ice; 4, pure ice. These physical types show differences in cryovegetation.

CLASSIFICATION OF THE CRYOBIONTS

A classification based on the preferred environments is possible; in some cases the choice is exclusive, but in others there is more or less adaptability to various conditions.

1. On the ice, and never found on snow, constituting characteristic ice algae which may be termed glacialis-cryobionts, are for example: *Ancyclonema* sp., and *Mesotaenium Berggrenii.*

2. On the snow and firn, but never on ice, constituting the snow algae or nivalis-cryobionts, are for example: *Raphidonema* spp., *Chlamydomonas nivalis, Scotiella nivalis, Chionaster bicornis.*

3. There may be recognized a group adapted both to snow and to ice, and these may be termed mixo-cryobionts, with *Cylindrocystis Brebissonii, Trochiscia nivalis,* and *T. antarctica* as examples.

4. Microorganisms appear on snow and ice which do not have this as their proper home, being transferred there from their normal location on neighboring damp cliffs. These are not real cryobionts, but may be termed cryoxen. Examples would be: *Gloeocapsa Ralfsiana, G. sanguinea, Stichococcus bacillaris, Phormidium antarcticum.*

[3] The term "firn" is given to the snow above the glaciers, which is partly consolidated by alternate thawing and freezing but has not become glacier ice.

TABLE 2.—*The snow and ice microorganisms of Alaska*

(The numbers in this table refer to the localities where samples were taken. See pp. 2-3.)

Microorganisms	Alaskan Range Mt. McKinley National Park					Wrangell Mts.	Chugatch Mountains				Coast Range							
	Head of the Savage River	Teklanika Glacier	Toklat Glacier	East Fork Glacier	Muldrow Glacier	Kennicott Glacier	Worthington Glacier	Thompson Pass	Valdez Glacier	Columbia Glacier	Mendenhall Glacier	Roberts Peak	Gastineau Peak	Microorganisms of snow	Microorganisms of ice	pH of the cryoenvironments	Occurrence of microorganisms	Type of microorganisms
ALGAE																		
CHLOROPHYCEAE																		
Protococcales																		
Chlamydomonas nivalis Wille	1, 3, 4	14–16	73, 74	77	..	....	..	35, 36, 43, 44, 47, 48	..	....	..	60	62, 63, 64	+	..	4.5–7.0	Very common	Nivalis
Chlamydomonas sanguinea Lagerh.	....	14	....	....	..	....	..	43	..	....	..	..	64	+	..	4.5–6.0	Rare	Nivalis
Smithsonimonas Abbotii Kol.	....	....	73, 74	77	..	....	..	35, 36, 43, 46	..	....	..	..	62	+	..	5.0–5.2	Not rare	Nivalis
Scotiella nivalis (Shuttlew.) F. E. Fritsch	1	....	70–75	76, 77	..	....	..	35, 43, 46, 48	52	....	53	60	62	+	..	4.5–6.5	Very common	Nivalis
Scotiella antarctica F. E. Fritsch	....	....	....	....	..	....	..	43	..	....	..	60	63, 64	+	..	4.5–6.5	Rare	Nivalis
Scotiella polyptera F. E. Fritsch	....	14–16	....	....	..	....	..	43	..	....	..	..	....	+	..	5.0–5.2	Very rare	Cryoxen
Chlorosphaera antarctica F. E. Fritsch	....	....	....	....	..	19	..	....	..	38, 39	..	..	....	+	..	4.5–7.0	Not rare	Glacialis
Mycacanthococcus cellaris f. *antarctica* Wille	....	....	....	....	..	21	29	35, 43	..	....	..	..	64	+	..	4.5–5.5	Not rare	Nivalis
Mycacanthococcus ovalis var. *juneauensis* Kol.	....	....	....	....	..	....	..	....	..	....	..	..	63	+	..	5.0	Very rare	Nivalis
Trochiscia antarctica F. E. Fritsch	....	....	....	....	..	....	..	....	..	38, 39	..	..	....	..	+	5.0	Rare	Mixo-cryobiont
Trochiscia nivalis Lagerh.	....	....	....	....	..	....	..	....	..	38, 38	..	..	....	..	+	5.0	Rare	Mixo-cryobiont
Trochiscia cryophila f. *longispina* Kol.	....	....	....	....	..	....	..	....	..	38, 39	..	..	....	..	+	5.0	Rare	Glacialis
Trochiscia cryophila f. *brevispina* Kol.	....	....	....	....	..	....	..	....	52	38, 39	..	..	....	..	+	5.0	Very rare	Glacialis
Tetraedron valdezii Kol.	....	....	....	....	..	....	..	46, 47	..	....	..	..	63	+	..	5.0–5.2	Very rare	Nivalis
Pleurococcus vulgaris β cohaerens Wittr.	....	....	....	....	..	....	..	35	..	....	..	..	....	+	..	5.0	Very rare	Nivalis
Chaetophorales																		
Raphidonema brevirostre Scherffel	....	....	....	....	..	....	..	35	..	....	..	..	....	+	..	5.0–5.2	Very rare	Nivalis
Raphidonema nivale Lagerh.	....	....	....	....	..	....	..	35, 43, 47	..	....	..	60	....	+	..	4.5–5.2	Not rare	Nivalis
Stichococcus bacillaris Näg.	....	....	....	....	..	....	..	47	..	....	..	..	....	+	..	5.2	Rare	Cryoxen
Zygnematales																		
Ancyclonema Nordenskioldii Berggr.	....	14–16	....	....	..	19–23	28, 29	....	52	38, 39	53, 54	..	....	..	+	4.5–7.0	Very common	Glacialis
Mesotaenium Berggrenii var. *alaskana* Kol.	....	14–16	....	....	12	19, 20	28, 29	....	52	38, 39	53	..	....	..	+	4.5–7.0	Very common	Glacialis
Cylindrocystis Brebissonii f. *cryophila* Kol.	....	14–16	....	....	12	19, 20	28, 29	....	52	38, 39	53, 54	..	....	+	..	4.5–7.0	Common	Mixo-cryobiont
Closterium exile var. *unicrystallatum* Kol.	....	....	....	....	..	....	..	....	..	....	54	..	62	+	+	5.0	Very rare	Mixo-cryobiont
CYANOPHYCEAE																		
Chroococcales																		
Gloeocapsa Ralfsiana (Harv.) Kütz	....	....	....	....	..	....	..	35, 43, 44, 47, 48	..	38, 39	54	60	62, 63	+	+	4.5–5.2	Common	Cryoxen
Gloeocapsa sanguinea (C. Agardh.) Kütz	....	....	....	....	..	....	..	47	..	38	..	..	62	+	+	4.5–5.2	Rare	Cryoxen
Dactylococcopsis alaskana Kol.	....	....	....	....	..	....	..	....	..	....	..	60	....	+	..	4.5	Rare	Nivalis
Hormogonales																		
Oscillatoria tenuis var. *teklanikana* Kol.	....	16	....	....	..	20	..	....	..	....	..	..	....	..	+	5.0–5.2	Very rare	Glacialis
Phormidium antarcticum West	....	14, 16	....	....	..	23	..	....	..	38, 39	..	..	....	..	+	5.0–7.0	Not rare	Cryoxen
Phormidium glaciale West	....	15	....	....	..	....	..	....	..	....	..	..	....	..	+	5.5	Rare	Cryoxen
Lyngbya Martensiana var. *mendenhalliana* Kol.	....	....	....	....	..	....	..	....	..	....	54	..	....	..	+	5.5	Very rare	Glacialis
Lyngbya Lagerheimii var. *Liekii* Kol.	....	15	....	....	..	....	..	....	..	....	..	..	....	..	+	5.5	Very rare	Glacialis
FUNGI																		
Chionaster bicornis Kol.	....	16	....	....	..	....	..	....	..	....	..	60	....	+	..	4.5–5.5	Common	Nivalis
Rhizophidium sphaerocarpum subsp. *cryophilum* Bérczi	....	....	....	....	..	....	..	....	52	38, 30	..	..	....	..	+	5.0	Common	Glacialis

THE CRYOBIOTA OF ALASKA

The variation in the composition of the algal vegetation in the cryoenvironments of Alaska is shown in table 2. From the table it may clearly be seen that some organisms, as *Ancylonema Nordenskioldii* and *Mesotaenium Berggrenii* var. *alaskana*, are exclusively to be found on ice. The former was noted on the interior glaciers of Alaska, such as Teklanika, Worthington, and Kennicott, as well as on the ice of the coastal glaciers, Valdez, Columbia, and Mendenhall, though now only the Columbia actually reaches the sea. These glacial ice sheets are seldom, perhaps never, covered by snow, because the temperature of the sea coast here seldom becomes low enough even in the winter to permit the deposition of snow on the glacier surface only a few feet above sea level. This produces an environment ideal for ice organisms. Rarely does one find a nivalis- or mixo-cryobiont organism among them. Pure ice dominates the aspect of the region. Under favorable circumstances in such an area ice algae give a peculiar color to the surface of the icefield.

In contrast to this, mass vegetation is very rare on the inland glaciers, and their surfaces are often covered with snow. Especially at high elevations glaciers are often exposed to snowfalls, and then nivalis- and glacialis-cryobionts occupy the snow-covered or uncovered pure ice areas, while organisms derived from neighboring cliffs cause a mixed vegetation in some places.

The algal vegetation for each location is given below:

I. Snowfields

Alaskan Range, Mount McKinley National Park:

Head of the Savage River (samples 1-4)

	Occurrence
Chlamydomonas nivalis	Few
Scotiella nivalis	Few

The vegetation here is very scanty. The samples also contain hyphae and spores of fungi, phanerogam pollen, fragments of various plants, and very large quantities of cryoconite (gray dust found on the surface of the ice).

Thompson Pass (red snow, samples 35-37, 43, 48)

	Occurrence
Chlamydomonas nivalis	Very many
C. sanguinea	Many
Smithsonimonas Abbotii	Very many
Scotiella nivalis	Many
S. antarctica	Many
S. polyptera	Isolated
Mycacanthococcus cellaris f. *antarctica*	Few
Tetraedron valdezii	Very few
Pleurococcus vulgaris var. *cohaerens*	Few
Raphidonema brevirostre	Few
R. nivale	Few
Stichococcus bacillaris	Isolated
Gloeocapsa Ralfsiana	Few
G. sanguinea	Isolated

The vegetation, appearing as a red snow bloom, is very rich. In the samples were also frustules of diatoms, hyphae and spores of fungi, phanerogam pollen, and spores of cryptogams, fragments of various plants and large quantities of cryoconite.

Roberts Peak (samples 60, 61)

	Occurrence
Chlamydomonas nivalis	Many
Scotiella nivalis	Many
S. antarctica	Few
Raphidonema nivale	Few
Gloeocapsa Ralfsiana	Few
Dactylococcopsis alaskana	Few
Chionaster bicornis	Very few

The vegetation appears poor. The samples contain also frustules of diatoms, hyphae and spores of fungi, spores of cryptogams and phanerogam pollen, fragments of various plants, and large quantities of cryoconite.

Gastineau Peak (samples 62-67)

	Occurrence
Chlamydomonas nivalis	Many
C. sanguinea	Few
Smithsonimonas Abbotii	Few
Scotiella nivalis	Many
S. antarctica	Few
Mycacanthococcus cellaris f. *antarctica*	Isolated
M. ovalis var. *juneauensis*	Few
Closterium exile var. *unicrystallatum*	Very few
Gloeocapsa Ralfsiana	Few
G. sanguinea	Very few

The vegetation should not be considered as a poor one. There were associated very many nests of *Isotoma,* or snow fleas. In the samples also were frustules of diatoms, spores of fungi, phanerogam pollen, fragments of various plants, and cryoconite.

II. Glaciers

Teklanika Glacier (samples 14-16)

	Occurrence
Chlamydomonas nivalis	Many
C. sanguinea	Few
Chlorosphaera antarctica	Few
Ancyclonema Nordenskioldii	Few
Mesotaenium Berggrenii var. *alaskana*	Few
Cylindrocystis Brebissonii f. *cryophila*	Very few
Oscillatoria tenuis var. *teklanikana*	Few
Phormidium antarcticum	Few
P. glaciale	Few
Lyngbya Lagerheimii var. *Liekii*	Few
Chionaster bicornis	Few

The vegetation is not a rich one. The samples in addition contained the frustules of diatoms, spores of fungi, phanerogam pollen, fragments of various plants, and much cryoconite.

Toklat Glacier (samples 70-75)

	Occurrence
Chlamydomonas nivalis	Few
Smithsonimonas Abbotii	Few
Scotiella nivalis	Many

The vegetation is very poor. The samples contained spores of fungi, the leaves of mosses, fragments of higher plants, and cryoconite in very large quantities.

East Fork Glacier (samples 76, 77)

	Occurrence
Chlamydomonas nivalis	Few
Smithsonimonas Abbotii	Very few
Scotiella nivalis	Many

The vegetation is very poor. The samples also contained spores of fungi, fragments of various plants, and cryoconite in very large quantities.

Muldrow Glacier (sample 12)

	Occurrence
Mesotaenium Berggrenii var. *alaskana*	Few
Cylindrocystis Brebissonii f. *cryophila*	Very few

The vegetation is very poor. The samples also contain fragments of different plants and very large quantities of cryoconite.

Kennicott Glacier (samples 19-24)

	Occurrence
Chlorosphaera antarctica	Few
Mycacanthococcus cellaris f. *antarctica*	Very few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few
Oscillatoria tenuis var. *teklanikana*	Very few
Phormidium antarcticum	Few

The vegetation is rich. The samples also contained frustules of diatoms, spores of fungi, phanerogam pollen, fragments of various plants, and cryoconite.

Worthington Glacier (samples 28-31)

	Occurrence
Mycacanthococcus cellaris f. *antarctica*	Very few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few

The vegetation was a rich one. The samples also contained spores of fungi, phanerogam pollen, plant fragments, and much cryoconite.

Valdez Glacier (sample 52)

	Occurrence
Scotiella nivalis	Few
Trochiscia cryophila f. *brevispina*	Very few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few
Rhizophidium sphaerocarpum subsp. *cryophilum*	Isolated

The vegetation is a rich one. The samples also contained phanerogam pollen, plant fragments, and much cryoconite.

Columbia Glacier (ice bloom, samples 38, 39)

	Occurrence
Chlorosphaera antarctica	Many
Trochiscia antarctica	Very few
T. nivalis	Very few
T. cryophila f. *longispina*	Very few
T. cryophila f. *brevispina*	Very few
Ancyclonema Nordenskioldii	Very many
Mesotaenium Berggrenii var. *alaskana*	Very many
Cylindrocystis Brebissonii f. *cryophila*	Few
Gloeocapsa Ralfsiana	Few
G. sanguinea	Very few
Phormidium antarcticum	Few
Rhizophidium sphaerocarpum subsp. *cryophilum*	Few

The vegetation is a very rich one, forming an ice bloom. The samples also contained phanerogam pollen, plant fragments, and cryoconite.

Mendenhall Glacier (samples 53, 54)

	Occurrence
Scotiella nivalis	Few
Ancyclonema Nordenskioldii	Many
Mesotaenium Berggrenii var. *alaskana*	Many
Cylindrocystis Brebissonii f. *cryophila*	Few
Closterium exile var. *unicrystallatum*	Isolated
Gloeocapsa Ralfsiana	Few
Lyngbya Martensiana var. *mendenhalliana*	Few

The vegetation was a rich one. The samples also contained frustules of diatoms, fragments of various plants, and cryoconite.

On nearly every glacier one may find *Ancyclonema Nordenskioldii, Mesotaenium Berggrenii,* var. *alaskana,* and *Cylindrocystis Brebissonii* f. *cryophila,* while *Chlamydomonas nivalis* and *Scotiella nivalis* appear on nearly every snowfield. The presence of the different microorganisms depends on the environmental factors, and their optimal development upon the dominating factors in the cryoenvironment, but transportation of the spores by wind is necessary to the establishment of these plants (Pettersson 1940, p. 73).

Table 2 also shows that the cryobionts find the requisite pH for development between pH 4.5 and 7.0. The cryobionts of ice of the silicotroph snowfields require approximately pH 5.0. It is to be recognized from the above list that both in variety of species and in mass the vegetation of the snowfields of Thompson Pass and the ice vegetation of the Columbia Glacier were the richest in their respective categories The Alaskan specimens comprise 13 nivalis-cryobionts, 9 glacialis-cryobionts, 4 mixo-cryobionts, and 5 cryoxen.

RED SNOW

On August 5 there were snowfields lying on the inner side of Thompson Pass upon which, almost without exception, red snow was clearly to be seen from the highroad. The color was deepest where the snow spread over the rubble-covered incline along the road at the top of the Pass. As is generally the case with red snow, it appeared in spots scattered over the surface. The red color was centered about a point in the middle of the bright-colored snowfield in the Pass, with the coloration progressively paler farther from the center. Likewise the depth of penetration varied from about 2 feet in the central area to the marginal spots, where only the surface was colored. This distribution showed resemblance to the spread of an organism in culture from the point of inoculation. Probably the central point here also represented the original point of colonization, from which the organism spread. In most cases the spores of these microorganisms are scattered by wind (Pettersson, 1940, p. 1 ff.), and this easily explains how such a macroculture could appear on the surface of a snowfield. The shade of red on Thompson Pass resembled a sprinkling of red pepper, rather than the light raspberry red of other snowfields, and probably is due to the fact that *Chlamydomonas nivalis, C. sanguinea,* and *Gloeocapsa Ralfsiana* join in causing the color, together with *Smithsonimonas Abbotii* and three species of *Scotiella,* their orange-red and yellow color contributing to alter the shade. A similar society of algae forming red snow has not been found elsewhere. It can be said that from the point of view of quantity and of variety, the cryovegetation of Thompson Pass is the richest observed in Alaska. I found 14 kinds of algae on these fields, 10 nivalis-cryobionts and 4 cryoxens, with hardly any glacialis-cryobionts among them.

SNOW FLEAS

Another very interesting phenomenon of the Alaskan snowfields, not part of the vegetation, but nevertheless frequent in the cryo-environment, is the occurrence of colonies of snow fleas of the genus *Isotoma* (Collembola). On September 5 I noticed on a small snow-field at an altitude of 3,000 feet on the side of Gastineau Peak above Juneau a bluish-gray (steel-gray) spot on the dirty surface of the

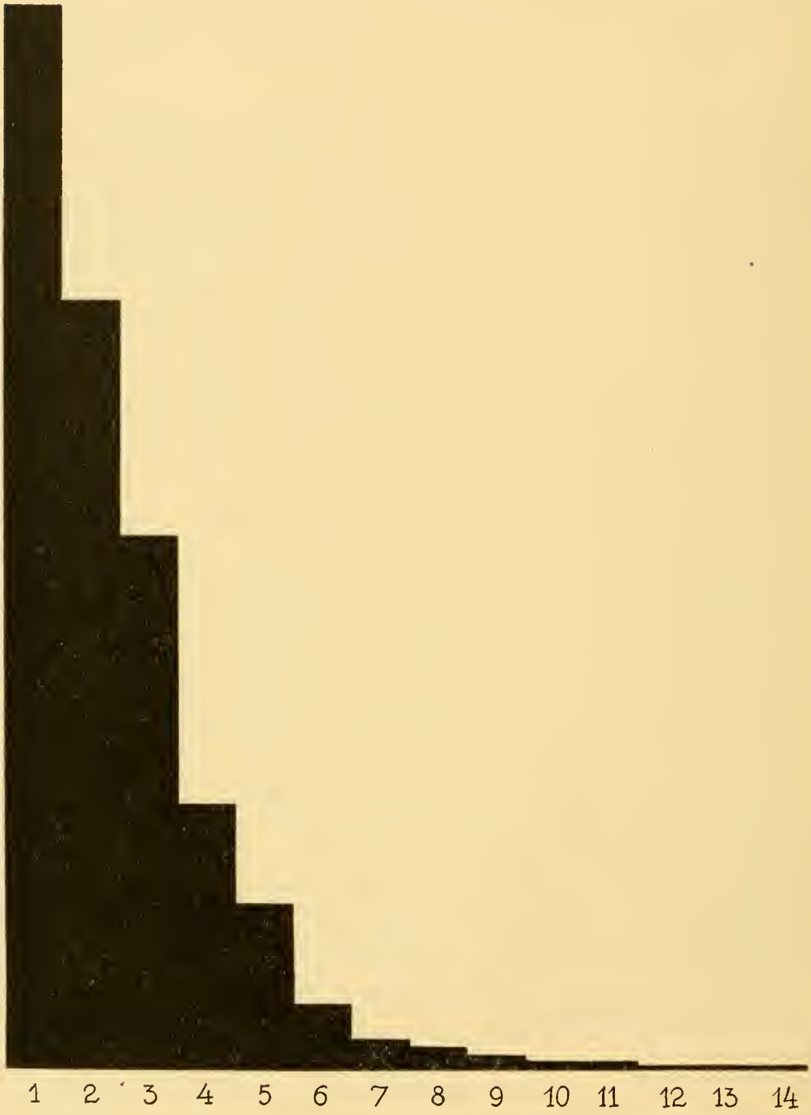

FIG. 2.—The quantitative relations of the microorganisms of the red snow on Thompson Pass. 1, *Chlamydomonas nivalis;* 2, *Smithsonomonas Abbotii;* 3, *Scotiella nivalis;* 4, *Chlamydomonas sanguinea;* 5, *Gloeocapsa Ralfsiana;* 6, *Scotiella antarctica;* 7, *Pleurococcus vulgaris β cohaerens;* 8, *Raphidonema nivale;* 9, *Mycacanthococcus;* 10, *Tetraedron valdezii;* 11, *Raphidonema brevirostre;* 12, *Gloeocapsa sanguinea;* 13, *Scotiella polyptera;* 14, *Stichococcus bacillaris.*

FIG. 3.—The quantitative relations of the microorganisms of the ice bloom of Columbia Glacier. 1, *Ancyclonema Nordenskioldii;* 2, *Mesotaenium Berggrenii* var. *alaskana;* 3, *Chlorosphaera antarctica;* 4, *Cylindrocystis Brebissonii* form *cryophila;* 5, *Gloeocapsa Ralfsiana;* 6, *Phormidium antarcticum;* 7, *Trochiscia antarctica;* 8, *Trochiscia cryophila* form *longispina* and form *brevispina;* 9, *Trochiscia nivalis;* 10, *Gloeocapsa sanguinea;* 11, *Rhizophidium sphaerocarpum* subsp. *cryophilym.*

snow which proved to be a nest of these. The thin covering of snow here was full of many thousands of lively *Isotoma.* According to the work of Wailes (1935, p. 1) snow fleas are frequent on the Canadian snowfields, and they are known in Europe as well.

ICE BLOOM

On August 5 I succeeded in reaching the Columbia Glacier by means of a little motorboat. This is one of the most active glaciers in Alaska and is also one of the greatest on the coast. It is located at about long. 174° W., lat. 61° N., in the vicinity of Valdez. Descending into Columbia Bay, it forms an ice wall 150 to 250 feet high, is about 25 miles long and 3 to 4 miles wide. I approached the glacier from the east side and collected cryoorganisms from the ice surface at about 1 mile from the ocean. The surface of the ice was not covered by snow at this place, as it usually is at higher altitudes where there are frequent snowfalls. By several measurements the ice was found to have a pH of 0.5. For many miles it showed an ice bloom, characterized by *Ancylonema Nordenskioldii* and *Mesotaenium Berggrenii* var. *alaskana.* The greatest mass of vegetation was on the Columbia Glacier. On the Mendenhall Glacier there was a much smaller quantity causing a pale bloom.

In these places *Ancylonema* forms long filaments in bunches 1 to 2 mm. in diameter on the ice surface. These are sometimes close together, sometimes a few centimeters apart. The ice bloom is rare in the interior of Alaska but more frequent on the coast glaciers. We can find little about this phenomenon in the literature, but this means, not that it is rare, but that few scientists have visited its habitats, chiefly in the Arctic regions. So far as I know only A. E. Nordenskiöld and S. Berggren have seen it, on the Greenland ice in July 1870 (Wittrock 1883, p. 65 ff). The color of the bloom on the Columbia Glacier ice was purple brown from a moderate distance (pl. 1, fig. 4). When observed closely, the bundles of algal filaments could be seen (pl. 1, figs. 3, 5), spread irregularly over the ice surface, clearly visible to the unaided eye. The chief mass was due to *Ancylonema,* but *Mesotaenium* was also abundant. The filaments of *Ancylonema* (pl. 1, figs. 3, 5) are seen to be found on the sides or bottoms of little hollows formed by the melting of the ice, the bundles occupying slight depressions. On the bottom of the depressions was also a fine dust, cryoconite (called Kryokonite by Nordenskiöld), much of which was found with the microorganisms on the glaciers.

ANNOTATED SYSTEMATIC LIST

ALGAE

CHLOROPHYCEAE

PROTOCOCCALES

CHLAMYDOMONAS NIVALIS Wille

Plate 6, Figures 42-50

Bright red spherical cells 20 μ diam. I found a great many smaller cells 7–18 μ diam., some of them with a mucilaginous envelope (pl. 6, figs. 42, 45). In sample No. 63 I found vegetative cells, several of which were 18 μ long and 11 μ diam, and which had lost their flagella. In samples Nos. 36 and 43 I saw aplanospore formation (pl. 6, fig. 47), the spore 7 μ diam. in a cell 22 μ diam. (pl. 6, figs. 46, 48). The diameter of the spherical zygospore is 24 μ (pl. 6, fig. 44), and the wall shows a netlike ornamentation. In formalin-preserved material the wall was orange red (pl. 6, fig. 49), and the inner wall layer of the zygospore was similarly colored. In these cases the orange-red color of the wall is probably caused by extraction of the color from the cell interior and subsequent staining of the wall during preservation, a phenomenon which I have noticed in nearly every case in which a red organism has been preserved in formalin. I am not describing the cell structure in detail, as it accords with the well-known published descriptions.

Today the name *Chlamydomonas nivalis* is used in a collective sense, and probably covers several different kinds of *Chlamydomonas*, each of which is a facultative cryobiont and may produce carotin and xanthophyll. While at the present there appears no possibility of distinguishing these "species" of *Chlamydomonas*, discovery of a method of keeping them in pure culture would open the path to a solution of the problem.

This typical snow alga is to be found on nearly every Alaskan snowfield.

Distribution in samples: 1, 3, 4, very rare; 14, 15, 16, not rare; 35, 36, 43-48, abundant; 60, 62, 63, 64, not rare; 73, 74, rare; 77, very rare.

CHLAMYDOMONAS SANGUINEA Lagerh.

Plate 6, Figures 54-61

Large spherical or oval blood-red cells, 50–52 μ long, 36–40 μ diam., sometimes with a thick mucilaginous envelope (pl. 6, fig. 59), and with one large pyrenoid in the chromatophore. Only motionless vegetative cells were seen, and they were mostly 40–42 μ long, 22–33 μ diam., with a wall of several layers, rough on the surface (pl. 6, figs. 57, 58, 61).

This organism is differentiated from *C. nivalis* by its greater size, dark blood-red color, and the proportions of its shape. It was first described by G. Lagerheim (1892) from the red snow of Pichincha; it is a nivalis-cryobiont. The orange-red color of the cell wall of the preserved material shows in plate 6, figures 55, 57, 58, 61. Since I did not see the motile form and since the Alaskan cells are larger than the type this form could not be identified in all respects with that from Pichincha, but I am satisfied that it is the same species.

Distribution in samples: 14, rare; 43, not rare, 60, 62-64, common.

SMITHSONIMONAS, gen. nov.

Chlamydomonadearum; proximum adest ad genus Lobomonadis. Denominavi ad honorem fundatoris instituti "Smithsonian Institution," Washington. Species unicum:

SMITHSONIMONAS ABBOTII, sp. nov.

Plate 6, Figures 2-21

Diameter solum cellulae 9–12 μ, longitudo tegumenti 16–21 μ et latitudo ejusdem 14–21 μ. Tegumento lateribus aut parallelis, aut adversa diverentibus; in parte superiore aut acuto, aut camerato denique aut undulato. Tegumento in superiore visu optico cyclico, superficie tegumenti, in stadio iuvenili levi; sero in aetate vetusta cum verrucis regulariter obtecta. Vegetativis cellulis semper solitariis et globosis, cum integumentis amplis campanulaeformibus obtectis; Chromatophoro globoso-cavo, vel campanulaeformi, pyrenoide centrali, stigmate globoso, nucleoque medio cellulae in positione aliquando posteriore iacente; flagellis binis antice positis, longitudine cellulae aequantibus; amylis multis; vacuolis binis. Propagatio: cum autosporis, 2–4 ibus intra vegetativam cellulam ortis. Hab. in North America in nivibus Alaskae.

Denominavi ad honorem viri illustrissimi ac clarissimi Domini Doctoris Charles G. Abbot, secretarii instituti Smithsonian, Washington, D. C., U. S. A.

Cells spherical, 9–12 μ diam., in a bell-shaped envelope 16–21 μ long, 14–21 μ diam., convex anteriorly, circular in cross section. I found several variants of the general bell-shaped form. In one we saw a shoulderlike elevation at the forward edge as in *Pteromonas protracta* (pl. 6, fig. 11). In another the usual convex front extended wedge-shaped toward the point of issue of the flagella (pl. 6, figs. 4-6, 10). The two sides of the bell-shaped form are sometimes nearly parallel, sometimes diverge considerably (pl. 6, figs. 10, 11), with many transitional individuals (pl. 6, figs. 4, 7, 9). The chromatophore is pot- or bell-shaped, with starch and a large pyrenoid in the central part. The circular stigma is placed a little behind the center of the cell; the nucleus is central. The flagella issue from the anterior end, and equal the body of the cell in length. There are two vacuoles. The envelope about the cell is smooth when young, progressively more warty when older (pl. 6, figs. 8, 12, 17-21). When this envelope thickens, the cell discharges its flagella and a resting condition sets in with an oval cell and radial ornamentation. While this occurs on the envelope, the inner cell wall becomes thinner. The protoplast becomes nearly quadrangular (pl. 6, figs. 8, 20), without any firm wall surrounding it, but connected with the envelope by thin strands of protoplasm. In spite of the changes in the cell contents the pyrenoid can be seen in some instances.

I observed autospore formation in sample No. 36 (pl. 6, fig. 4). The spherical autospores were within an envelope 16 μ long, 15 μ diam., and themselves are 6.5–8 μ diam. In the same sample there were numerous spherical cells 8–12 μ diam., which had escaped from their envelopes by the gelatinous anterior portion (pl. 6, fig. 4). The cell wall and envelope are colorless. An interesting case of aplanospore formation appeared in sample No. 35 (pl. 6, fig. 16). A spore 15 μ long and 12 μ diam. was visible in the envelope (22 μ long, 21 μ diam.). I found propagation by autospores only. Variation in the form of the organism can be seen in plate 6, figures 2-11; lacking living material for a critical analysis of the population I am classing them as variations of one species. The systematic position of this microorganism is near *Lobomonas* in the suborder Chlamydomonadeae. It differs considerably from that genus, and so I am describing it as new under the name *Smithsonimonas* after James Smithson, founder of the Smithsonian Institution in Washington. As a token of my gratitude for his help, I am naming the species after Charles G. Abbot, Secretary of the Smithsonian Institution.

This microorganism is a principal component of the red snow on Thompson Pass. It is a typical nivalis-cryobiont unknown elsewhere.

Distribution in samples: 35, 36, 43, very abundant; 62, rare; 73, 74, 77, very rare.

SCOTIELLA NIVALIS (Shuttlew.) F. E. Fritsch

Plate 6, Figures 62-74

Cells 10–12 μ diam., 18–20 μ long. Form various; generally in young cells the ribs absent or only beginning to develop (pl. 6, figs. 64-72). Autospores numerous, spherical (pl. 6, figs. 64, 65). Liberation of the autospores was also seen (pl. 6, figs. 62, 63).

This appears to be the first microorganism to settle on the snowfields, and is one of the most common organisms on these fields in Alaska. It is a nivalis-cryobiont appearing frequently over the whole world.

Distribution in samples: 35, 43, 46, 48, common; 1, rare; 52, 53, very rare; 60, 62, 63, common; 70-75, not rare, 76, 77, rare.

SCOTIELLA ANTARCTICA F. E. Fritsch

Plate 6, Figures 35-41

Cells 21 μ diam., 27 μ long, usually with six ribs. Sample No. 60 showed a specimen with seven ribs (pl. 6, fig. 37). In sample No. 60 I found an autosporangium 30–33 μ diam., 50 μ long (pl. 6, figs. 35, 36). In sample No. 63 cells were found with smooth walls, 50–57 μ diam., and spherical cells were found as a variant of this organism.

This alga was first described by Fritsch (1912, p. 125) from the yellow snow of the Antarctic. It is a nivalis-cryobiont known from the Western Hemisphere.

Distribution in samples: 43, rare; 60, 63, 64, not rare.

SCOTIELLA POLYPTERA F. E. Fritsch

Plate 6, Figures 79, 80

Cells wide, elliptical, 24 μ diam. and 30 μ long, with longitudinal ribs. The ribs are not spiral as described by Fritsch (1912, p. 108) but straight and not undulating. It much resembles *S. polyptera* Fritsch (*Pteromonas Penardi* Gain, 1912, p. 177, pl. 3, fig. 8) described from among the mosses of antarctic Peterman Island.

It is a typical nivalis-cryobiont. I also found it in the green snow of Yellowstone National Park (Kol, 1941, p. 189).

Distribution in sample: 43, rare.

CHLOROSPHAERA ANTARCTICA F. E. Fritsch

Plate 3, Figures 17-24; Plate 5, Figures 1-4, 7, 9

Cells spherical, 10–25 μ diam., membrane thick and sometimes with a very thick mucilaginous envelope. Wall sometimes clearly stratified (pl. 3, fig. 17). Diameter of envelope to 50 μ, thickness of inner wall 2–3 μ. Chromatophore large, spherical, sometimes with a small pyrenoidlike body (pl. 3, fig. 18), but starch was not observed. Cells solitary or sometimes grouped (pl. 5, fig. 4). Reproduction by cell division, by zoospore formation, and by autospores. The zoosporangium, previously unreported, is 28 μ diam. and the zoospores egg-shaped (pl. 3, fig. 23).

This microorganism was first described from the yellow snow of the Antarctic by Fritsch (1912, p. 123), but so far as I know has not been seen in the interval. It is a glacialis-cryobiont, and I found it mostly on the glaciers in Alaska—only once on a snowfield.

Distribution in samples: 14-16, not rare; 19, rare; 38, 39, common.

MYCACANTHOCOCCUS CELLARIS Hansg., f. ANTARCTICA Wille

Plate 6, Figures 82, 83

Cell spherical, 10 μ diam., with a thick wall ornamented with spines.

This organism was first described by Wille from the green snow of the Antarctic.

Distribution in samples: 21, 29, very rare; 35, 43, 64, rare.

MYCACANTHOCOCCUS OVALIS Gain, var. JUNEAUENSIS, var. nov.

Plate 6, Figure 84

Differt a typo: mensura minore et spinis sparse praeditis.

Cells 9 μ long, 7–8 μ diam., oval, sparingly bedecked with scattered spines.

This microorganism is closely related to *M. ovalis* Gain, but differs in its smaller size.

Distribution in sample: 63, rare.

TROCHISCIA ANTARCTICA F. E. Fritsch

Cells spherical, diam. 6–14 μ, wall thick with emergences 1–2 μ long. Their aspect differs with the stage of development.

This organism was first reported from the Antarctic by F. E. Fritsch (1912, p. 123), and has not since been rediscovered. It belongs to the group of organisms existing on both permanent ice and on snowfields.

Distribution in samples: 38, 39, rare.

TROCHISCIA NIVALIS Lagerh.

Plate 3, Figure 27

Cells spherical, 14–18 μ diam., the wall thickly covered with little spines.

This microorganism was first described by Lagerheim (1892) from the Andes. Since then it has been collected in the Antarctic, and was described by Fritsch (1912, p. 124). It is a mixo-cryobiont.

Distribution in samples: 38, 39, rare.

TROCHISCIA CRYOPHILA Chodat

Cell surface ornamented with blunt-ended spines 2–4 μ long, the over-all diameter being 14–24 μ.

The species *T. cryophila* was first found in Switzerland, and was described by R. Chodat (1896). It was also mentioned by Krieger from Spitzbergen. Two variants of this species were noticed in Alaskan material.

TROCHISCIA CRYOPHILA f. LONGISPINA, f. nov.

PLATE 3, FIGURES 58, 59; PLATE 5, FIGURE 10

Differt a typo: cellula spinis longioribus obtecta.

This form of *T. cryophila* has close-placed spines 4 μ long.

Distribution in samples: 38, 39, rare.

TROCHISCIA CRYOPHILA f. BREVISPINA, f. nov.

PLATE 3, FIGURE 26

Differt a typo: cellula brevioribus et sparse dispositis spinis obtecta.

This form of *T. cryophila* has sparsely placed spines 2 μ in length.

Distribution in samples: 38, 39, 52, rare.

TETRAEDRON VALDEZII, sp. nov.

PLATE 6, FIGURES 87, 88

Cellulis octogonis, membranis planis, crassis, saepe violaceis.

Proximum adest ad *T. pachydermum* (Reinsch) Hansg. sed differt ab eo: membranis planis, non concavis (uti apud *T. pachydermum*). Hab. in nivibus Alaskae.

Cells octagonal in cross section, 9 μ diam., the sides of equal length and the tips are not rounded. Wall thick, of two layers and sometimes pale violet.

This organism is close to *T. pachydermum* (Reinsch) Hansg., but differs from it in its dimensions and in that the sides are not concave. It is a typical snow alga.

Distribution in samples: 46, 47, rare; 63, very rare.

PLEUROCOCCUS VULGARIS Menegh. var. COHAERENS Wittr.

Plate 6, Figure 85

Cells 6–8 μ diam., in groups of various sizes.

This microorganism was reported by Wittrock first from the snowfields of Greenland, and since has been found in the Antarctic (Gain, 1912, p. 188) and in Yellowstone National Park (Kol, 1941, p. 190).

Distribution in sample: 35, rare.

CHAETOPHORALES

RAPHIDONEMA BREVIROSTRE Scherffel

Plate 6, Figure 27

Filaments short, to 40 μ long, of 2-8 cells, straight or curved, ends slightly pointed; cells usually shorter than broad to cylindrical, 2.5 μ diam.

This alga was collected by Prof. Istvan Györffy in Hungary in 1910, and was described by Scherffel in the same year (1910). I found it in Switzerland in 1930, and described a variety of it, *R. brevirostre* var. *canadense* in the material collected by Prof. Wm. Randolph Taylor in British Columbia. This organism is a typical nivalis-cryobiont.

Distribution in sample: 35, rare.

RAPHIDOMEMA NIVALE Lagerh.

Plate 6, Figure 86

Filaments short, to 80 μ long, of 4-8 cells, straight or slightly curved, with pointed ends; cells long, cylindrical, 2.5–3 μ diam.

This organism was first described by Lagerheim (1892) from the red snow of Ecuador. It is very common on European snowfields. It is not rare on Alaskan snowfields, but always sparingly represented by a few individuals. Like all other species of *Raphidonema* it is characteristically a nivalis-cryobiont.

Distribution in samples: 35, 43, 47, 60, rare.

STICHOCOCCUS BACILLARIS Näg., sensu stricto

Plate 6, Figure 22

Cells long cylindrical, 3 μ diam., 4–6 μ long.

This organism is very common on the snowfields of Europe. I only found it on one snowfield in Alaska. It is a typical cryoxen organism.

Distribution in sample: 47, few.

ZYGNEMATALES

ANCYCLONEMA NORDENSKIOLDII Berggren

Plate 3, Figures 1-16, 37, 38; Plate 4, Figures 1, 2, 4-10, 13-15, 20, 21; Plate 5, Figures 15, 17

Filaments very fragile, of 2–12, rarely 16 cells. A mucilage sheath is sometimes present. Cells just before division rather elongate, otherwise shorter; ends rounded. Cells 7–14 μ diam., 12–35 μ long, with 1-2 pyrenoids in a narrow, twisted parietal platelike chloroplast. Vacuolar content light to dark brownish purple, so that the whole cell appears brownish. Multiplication by cell division, first with elongation of cells and chromatophore, then division of nucleus and pyrenoids, and finally formation of the new cell wall (pl. 3, figs. 2-12). Rounding of the cell ends decreases the contact between the cells, so that the filaments become weaker as they become older. For example, a filament of eight cells will bend and separate as a rule between the fourth and fifth cells, this being the oldest point of division between cells in it.

Sexual reproduction occurs by conjugation. Zygospore spherical, 20 μ diam., with a very thick wall, formed in the conjugation tube (pl. 3, figs. 13, 16, pl. 4, figs. 5, 6). The formation of the zygospores resembles that of Roya. Germination of the zygospores results in the formation of four cells, at first spherical when liberated, later becoming somewhat elongated, and showing one pyrenoid, at which time they are 5 μ diam., 8 μ long, much below the normal size for adult cells of the species, but they may begin to divide before having reached full size.

Reproduction by asexual autospores was observed. The cell contents of the sporangia are divided into many spherical cells 2–2.5 μ diam., around each of which a cell wall is formed. After liberation these little cells begin to grow (pl. 3, figs. 14, 15; pl. 4, fig. 9).

Optimum growing conditions for *Ancyclonema* call for a pH of 5. It is a characteristic plant of permanent ice, where exclusively it is to be found. Nordenskiöld and Berggren collected this organism in July 1870 on the ice of Greenland, where it colored the surface, and in lesser quantities it has been found at various other places in the Northern Hemisphere. It was found also in Switzerland by R. Chodat and E. Kol on Mont Blanc in 1934. Gain reported it from the Antarctic (1912, p. 188) but indicated uncertainty in the determination; from the illustration I would judge that he had *Mesotaenium Berggrenii* instead.

Distribution of *Ancylonema Nordenskioldii* may be summarized: Greenland (ice bloom), Berggren, 1871, p. 295; Wittrock, 1883, p. 79. Franz Josef Land, Borge, 1899, p. 760. Spitzbergen, Lagerheim; Borge, 1911, p. 7. Norway, Nordstedt, Lagerheim. Alaska, Kol, in the present paper.

This characteristic glacialis-cryobiont I found on every Alaskan glacier. On the coast glaciers it forms long filaments and appears in great quantities, but on the interior glaciers it forms short filaments and is rare, because exclusively an ice organism (see p. 8).

In the cells of Ancylonema I found a parasitic fungus, *Rhizophidium sphaerocarpum* (Zopf) Fischer, subsp. *cryophilum* Bérczi, which I called to that author's attention, and which is described later in this publication (p. 29).

According to Lagerheim (1892, p. 531) the irregular *Ancylonema* cells found by Berggren in Greenland (1871, p. 295, pl. 5, fig. 11) also contained a parasitic fungus which belonged to the Chytridiaceae or to the Monadinae, but these differ entirely from the specimens from Alaska.

Distribution in samples: 14, 15, 16, 52, common; 19-23, 28, 29, 53, 54, abundant; 38, 39, very abundant (ice bloom).

MESOTAENIUM BERGGRENII (Wittr.) Lagerh., var. ALASKANA, var. nov.

PLATE 3, FIGURES 32, 39-57; PLATE 4, FIGURES 3, 11, 12, 16-19; PLATE 5, FIGURE 8

Proximum adest ad *Mesotaenium Berggrenii* (Wittr.) Lagerh. sed differt ab ea: 1, forma et dimensione cellularum; 2, chlorophoris singulis et pyrenoide singula.

Detexi et iuveni; in glacie aeterna Alaskae.

Cells single, or paired for a short time after division, cylindrical, 4–6 μ diam., 1–2 diameters long, apices broadly rounded; chloroplast single with one pyrenoid; vacuolar sap dark purple violet, sometimes rather dark brown.

The cells of this alga are far deeper in color than those of *Ancylonema*. Sexual reproduction is by conjugation (pl. 4, fig. 11). The zygospore is regular or irregular, quadrate or subquadrate to subspherical, 16–20 μ diam., dark brown with a very thick wall (pl. 3, fig. 32). In germination four daughter cells are formed, which at first are spherical, 4 μ diam., with one chromatophore and one pyrenoid. The color of the cell sap is purple violet, though the cells appear brown (pl. 3, figs. 40, 41).

When cells are twice as long as broad they divide, beginning with the division of chloroplast and pyrenoid, then the nucleus, and only then does the new wall appear between the cells (pl. 3, figs. 42-57).

Later the young cells become rounded at the apices where they are in contact, and separate before reaching full size; the number in contact does not exceed two.

This Alaskan organism is closely related to *M. Berggrenii* (Wittr.) Lagerh., but differs in size, shape, and the presence of only a single pyrenoid and chromatophore. Like *Ancylonema Nordenskioldii* this microorganism is a characteristic plant of permanent icefields and important in establishing ice bloom on the Columbia glacier. It is found on both coastal and inland glaciers. The species is the most frequent ice alga in the Northern Hemisphere and is also found in the Southern Hemisphere, namely, in the Andes (Lagerheim, 1892, p. 527) and Antarctica (Gain, 1912). It was first found on the icefields of Greenland, where it appeared together with *Ancylonema*.

Distribution in samples: 12, 14–16, rare; 19–23, 28, 29, 52, not rare; 53, 54, common; 38, 39, very abundant.

CYLINDROCYSTIS BREBISSONII Menegh., oic. f. CRYOPHILA, f. nov.

Plate 3, Figures 28-31, 33, 34, 36; Plate 5, Figures 5, 6; Plate 6, Figures 30, 31

Cells cylindrical with rounded apices, 14–32 μ diam., 32–70 μ long, with a radiating chloroplast and one pyrenoid in each semicell. The zygospores are 18–25 μ diam. Reproduction is by cell division and by conjugation.

This organism is very common, appearing on icefields and snowfields, and in fresh water all over the world. In my opinion we must distinguish two biological types, the aquatic and the cryophile. The latter is a permanent element of the cryophyte vegetation. It is known from several Western Hemisphere stations: Greenland, Franz Josef Land, Spitzbergen, Siberia, Norway, Switzerland, Hungary, etc. It is a characteristic cryoxen.

Distribution in samples: 14, 16, 19, 20, 38, 39, common; 28, 29, 53, 54, not rare; 12, 52, rare.

CLOSTERIUM EXILE W. & G. S. West, var. UNICRYSTALLATUM, var. nov.

Plate 6, Figures 75, 76

Proximum adest ad *Closterium exile* W. & G. S. West sed differt ab eo: cellulae cryst allum unicum ferentes, et in dimensionem cellulae.

Cells small, moderately curved, inner margin moderately concave 6 μ diam., 36–45 μ long, cell wall smooth and colorless, chloroplast with 3-4 pyrenoids; terminal vacuoles with one moving granule. Zygospores not observed.

This organism differs from *C. exile* in shape, in its smaller size, and in the presence of but one granule in each terminal vacuole. In sample No. 54 I found one specimen with a 10-μ-thick mucilaginous envelope, which was probably evoked by adjustment to the conditions of life on ice and snow (pl. 6, fig. 75).

Distribution in samples: 54, very rare; 62, rare.

CYANOPHYCEAE

CHROOCOCCALES

GLOEOCAPSA RALFSIANA (Harv.) Kützing

PLATE 5, FIGURE 13; PLATE 6, FIGURES 24-26

Diameter of envelope 12–21 μ, of protoplasts 4–9 μ, the envelope stratified, with the inner layers blood red, and the outer lighter red.

This is a typical cryoxen. In sample No. 35 I found some resting stages (pl. 6, figs. 24, 25) which were 6–8 μ long and 5–8 μ diam. This organism is frequent on the snowfields of Europe.

Distribution in samples: 35, 43, 44, 47, 48, not rare; 38, 39, 54, 62, 63, rare.

GLOEOCAPSA SANGUINEA (C. Agardh.) Kützing

Cells spherical, 4–6 μ diam., with blood-red mucilage envelopes 10–12 μ diam.

This is also a characteristic cryoxen organism.

Distribution in samples: 38, 47, rare; 62, very rare.

DACTYLOCOCCOPSIS ALASKANA, sp. nov.

PLATE 6, FIGURES 51-53

Proximum adest ad *D. irregularem* G. M. Smith, sed differt ab ea: cellulis apicibus non acutis; spiraliter non torsis, sed irregulariter undulatis; demi que habitatione, planta nivicola. Hab. in nivibus Alaskae.

Variously curved, pale bluish-green cells with blunt ends, 1–1.5 μ diam., 42–45 μ long, often several specimens interlaced.

This alga differs from *D. irregularis* G. M. Smith in the less pointed apices, lack of spiral twist, and in habitat. I found it only on Roberts Peak (sample No. 60, rare) together with snow fleas.

HORMOGONALES

OSCILLATORIA TENUIS C. Ag., var. TEKLANIKANA, var. nov.

Plate 6, Figure 81

Differt a typo: dimensione, filamento solitario denique biotope.

Filaments solitary, cells 4 μ diam., one-half to three-fourths times as long as broad, apical cells simple. The difference in size, lack of grouping of the filaments, and the fact that it is a glacialis-cryobiont differeniate it from the type.

Distribution in samples: 16, rare; 20, not rare.

PHORMIDIUM ANTARCTICUM W. & G. S. West

Plate 6, Figure 1

Filaments solitary, more or less curved, with the mucilaginous investment more or less definite, cells in the filaments 1–1.5 μ diam., and twice as long.

This organism was first found in fresh water in the Antarctic. It is a cryoxen type, which I found on the Columbia Glacier in fairly large quantities.

Distribution in samples: 14, 16, rare; 23, not rare; 38, 39, common.

PHORMIDIUM GLACIALE W. & G. S. West

Plate 6, Figure 78

Filaments solitary, with a definite mucilage investment; cells 1.8–2 μ diam., as long as broad or longer.

This plant was first described from fresh-water samples from the Antarctic. It is a cryoxen organism.

Distribution in sample: 15, rare.

LYNGBYA MARTENSIANA Menegh. var. MENDENHALLIANA, var. nov.

Plate 6, Figure 23

Differt a typo: in colore, filamento solitario et denique biotope.

The filaments, 6 μ diam., are spirally curved and have a yellowish-green color. The cells of the trichomes are 4 μ diam., shorter than wide, and show granules beside the cross-walls. There is a colorless mucous investment about the filament. The apical cell is simple.

This organism differs from the type of the species in its greater slenderness, thinner investment, yellowish color and the fact that its filaments grow dispersed on the ice.

LYNGBYA LAGERHEIMII (Möb.) Gom. var. LIEKII, var. nov.

PLATE 6, FIGURE 77

Differt a typo: in dimensione, filamento solitario et denique habitione.

Denominavi ad honorem illustrissimi ac clarissimi Domini Directoris of Mount McKinley National Park, Harry J. Liek.

Filaments single, more or less spirally curved, 4 μ diam. Mucous investment colorless. Apical cell simple; transverse walls granulated.

This plant differs from the type of the species in its larger filaments, granulated cross-walls, and habitat as a glacialis-cryobiont.

I have named this species after Harry J. Liek, Superintendent of Mount McKinley National Park, 1936.

Distribution in sample: 15, rare.

FUNGI

CHIONASTER BICORNIS, sp. nov.

PLATE 6, FIGURES 32-34

Cellulae constanter duo cornua nunquam pluria ferentes.

Cells with two long, pointed horns 4 μ wide and 60 μ long, and a thick cell wall.

This plant resembles *C. nivalis* (Bohl.) Wille, except in the constant presence of two pointed horns. I have not seen any developmental stages, such as I saw for *C. nivalis* on the snowfields of the Retyezát, Hungary, on which basis I placed that plant among the fungi. It is a characteristic snow organism.

Distribution in samples: 16, 60, rare.

RHIZOPHIDIUM SPHAEROCARPUM (Zopf)[4] Fischer,[5] subspecies CRYOPHILUM Laszló Bérczi, subsp. nov.

TEXT FIGURES 4 AND 5

Proximum adest ad *R. sphaerocarpum,* sed differt ad hoc: quo rationem vivendi attinet. Etenim in glacie et in tali planta inveniri protest, auali *R. sphaerocarpum* non adhaeret.

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[4] Zopf, W., Zur Kenntnis der Phycomyceten, I. Zur Morphologie und Biologie der Ancylisteen und Chytridiaceen, zugleich ein Beitrag zur Phytopathologie. Nova Acta Kaiserl. Leop. Carol. Deutsch. Acad. Naturf. vol. 48, No. 4, pp. 141-236, 1884.

[5] Fischer, A., Die Pilze Deutschlands, Oesterreichs und der Schweiz. Abt. 4: Phycomycetes. Leipzig, 1892.

I called Mr. Bérczi's attention to a parasitic fungus which I had observed in the cells of *Ancylonema Nordenskioldii* collected from the Columbia Glacier.

The sporangia of this chytrid are extramatrical and they lie close together on the vegetative cells of the *Ancylonema*. Young, ripe sporangia are spherical, 7–10 μ diam., with a rhizoid slight in development and ramification. The zoospores are spherical, 3 μ diam., and they emerge from the sporangium through a large apical pore. The new species belongs to the group *Unipora* of the section *Globosa*

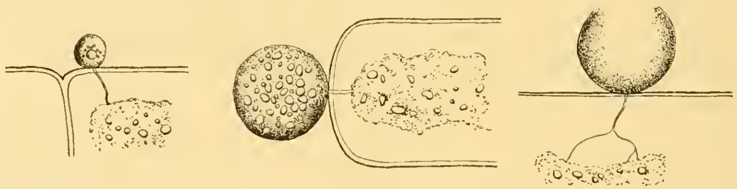

FIG. 4.—*Rhizophidium sphaerocarpum* (Zopf) Fischer, subspecies *cryophilum* Laszló Bérczi, new subspecies.

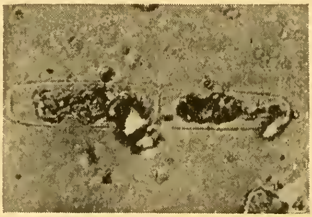

FIG. 5.—*Rhizophidium sphaerocarpum* (Zopf) Fischer, subspecies *cryophilum* Laszló Bérczi, new subspecies.

of *Rhizophidium*. While closely related to *R. sphaerocarpum* I could not find the type of discharge characteristic of that species, and so am unwilling to consider it identical. I know of no fungi reported as parasites on *Ancylonema*. The new subspecies is a typical cryobiont.

Distribution in samples: 52, rare; 38, 39, not rare.

SUMMARY

My cryobiological research on the snowfields and glaciers of Alaska during the summer of 1936 indicates that these show a unique society of cryomicroorganisms. This is the first research on the cryoorganisms and their environment that has been carried out in North America.

The range of pH of the snowfields is 4.5-6.5, and of the ice surface 5-7. Besides the range of surface variation, differences with depth also appear down to 1 foot. It is also influenced by the proximity of rocks, the dust from them falling on the surface. From the point of view of their chemical character we may distinguish calcitroph and silicotroph environments, and from their physical character snow, firn, and ice.

The plants which grow in these places may be designated snow- or nivalis-cryobionts (planta nivicola), ice- or glacialis-cryobionts (planta glacicicola), and mixo-cryobionts or cryoxen.

Three very interesting natural phenomena appear in the cryo-environments of Alaska: The red-pepper-colored snow on Thompson Pass, the brown-violet ice bloom on the Colombia Glacier, and the colonies of snow fleas on Gastineau Peak. The red snow is caused by *Chlamydomonas nivalis, C. sanguinea, Smithsonimonas Abbotii,* and *Scotiella nivalis,* with 10 other organisms in smaller numbers. The purple-brown bloom is caused by *Ancylonema Nordenskioldii* and *Mesotaenium Berggrenii* var. *alaskana,* with nine other kinds of organisms in minor association and not affecting the color. This is the first American record of ice bloom.

Altogether, 32 cryomicroorganisms are listed from Alaska (Algae: Chlorophyceae 22, Cyanophyceae 8. Fungi: 2). I describe as new: *Smithsonimonas,* new genus; *S. Abbotii, Tetraedron valdezii, Dactylococcopsis alaskana, Chionaster bicornis,* new species; *Mycacanthococcus ovalis* var. *juneauensis, Mesotaenium Berggrenii* var. *alaskana, Closterium exile* var. *unicrystallatum, Oscillatoria tenuis* var. *teklanikana, Lyngbya Lagerheimii* var. *Liekii, L. Martensiana* var. *mendenhalliana,* new varieties; *Rhizophidium sphaerocarpum* subsp. *cryophilum* Laszló Bérczi, new subsp.; *Trochiscia cryophilum* f. *longispina,* f. *brevispina, Cylindrocystis Brebissonii* oic. f. *cryophila,* new forms. Among these microorganisms were 12 nivalis-cryobionts (snow algae), 10 glacialis-cryobionts (ice organisms), 3 mixo-cryobionts, and 4 cryoxen. These include organisms such as had previously been considered as restricted to Northern, Western, Southern, or Eastern Hemispheres. From this we may conclude that the distribution of cryovegetation depends on the environment and geographical position as well. It is evident that the Alaskan cryovegetation is varied and rich.

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EXPLANATION OF PLATES

PLATE 1

(Photographs by E. Kol.)

FIGS. 1, 2. Ice mounds of Columbia Glacier, at a distance of about 1 mile from the ocean, covered with brownish ice bloom.

FIGS. 3, 5. A dark brown spotted algal mass consisting principally of *Ancylonema* filaments spread over the surface of the ice, mostly at the bottom of the holes melted in the ice.

FIG. 4. Icefield covered with *Ancylonema* and *Mesotaenium*.

FIG. 6. Ice mounds covered with ice bloom.

FIG. 7. Photograph of Columbia Glacier, taken from Columbia Bay.

PLATE 2

FIG. 1. Silicotroph snowfield with red snow, lying below Thompson Pass.

FIG. 2. Snowfield covered with pinkish snow, below Thompson Pass. The edge of the melting snow is covered with blackish dust.

FIG. 3. Silicotroph snowfield in the vicinity of Thompson Pass.

FIG. 4. Snowfield lying at the head of the Savage River, with very poor cryovegetation, covered with much refuse and dust.

FIG. 5. Silicotroph snowfield with red snow 2 feet deep on Thompson Pass.

FIGS. 6, 7. Snowfields at the head of the Savage River, with very poor vegetation.

FIGS. 8, 9. Teklanika Glacier.

Plate 3

Figs. 1–16. *Ancylonema Nordenskioldii* Berggr., normal filaments and cell division. 1, normal filament after cell division (× 1,000); 2–12, first division of the young cells after the germination of the zygospore; 2, 4, the young cell has one small pyrenoid (× 1,000); 3, 5, the pyrenoid becomes larger (× 1,250); 6–10, division of the pyrenoid and the chloroplast (× 1,000); 11, 12, formation of the new cell wall (× 1,000); 13, conjugation (three filaments) (× 1,000); 14, 15, liberation of autospores (× 1,000); 16, conjugation (× 1,000).

Figs. 17–24. *Chlorosphaera antarctica* Fritsch. 17, a cell with very thick and stratified membrane (× 750); 18, a cell with a pyrenoidlike round body in the chloroplast (× 660); 19, 20, cells with a chloroplast without the pyrenoidlike body; 19, (× 660); 20, (× 1,250); 21, a cell with a wide mucilage envelope (× 700); 22, a cell with segregated masses of fat (× 700); 23, zoosporangium—formation of zoospores (× 1,000); 24, cell division (× 1,000).

Fig. 25. *Scotiella nivalis* (Shuttlew.) Fritsch.

Fig. 26. *Trochiscia cryophila* f. *brevispina* Kol (× 700).

Fig. 27. *Trochiscia nivalis* Lagerh. (× 1,300).

Fig. 28. *Cylindrocystis Brebissonii* Menegh. f. *cryophila* Kol, abnormal cell division (× 660).

Fig. 29. *Cylindrocystis Brebissonii* Menegh. f. *cryophila* Kol, early conjugation stage (× 1,000).

Figs. 30, 31, 33, 34. *Cylindrocystis Brebissonii* f. *cryophila* Kol, zygospores (× 1,000).

Fig. 32. *Mesotaenium Berggrenii* var. *alaskana* Kol, zygospore (× 1,000).

Fig. 35. *Ancyclonema Nordenskioldii,* germination (× 1,300).

Fig. 36. *Cylindrocystis Brebissonii* f. *cryophila* Kol, normal cell (× 900).

Figs. 37, 38. *Ancyclonema Nordenskioldii.* 37, beginning of fragmentation (× 750); 38, zygospore (× 1,500).

Figs. 39–41. *Mesotaenium Berggrenii* var. *alaskana* Kol. Different stages of the opening of the zygospore (× 1,000).

Figs. 42–57. *Mesotaenium Berggrenii* var. *alaskana* Kol (× 1,300). Different stages of division of the young cells, after the germination of the zygospore. 42–44, young cells with one pyrenoid; 45–51, division of the chloroplast and pyrenoid; 53, 54, formation of the new cell wall between the young cells; 55–57, separation of the two young cells.

Figs. 58, 59. *Trochiscia cryophila* f. *longispina* Kol (× 1,000).

Plate 4

(Photomicrographs by E. Kol.)

Figs. 1, 2, 7, 8. *Ancyclonema Nordenskioldii,* normal filaments (× 400).

Fig. 3. *Mesotaenium Berggrenii* var. *alaskana* Kol, zygospore (× 800).

Fig. 4. *Ancyclonema Nordenskioldii,* zygospore (× 600).

Figs. 5, 6, 13. *Ancyclonema Nordenskioldii,* conjugation.

Fig. 9. *Ancyclonema Nordenskioldii,* liberation of autospores.

Fig. 10. *Ancyclonema Nordenskioldii,* young plant.

FIGS. 11, 12, 16–19. *Mesotaenium Berggrenii* var. *alaskana* Kol. 11, conjugation (× 800); 12, 17, 18, 19, zygospores; 16, normal cell (× 800).

FIGS. 14, 15, 20, 21. *Ancylonema Nordenskioldii.* 14, 15, beginning of the fragmentation of the filament; 20, normal filament; 21, division of the cells of the filament.

PLATE 5

(Photomicrographs by E. Kol.)

FIGS. 1–4, 7, 9. *Chlorosphaera antarctica* Fritsch. 1, 2, cells with thick cell wall and with pyrenoidlike body on the chloroplast (× 800); 3, a cell with segregated masses of fat (× 800); 4, a group of cells with mucilage envelope (× 160); 7, 9, a cell with very thick mucilage envelope (× 400).

FIGS. 5, 6. *Cylindrocystis Brebissonii* f. *cryophila* Kol. 5, (× 600); 6, (× 800).

FIG. 8. *Mesotaenium Berggrenii* var. *alaskana* Kol, zygospore.

FIG. 10. *Trochiscia cryophila* f. *longspina* Kol (× 800).

FIG. 11. *Trochiscia cryophila* var. *brevispina* Kol (× 800).

FIGS. 12, 14. *Trochiscia nivalis.* 12, (× 400); 14, (× 800).

FIG. 13. *Glococapsa Ralfsiana* (Harv.) Kütz (× 800).

FIGS. 15, 17. *Ancylonema Nordenskioldii,* normal filaments.

[Reference to fig. 16 not supplied by author.]

PLATE 6

FIG. 1. *Phormidium antarcticum* W. & G. S. West (× 666).

FIGS. 2–21. *Smithsonimonas Abbotii* Kol. 2, vegetative cell before the formation of the warts (× 833); 3, vegetative cell (× 500); 4, two autospores in the autosporangia (× 666); 5–7, different vegetative cells; 8, the beginning of the formation of the warts on the surface of vegetative cell (× 833); 9–11, different forms of the envelope of the vegetative cells; 12, the envelope covered by warts, resting stage (× 666); 13–15, liberated autospores (× 500); 16, formation of aplanospore (× 666); 17–21, resting stages, decorated by warts (× 666).

FIG. 22. *Stichococcus bacillaris* Näg. (× 666).

FIG. 23. *Lyngbya Martensiana* var. *mendenhalliana* Kol (× 500).

FIGS. 24–26. *Gloeocapsa Ralfsiana* (Harv.) Kütz. 24, 25, resting stages (× 666); 26, (× 333).

FIG. 27. *Raphidonema brevirostre* Scherffel (× 500).

FIGS. 28, 29. *Raphidonema nivale* Lagerh. (× 333).

FIGS. 30, 31. *Cylindrocystis Brebissonii* f. *cryophila* Kol (× 500). 31, apical view.

FIGS. 32–34. *Chionaster bicornis* Kol. 32, (× 333); 33, 34, (× 666).

FIGS. 35–41. *Scotiella antarctica* Fritsch. 37, an irregular individual with seven ribs (× 500); 38, 39, liberated autospores (× 250); 35, 36, autosporanguim (× 333); 40, resting stages (× 500); 41, resting stage (× 500).

FIGS. 42–50. *Chlamydomonas nivalis* Wille. 42, (× 333); 43, (× 500); 45, with very thick mucilage envelope (× 500). All motionless spherical cells. 44, zygospore (× 500); 46–48, aplanospore (× 500); 49, 50, cells with thick cell wall (× 500).

FIGS. 51–53. *Dactylococcopsis alaskana* Kol. 51, 52, (× 500); 53, (× 166).

FIGS. 54–61. *Chlamydomonas sanguinea* Lagerh. (× 333). Cells preserved in formalin. 57, 58, 61, the surface of the cell wall rough; 59, with very thick mucilage envelope.

FIGS. 62–74. *Scotiella nivalis* (Shuttlew.) Fritsch. 62, 63, autosporangium; 62, (× 666); 63, (× 500); 64, 65, 73, liberated autospores (× 666); 66–72, different stages of the development (× 500); 74, the ribs are developed (× 666); 72, (× 666).

FIGS. 75, 76. *Closterium exile* var. *unicrystallatum* Kol. 75, (× 333); 76, (× 500).

FIG. 77. *Lyngbya Lagerheimii* var. *Liekii* Kol (× 500).

FIG. 78. *Phormidium glaciale* W. & G. S. West (× 500).

FIGS. 79, 80. *Scotiella polyptera* Fritsch. (× 500).

FIG. 81. *Oscillatoria tenuis* var. *teklanikana* Kol (× 500).

FIGS. 82, 83. *Mycacanthococcus cellaris* f. *antarctica* Wille (× 500).

FIG. 84. *Mycacanthococcus ovalis* var. *juneauensis* Kol (× 666).

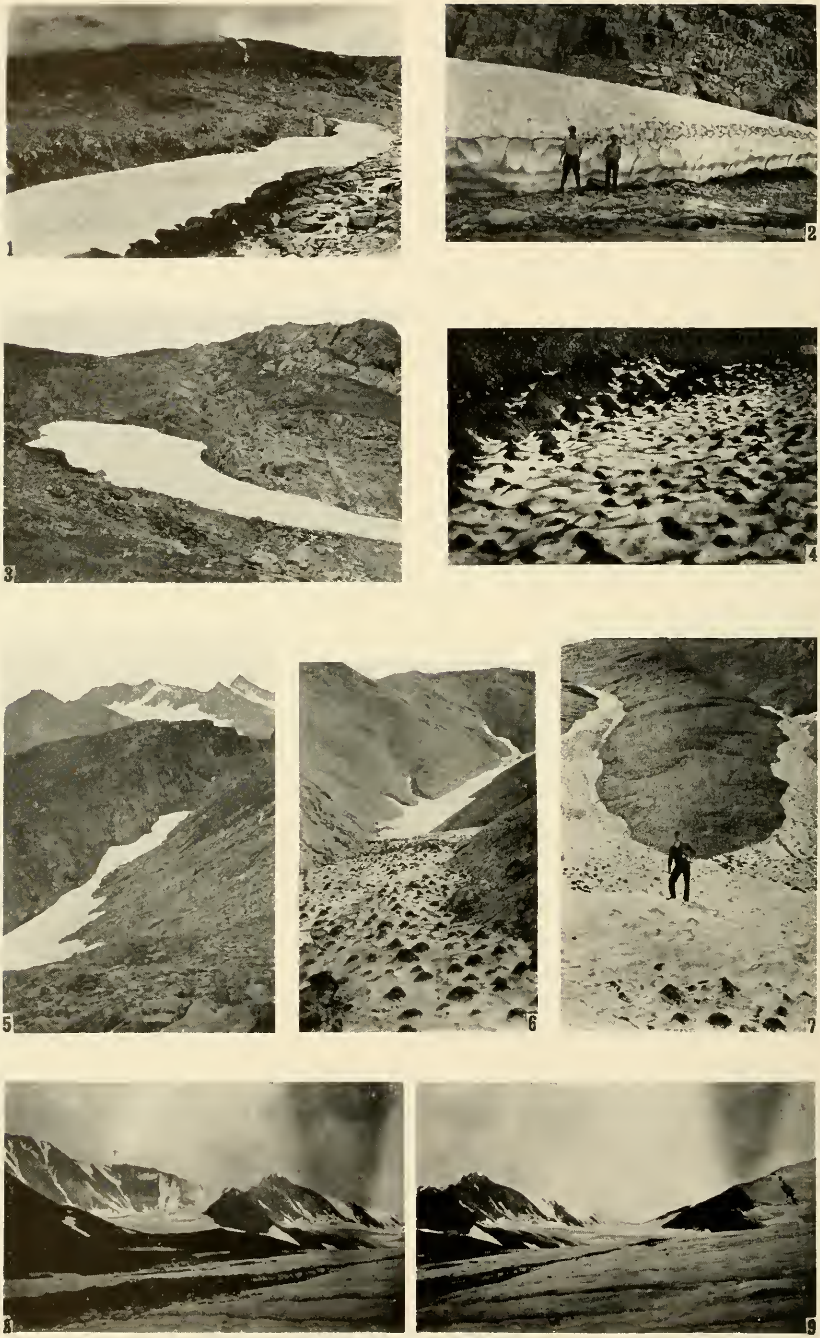
FIG. 85. *Pleurococcus vulgaris* β *cohaerens* Wittr. (× 666).

FIG. 86. *Raphidonema nivale* Lagerh. (× 666).

FIGS. 87, 88. *Tetraedron valdezii* Kol (× 666).

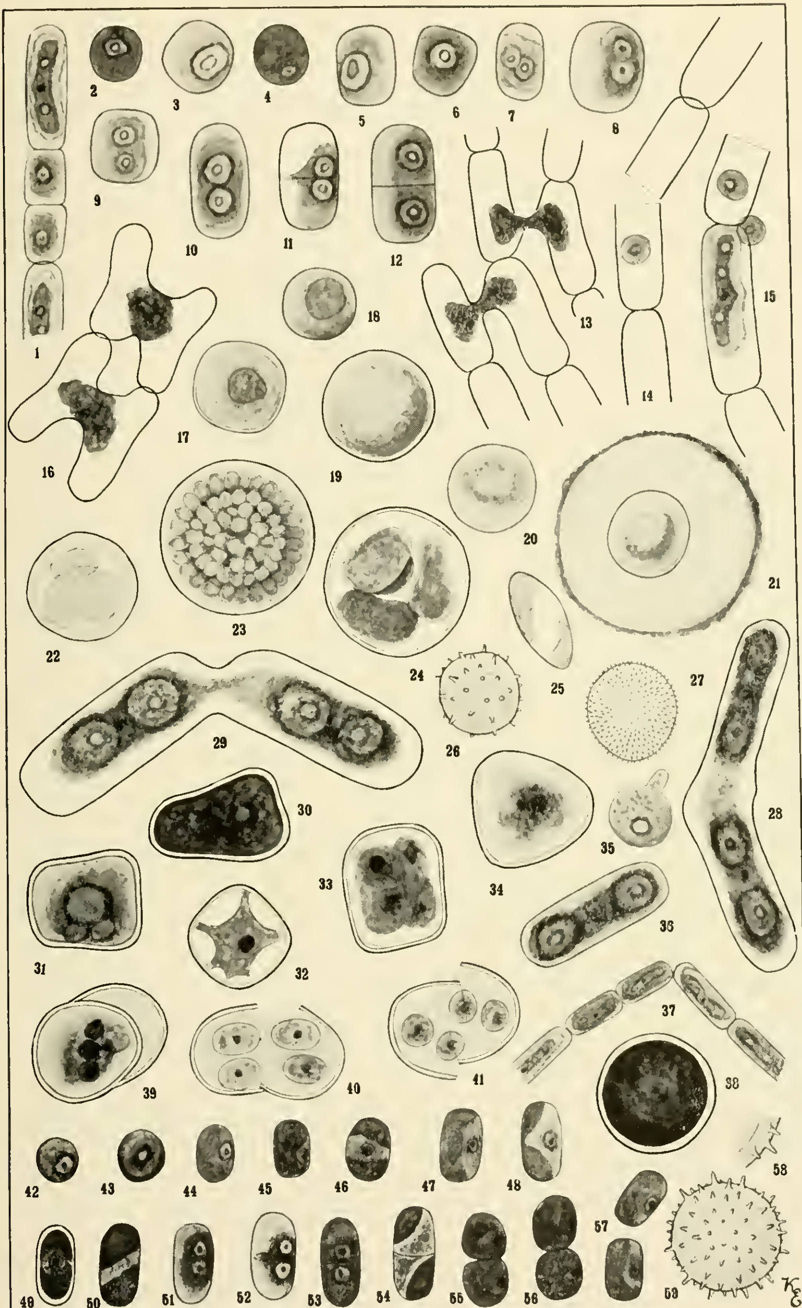
ICEFIELDS AND GLACIERS OF ALASKA

(For explanation, see p. 33.)



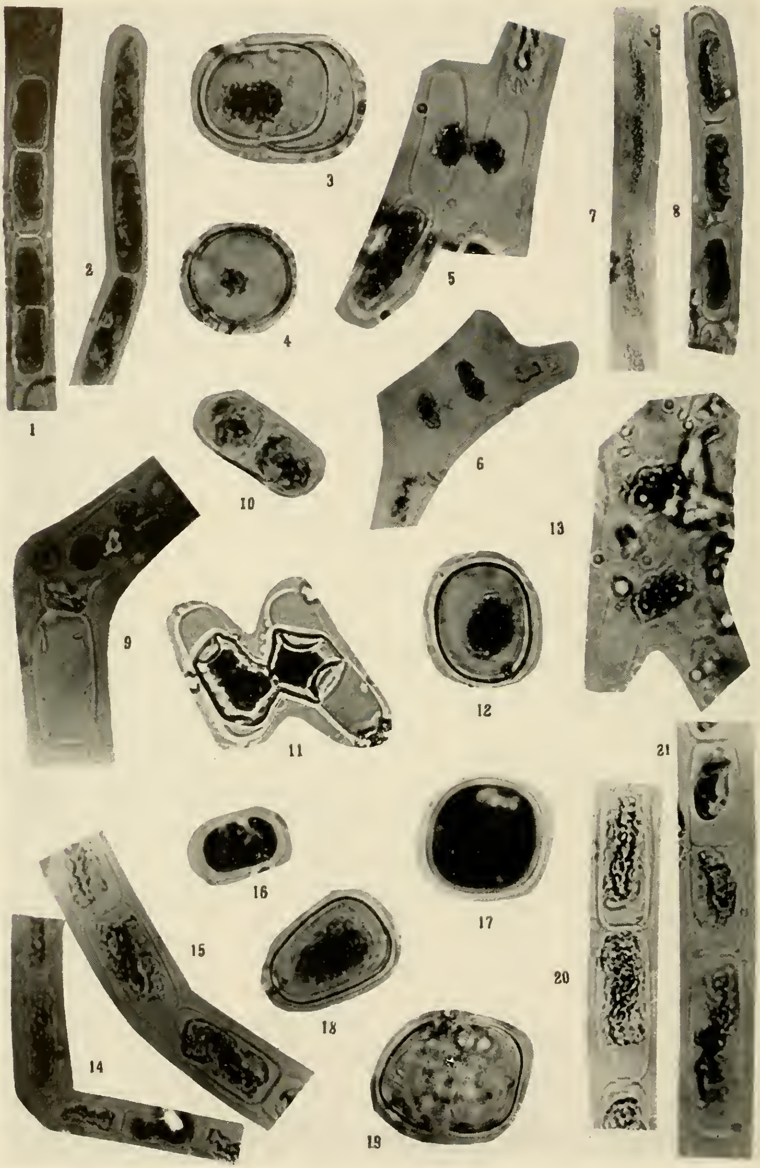
SNOWFIELDS AND GLACIERS OF ALASKA

(For explanation, see p. 33.)



CRYOVEGETATION OF ALASKA

(For explanation, see p. 34.)

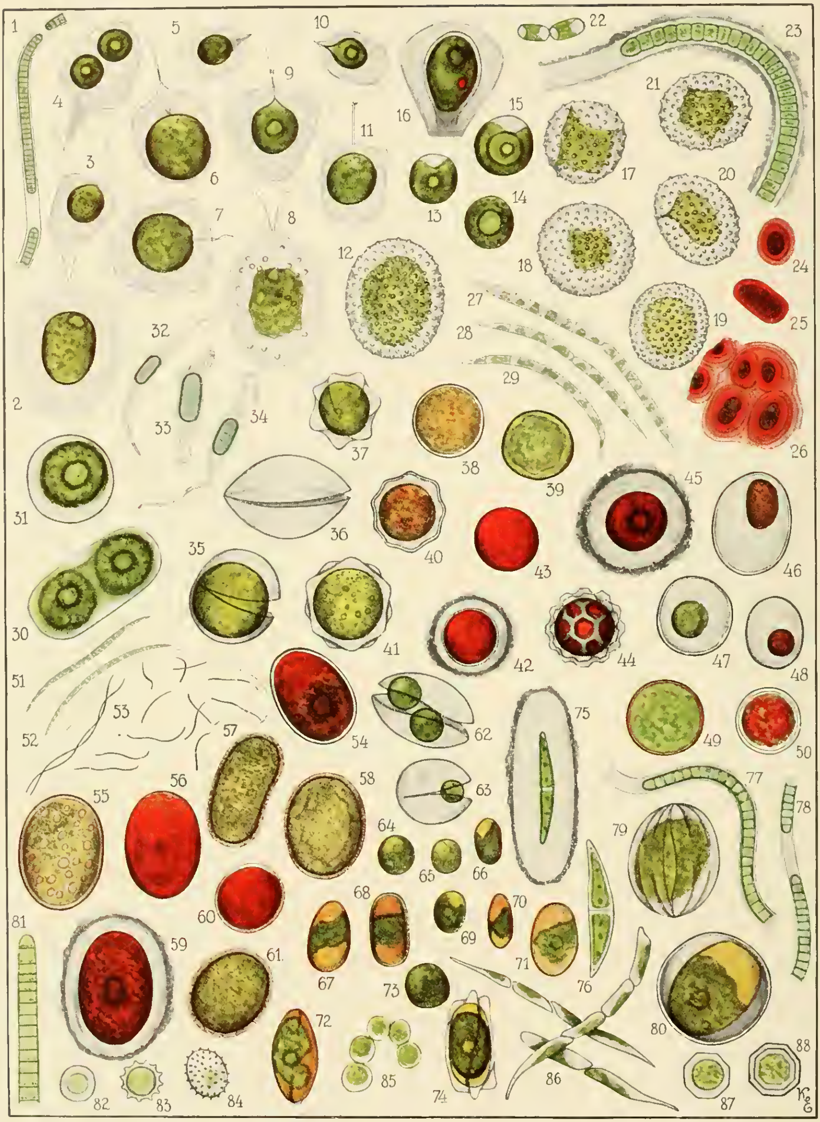


CRYOVEGETATION OF ALASKA

(For explanation, see pp. 34-35.)

CRYOVEGETATION OF ALASKA

(For explanation, see p. 35.)



CRYOVEGETATION OF ALASKA

(For explanation, see pp. 35-36.)