

# THE BOTANY OF ICELAND

EDITED

BY

L. KOLDERUP ROSENVINGE

PH. D.

AND

EUG. WARMING (†)

PH. D., SC. D.

---

VOL. II

WITH 6 PLATES AND 73 FIGURES IN THE TEXT



COPENHAGEN  
J. FRIMODT

---

LONDON  
HUMPHREY MILFORD  
OXFORD UNIVERSITY PRESS

1932

BOTANISK  
CENTRALMUSEUM

2015/

6.

THE LICHEN FLORA AND  
LICHEN VEGETATION  
OF ICELAND

BY

OLAF GALLØE

PH. D.

1919—1920.

## INTRODUCTION.

IN 1913, after deliberation with Professor E. Warming, I made a journey to Iceland to investigate the island lichenologically, as far as this could be done during the course of one summer. I had visited the island once before, (1906) and had become interested in its lichen-vegetation, which impressed me as presenting many features of great interest. At that time I had, however, very little opportunity of making investigations, therefore I eagerly seized the opportunity of investigating the lichens, which offered itself in 1913. Already, before this last journey, I had studied the lichen-vegetation more thoroughly in the different plant-associations of Denmark, and had published my investigations on this subject in 1908; afterwards (in the early summer of 1913) I published my "Forberedende Undersøgelser til en almindelig Likenøkologi" ("Introductory Investigations concerning a general Lichen-Ecology"), and was therefore now highly interested in extending my investigations to a country, which was not situated in the same climatic zone as Denmark, because I might expect to find there essentially different vegetational and floral conditions; and I was not disappointed with regard to this point. I made collections and notes as assiduously as the somewhat difficult conditions of travelling permitted, but I am sorry to say that I must admit, in my own case and probably in that of others also, that Iceland is too large to survey fully during one summer's travel.

However, I hope, and also believe, that the descriptions I have been able to give below, will not be altered essentially by investigations, which may possibly be made by future travellers.

The districts which I investigated most thoroughly were those

around Reyðarfjörður and Seyðisfjörður on the east coast, the country around Húsavík and Eyjafjörður on the north coast, Isafjörður on the north-western peninsula, Reykjavík and Hafnarfjörður in South-west Iceland, the districts around Mývatn, Jökulsá and Laxá in the interior of North Iceland proper, and the districts about Thingvellir and Geysir. In addition, I paid a flying visit to the islands of Vestmannaeyjar.

I had a fairly good opportunity of investigating these districts somewhat thoroughly. But unfortunately, on the other hand, I had no chance of seeing anything worth mentioning of the desert-interior of Iceland. Among other specially interesting localities were the numerous sea-fowl cliffs along the coasts: no doubt these would prove remarkable in many ways, but I had no opportunity of making independent observations in such spots.

The results of these investigations I have embodied in the following Lichen Flora (which, by my work, contains a fairly considerable number of species not found previously,) and Lichen Vegetation of Iceland; this latter subject has been studied only partially and not at all exhaustively by others (Grönlund and Helgi Jónsson).

As regards the literature on the subject, reference should be made to Deichmann Branth's "Lichenes Islandiæ" (Botanisk Tidskrift, vol. 25, 1903) in which all lichenological literature pertaining to Iceland has been enumerated, and a full record of collectors and collections from Iceland has been given. It is the newest and most exhaustive list of species, but now to it must be added those species which have subsequently been found by me. I have been obliged to make a few minor alterations in Branth's list, as the genus *Endococcus* can scarcely be maintained any longer as a lichen-genus, and is therefore omitted from the following list.

A full description of the conditions pertaining to vegetation in Iceland, and the references to literature will be found in the part of the present work (vol. I) written by Professor Thoroddsen. These two aids to the study of the literature are very exhaustive.

As regards the ecological and other biological conditions, I must refer the reader to my two papers mentioned above, "Danske Likeners Økologi" (Bot. Tidsskrift, vol. 28, 1908) and "Forberedende Undersøgelser til en almindelig Likenøkologi," (Dansk botanisk Arkiv, vol. 1, no. 3, 1913). In these papers full references will be



found to all the literature of the biology of Lichens, so that it is unnecessary to cite it more particularly here.

---

The Directors of the Carlsberg Fund have, with their usual generosity, supplied the funds for the investigations and for the journey to Iceland; for which I tender my best thanks to the said Directors.

---

## I. THE LICHEN FLORA OF ICELAND.

THERE is hardly any other group of plants in which the boundary line between the species is so indefinite as it is in the Lichens. Several types are easy to describe, and readily recognizable after description, but between such readily recognizable types there frequently occur so many intermediate forms, that we are quite perplexed in deciding to which type or species — or whatever we now choose to call it — the plant in question should be referred, when it is to be included in a list of species. No doubt the majority of botanists have occasionally tried to determine, for instance, some or other *Cladonia*-species and have thereby experienced for themselves the difficulties which thus arise. But as with *Cladonia*, so is it with the majority of the genera, only, in many cases, the difficulties are even more considerable. To the less skilful investigators any sure determination is usually impossible, but even for the best-trained lichenologist, it is often extremely difficult to identify a species which he has before him, with one already known and described by others, a circumstance which has caused much controversy, to a great extent unnecessary, between the “patres” of lichen-systematology.

The reason of this richness of forms, this abundance of forms intermediate between the most easily distinguishable types, is not known. We may naturally form our surmises on the subject. It may be assumed that the lichen-group, taken as a whole, is a group in process of rapid development, that is to say, in the act of forming numerous new species which, in the course of time, will separate themselves into a smaller number of easily distinguishable species, through many of the intermediate forms dying out. Or we may suppose that the types in themselves are few, but possess a wide,

individual range of variations, which is the reason that the boundary line between the species, is difficult to distinguish.

But this is, at present, mere assumption, and as such will not be discussed here more fully. I shall only remark, that any certain decision on the matter can only result from making experimental cultures with the types along the lines, on which researches on heredity are now carried out. But unfortunately we have far to go before we reach this stage, for lichens are generally very difficult to cultivate and, in addition, grow very slowly, so that they would not give quick results.

This best mode of separating the species — the experimental mode — will perhaps never be followed by any one. The next-best method — which, indeed, must form the introduction to the experimental method — has not been adopted to any extent by lichenologists. I shall now briefly explain what I mean.

In order to be able to decide how many types (species) there exist, it is absolutely necessary to follow quite another method than that hitherto followed by lichenologists. From the infancy of lichenology up to the present time, the systematists, dazzled by Linné's short, emphatic diagnosis of higher plants, have endeavoured to create a similar diagnosis for the lichen-species. Anything like this is however impossible, and has caused the greater part of the systematic chaos in which we now find ourselves. If we bear in mind what I wrote above on the abundance of the intermediate forms, and the absence of corresponding boundary lines, it is self-evident that each single type must be described and figured as exhaustively as possible, in order to be recognized by other workers.

The only sure means of making a type recognizable for others is to examine, figure and describe one single individual of the type, making sure that we do not unintentionally confuse two nearly allied types together in one mixed description, as for instance might happen through investigating the thallus of one specimen and the apothecium of another.

This method, which has as yet never been practised in works on lichen-systematology, (I myself have, however, material in hand, not published, for some type-descriptions of such a kind), will be the only means of distinguishing the types from each other, and of eventually forming an introduction to culture-experiments, (which as already mentioned must begin with well-defined types), so that

we may finally emerge from the systematic and synonym-chaos in which we now find ourselves.

The method in question involves however a certain danger, as it might end in our establishing almost every individual in the world as a distinct type. And a danger just like this can only be avoided by proving once for all, at some future time, by culture-experiments, how many of the types established by thorough observations and descriptions, are so nearly related to each other, that they must be referred to the same species.

It is clear that this "method of individuals," as I will call it, will be able to revolutionize our apprehension of species, and is for the time being the only way out of the difficulty. But it is equally clear that such a method is not a brief affair, which the individual investigator can accomplish with regard to more than a very restricted number of types. Lists of species and local floras — and also the present one — must consequently still be worked out according to the prevalent, old-fashioned principles, although, as I have been working with them, I have gradually become convinced of their drawbacks, and of how obsolete and defective they are.

Let us therefore briefly regard these defects and the lichen-synonymy, in order better to understand their nature.

The greatest defects of the lichen-systematology lie in the fact, that the one group of investigators are greatly inclined to include as many forms as possible in one large comprehensive species, while others (and these the majority) are inclined to separate the species into many smaller species, each with its own name. In the former group may be reckoned for instance Deichmann Branth in Denmark. This tendency of his to restrict the number of the species, runs as a leading thread through his works on the lichens of Iceland, Greenland and Denmark, and what I cite from his works in my following list will prove this in several instances. I must, however, acknowledge that his observations on species, and his critical remarks on the "species" of other investigators, have several times struck me on account of their original and clear-sighted view of the relationship and genealogical affinity of the species. I am not to be understood to concede that this investigator can prove, for instance, that *Cladonia uncialis* and *C. amanrocreoa* (just to give one single example) are really genealogically allied, whilst others classify them as two distinct species; but Deichmann Branth's suggestions regarding this point, and his many other critical remarks

on the unity where others see diversity of species, show a comprehension of the relationship of the lichens which, I believe, will prove to contain many truths when once, at some future time, we succeed, by experiments, in clearing up the limitation of the species. But it should be borne in mind that, for the time being, his systematic considerations (which are excellent according to my opinion) are theories, pure and simple, which experiment alone can set upon a firm foundation, and Deichmann Branth himself must have had a clear understanding of this. It is only to be hoped that, one day, the necessary culture-experiments will be made, which will eventually do that justice to his considerations, which up to the present, has been too scanty.

To the other group of investigators belong virtually all the lichenologists of the present day — all those who so often establish species upon quite slight peculiarities of structure in the individuals considered.

The inconveniences this causes with regard to the synonymy of the lichens, is evident. The same name is sometimes used in a limited and sometimes in a very wide sense. The same species is sometimes referred to one, and sometimes to another genus. This creates a confusion, which in several cases, is simply impossible to reduce to order.

In order to clear away the difficulties with regard to synonyms, it has been the custom from the earliest times, to preserve in museums "original specimens," i. e. the specimens on which the author has founded his species. This custom is very commendable, but by no means so satisfactory, as we are frequently inclined to believe; the fact being that lichens alter rather essentially in the course of time, frequently change colour, and alter their chemical reactions, etc., to say nothing of the fact that the specimen may not be cut up to ascertain the anatomical resemblance between it and other specimens, the identity of which is wished to be ascertained; and without such anatomical investigation, comparison is simply worthless in all difficult cases. This fact should be emphasized in order to remove, once for all, the entire foundation built up under the persistent worship of "original specimens." We must demand that the author of the species should describe his species well, and not only leave some gnawed or doubtful original specimen, which is respected so highly that no one dares to dissect it, and thereby deprive it of its importance, while often the very specimen proves,

on closer investigation, to be an intermixture of individuals of fairly different species, and we are unable to decide, with any certainty, the individual for the sake of which the author has left it in trust for after times! Else we must yield to the inevitable, viz., that lichen determinations become rather uncertain, as they also prove to be in many cases, or that later lichenologists shall simply disregard the oldest author's right of priority, and re-establish the species with better definition. It is absolutely necessary to get away from the exaggerated belief in the principle of "original specimens."

The following list of the lichens of Iceland, as indicated above, is not based on my own studies of the species, according to the "method of individuals" mentioned above, — that would be an almost impossible work for one man, — but is arranged in compliance with the frequently-employed limitation of species, as they are presented to us in the commonly known lichenological works of Th. Fries, Crombie, Koerber, Nylander and others; the list, consequently, has the synonymic and systematic weaknesses belonging to the works in question, but also has their strong point, viz., it can safely and easily be compared with other lists worked out on the same principles, a thing rather necessary for lichenological reasons.

In the list given I have drawn special attention to the species which were found by myself as "new to Iceland," and which are not found in Deichmann Branth's list of 1903. The reason why these species have been specially mentioned is simply that I am myself responsible for their correct identification, and not that special attention might be drawn to these new finds, and this so much the less, as I cannot see anything specially meritorious in finding new species: every well-trained collector can do so much.

The following list by no means renders Deichmann Branth's excellent work superfluous. In his work we find geographical stations for all the species, and my own list merely supplements his by describing more fully the species new to Iceland, and by modernizing his limitation of species, making it more in agreement with the demands of the time, — without necessarily constituting a real improvement in the apprehension of the species, which, as already mentioned, will not be attained except by detailed investigations in the future, according to my "method of individuals."

The following species have been found: —



# I. PYRENOCARPEÆ.

## VERRUCARIACEÆ.

(Microglæna, Polyblastia, Staurothele, Verrucaria.)

### Microglæna.

**M. sphinctrinoides** Nyl. (D. B., p. 220, under Pyrenula)<sup>1</sup>.  
This species is wanting in Greenland.

### Polyblastia.

**P. hyperborea** Th. Fr.

On Basalt, Seyðisfjord, O. Galloe, 1913. New to Iceland.

**P. Henscheliana** Koerb. (D. B., p. 220, Pyrenula).

Absent from Greenland. Great Britain (Crombie)<sup>2</sup>.

### Staurothele.

**S. clopima** Wnbg. (D. B., p. 220, Pyrenula).

G. Brit.

### Verrucaria.

**V. margacea** Wnbg. (D. B., p. 219, with var. *aethiobola* Wnbg.).  
Absent from Greenland. G. Brit.

**V. maura** Wnbg. (D. B., p. 219).

Greenland. G. Brit.

**V. mucosa** Wnbg. (D. B., p. 219).

Greenland. G. Brit.

**V. nigrescens** Pers. (D. B., p. 219).

Absent from Greenland. G. Brit.

**V. rupestris** Schrad. (D. B., p. 219).

Greenland. G. Brit.

## DERMATOCARPACEÆ.

(Dermatocarpon.)

### Dermatocarpon.

**D. cinereum** Pers. (D. B., p. 219, Verrucaria).

Not found in Greenland. G. Brit.

**D. hepaticum** Ach. (D. B., p. 219).

Greenland. G. Brit.

**D. miniatum** L. *β. complicatum* Sw. (D. B., p. 219).

Greenland. G. Brit.

<sup>1</sup> Deichmann Branth: Lichenes Islandiæ, Botanisk Tidsskrift, 1903, vol. 25.

<sup>2</sup> Crombie: British Lichens, 1894—1911.

## PYRENULACEÆ.

(Arthopyrenia, Microthelia.)

**Arthopyrenia.**

**A. analepta** Ach. (D. B., p. 220, Sagedia, with f. **punctiformis** Ach.).  
Greenland. G. Brit.

**A. grisea** Schleich. (D. B., p. 220, Sagedia).  
Greenland. Not found in G. Brit.

**Microthelia.**

**M. micula** Flot. (D. B., p. 220).  
Not found in Greenland. G. Brit.

## II. CONIOCARPINEÆ.

## CALICIACEÆ.

(Coniocybe).

**Coniocybe.**

**C. furfuracea** L. (D. B., p. 220).  
Greenland. G. Brit.

## SPHÆROPHORACEÆ.

(Sphærophorus).

**Sphærophorus.**

**S. coralloides** Pers. (D. B., p. 220, Sphærophoron).  
Greenland. G. Brit.

**S. fragilis** L. (D. B., p. 220, Sphærophoron).  
Greenland. G. Brit.

## III. GRAPHIDINEÆ.

## ARTHONIACEÆ.

(Arthonia.)

**Arthonia.**

**A. proximella** Nyl. (D. B., p. 219).  
Greenland. G. Brit.

**A. punctiformis** Ach. (D. B., p. 219).  
Not found in Greenland. G. Brit.

**A. ruderalis** Nyl. On tuff, Reyðarfjord, O. Galløe, 1913.  
New to Iceland. G. Brit.



#### IV. CYCLOCARPINEÆ.

##### DIPLOSCHISTACEÆ.

(Diploschistes).

##### **Diploschistes.**

**D. scruposus** L. (D. B., p. 212, Urceolaria).  
Greenland. G. Brit.

##### GYALECTACEÆ.

(Gyalecta.)

##### **Gyalecta.**

**G. cupularis** Ehrh. (D. B., p. 217).  
Not found in Greenland. G. Brit.

**G. geoica** Ach.  
Upon moss on blocks of basalt, Seyðisfjord, O. Galloe, 1913. New to Iceland. G. Brit.

**G. foveolaris** Ach. (D. B., p. 217).  
Not found in Greenland. G. Brit.

##### COENOGONIACEÆ.

(Coenogonium, Racodium).

##### **Coenogonium.**

**C. ebeneum** Dillw. (D. B., p. 202, Cystocoleus).  
Not found in Greenland. G. Brit.

##### **Racodium.**

**R. rupestre** Pers.  
On basalt, Seyðisfjord, O. Galløe, 1913. New to Iceland. G. Brit.

##### LECIDEACEÆ.

(Bacidia, Lecidea, Rhizocarpon, Catillaria, Lopadium, Toninia).

##### **Bacidia.**

**B. abbrevians** Nyl. (D. B., p. 217, Gyalecta).  
Not found in Greenland and in G. Brit.

**B. atrosanguinea** Schaer. (D. B., p. 216, Gyalecta).  
Not found in Greenland. G. Brit.

**B. arceutina** Ach. (D. B., p. 217, Gyalecta, with var. **egenula** Nyl.  
and var. **albescens**).  
Not found in Greenland. G. Brit.

- B. Beckhausii** Koerb. (D. B., p. 217, Gyalecta).  
Not found in Greenland. G. Brit.
- B. caudata** Nyl. (D. B., p. 216, Gyalecta).  
Not found in Greenland. G. Brit.
- B. (Bllimbia) coprodes** Koerb.  
On pebbles. Húsavík (N. Iceland), O. Galloe. New to Iceland.
- B. (Arthrorhaphis) flavo-virescens** Dicks. (D. B., p. 217, Mycobacidia).  
Greenland. G. Brit.
- B. herbarum** Hepp. (D. B., p. 217, Gyalecta).  
Not found in Greenland. G. Brit.
- B. milliaria** Fr. (D. B., p. 216, Gyalecta).  
Not found in Greenland. G. Brit.
- B. obscurata** Sommerf. (D. B., p. 216, Gyalecta).  
Greenland. G. Brit. Var. **microcarpa** Th. Fr. was also found.
- B. rubella** Ehrh. (D. B., p. 216, Gyalecta).  
Not found in Greenland. G. Brit.
- B. sphaeroides** Sommerf. (D. B., p. 216, Gyalecta).  
Greenland. G. Brit.
- B. squalescens** Nyl. (D. B., p. 215, Gyalecta).  
Not found in Greenland. G. Brit.
- B. subfuscula** Nyl. (D. B., p. 216, Gyalecta).  
Greenland.
- B. umbrina** (Ach.) Br. & Rostr. (D. B., p. 217, Gyalecta).  
Greenland. G. Brit.

### **Lecidea.**

- L. aglæa** Sommerf. (D. B., p. 214).  
Greenland.
- L. alpestris** Sommerf. (D. B., p. 215).  
Greenland. G. Brit.
- L. arctica** Sommerf. (D. B., p. 215).  
Greenland. G. Brit.
- L. arctogena** Th. Fr.  
On palagonite-mountains south of Húsavík, N. Iceland, O. Galloe,  
1913. New to Iceland.
- L. assimilata** Nyl. with v. *infuscata* (D. B., p. 215).  
Greenland.
- L. atrobrunnea** Ram. (D. B., p. 215).  
Greenland.
- L. atrorufa** Dicks. (D. B., p. 212, Psora).  
Greenland. G. Brit.
- L. auriculata** Th. Fr. (D. B., p. 214).  
Greenland. G. Brit.
- L. Berengeriana** Mass. (D. B., p. 213).  
Greenland. G. Brit.

**L. cinereoatra** Ach.

Pebbles on mountain south of Húsavík, N. Iceland, O. Galloë, 1913.  
On lava near Havnefjord, SW. Iceland, O. Galloë, 1913. New to Iceland.

**L. confluens** Fr. (D. B., p. 214).

Greenland. G. Brit.

**L. contigua** Hoffm. with var. *flavicunda* Ach., *macrocarpa* D. C.  
and *platycarpa* Ach. (D. B., p. 214).

Greenland. G. Brit.

**L. convexa** (Fr.) Th. Fr.

On lava near Havnefjord, SW. Iceland, O. Galloë, 1913. On the mountain south of Húsavík, N. Iceland, O. G., 1913. New to Iceland.

**L. crassipes** Th. Fr. (D. B., p. 215).

Not found in Greenland.

**L. crustulata** (Ach.) Koerb.

On pebbles, mountain south of Húsavík in N. Iceland, O. Galloë, 1913;  
on stones, high on the mountains, Öfjord, in N. Iceland, O. G., 1913.  
New to Iceland.

**L. cuprea** Sommerf. (D. B., p. 213).

Greenland. G. Brit.

**L. cyanea** (Ach.) Th. Fr. (D. B., p. 214, *L. tesellata*).

Greenland.

**L. decipiens** Ehrh. (D. B., p. 212, *Psora*).

Greenland. G. Brit.

**L. decolorans** Hoffm. (D. B., p. 213).

Greenland. G. Brit.

**L. Diapsisæ** Th. Fr. (D. B., p. 213).

Not found in Greenland.

**L. Dicksonii** Ach. (D. B., p. 215, *L. atroferrata* v. *Dicksonii*).

Greenland. G. Brit.

**L. elæochroma** Ach. (D. B., p. 213, *L. enteroleuca* with var. *muscorum* Wulf., *achrista* Sommerf., *Laureri* Hepp., *latypea* Ach., *pilularis* Dav., *dolosa* Ach.).

Greenland. G. Brit.

**L. elata** Schær. (D. B., p. 214).

Greenland.

**L. erratica** Koerb.

Vertical face of basalt, Seyðisfjord, O. Galloë, 1913. New to Iceland.

**L. erythrophæa** Flk. (D. B., p. 213).

Greenland.

**L. furvella** Nyl.

Lava near Reykjavík, O. Galloë, 1913. New to Iceland.

**L. fusca** Schaer. (D. B., p. 212).

Greenland.

*L. fuscescens* Sommerf. (D. B., p. 212).

Greenland. G. Brit.

*L. fuscoatra* Ach. (D. B., p. 215).

Greenland.

*L. granulosa* (Ehrh.) Schær.

On birch, Reykjavík in N. Iceland, O. Galloe, 1913. New to Iceland.

*L. helvola* (Koerb.) Th. Fr. (D. B., p. 213, *L. vernalis* f. *helvola*).

*L. lapicida* (Ach.) Fr. (D. B., p. 214).

Greenland. G. Brit.

*L. limosa* Ach. (D. B., p. 215).

Greenland. G. Brit.

*L. lithophila* Ach. (D. B., p. 214).

Greenland. G. Brit.

*L. lugubris* Sommerf. (D. B., p. 212, Psora).

Greenland. G. Brit.

*L. lurida* Sw. (D. B., p. 212, Psora).

Greenland. G. Brit.

*L. neglecta* Nyl. (D. B., p. 215).

Not found in Greenland. G. Brit.

*L. Nylanderi* Anzi (D. B., p. 213).

Not found in Greenland.

*L. panæola* Ach. (D. B., p. 214).

Greenland. G. Brit.

*L. pantherina* (Ach.) Th. Fr. (D. B., p. 214; *L. polycarpa*).

Greenland.

*L. paupercula* Th. Fr.

Lava near Reykjahlið near Mývatn, O. Galloe, 1913; stones, high on the mountains, near Öfjord, O. G., 1913. New to Iceland.

*L. ramulosa* Th. Fr.

On earth near Háls parsonage, N. Iceland, O. Galloe, 1913. New to Iceland.

*L. rubiformis* Wahlenbg. (D. B., p. 212, Psora).

Greenland. G. Brit.

*L. Siebenhaariana* Koerb.

Uppermost bare summit of the mountain of "Sulur" near Öfjord, O. Galloe, 1913. New to Iceland.

*L. speirea* Ach. (D. B., p. 214).

Not found in Greenland. G. Brit.

*L. subconfluens* Th. Fr.

Gravelly soil on the mountain of "Sulur" near Öfjord, O. Galloe, 1913. New to Iceland.

*L. tenebrosa* Flot. (D. B., p. 215).

Greenland. G. Brit.

*L. Tornoensis* Nyl. (D. B., p. 213).

Greenland.

**L. uliginosa** Schrad. (D. B., p. 213).  
Greenland. G. Brit.

**L. vernalis** (L.) Ach. (D. B., p. 213).  
Greenland. G. Brit.

### **Rhizocarpon.**

**R. alboatrum** Th. Fr. v. **epipolia** Ach. (D. B., p. 218, Buellia).  
Not found in Greenland. G. Brit.

**R. calcareum** Weis. (D. B., p. 218, Buellia).  
Greenland. G. Brit.

**R. geminatum** (Fw.) Th. Fr. (D. B., p. 218, Buellia).  
Greenland. G. Brit.

**R. geographicum** (L.) D. C. (D. B., p. 218, Buellia).  
Greenland. G. Brit.

**R. petraeum** Wulfen. (D. B., p. 218, Buellia, including the species  
*R. grande* Arn., *distinctum* Th. Fr., *obscuratum* Th. Fr.).

**R. viridiatrum** Flk. (D. B., p. 218, Buellia).  
Not found in Greenland. G. Brit.

### **Catillaria.**

**C. athallina** (Hepp.) Hellb.

On earth near Einarstaðir parsonage, N. Iceland, O. Galloe, 1913.  
New to Iceland.

**C. cumulata** Sommerf. (D. B., p. 216, Gyalecta).  
Greenland. G. Brit.

**C. Jemtlandica** Th. Fr. (D. B., p. 216, Gyalecta).

**C. tenticularis** Ach. (D. B., p. 216, Gyalecta).  
Not found in Greenland. G. Brit.

### **Lopadium.**

**L. fuscoluteum** Dicks. (D. B., p. 218, Buellia).  
Greenland. G. Brit.

**L. pezizoideum** (Ach.) Koerb. (D. B., p. 218, Buellia).  
Greenland. G. Brit.

### **Toninia.**

**T. squalida** (Ach.) Nyl. (D. B., p. 216, Gyalecta squarrosa).  
Greenland. G. Brit.

**T. syncomista** (Flk.) Th. Fr. (D. B., Gyalecta).  
Greenland. G. Brit.

**T. vesicularis** Hoffm. (D. B., p. 215, Gyalecta).  
G. Brit.

## CLADONIACEÆ.

(Baeomyces, Cladonia, Stereocaulon).

**Baeomyces.****B. byssoides** (L.) Th. Fr. (D. B., p. 212, Sphyridium).  
Not found in Greenland. G. Brit.**B. placophyllum** Wahlenbg. (D. B., p. 212, Sphyridium).  
Not found in Greenland. G. Brit.**Cladonia.****C. amaurocræa** (Flk.) Schaer. (D. B., p. 202, under *C. uncialis*).  
Greenland. G. Brit.**C. bellidiflora** (Ach.) Schaer. (D. B., p. 202).  
Greenland. G. Brit.**C. cariosa** (Ach.) Spreng. (D. B., p. 201).  
G. Brit. Not found in Greenland.**C. coccifera** (L.) Willd. (D. B., p. 201, *C. cornucopioides*).  
Greenland. G. Brit.**C. decorticata** (Floerke) Spreng. (D. B., p. 201).  
Greenland.**C. fimbriata** (L.) Fr. (D. B., p. 201).  
Greenland. G. Brit.**C. Floerkeana** (Fr.) Sommerf. (D. B., p. 201).  
Greenland. G. Brit.**C. foliacea** (Hudg.) Schaer. (D. B., p. 201, *C. aleicornis*).  
Greenland. G. Brit.**C. furcata** (Huds.) Schrad. (D. B., p. 201, with var. *subulata* Flk.,  
*racemosa* Hoffm. and *pungens* Ach.).  
Greenland. G. Brit.**C. gracilis** (L.) Willd. (D. B., p. 201, with var. *chordalis* Flk., *cervi-*  
*cornis* Ach. and *firma* Nyl.).  
Greenland. G. Brit.**C. pityrea** (Floerke) Fr. (D. B., p. 201, under *C. pyxidata*).  
G. Brit.**C. pyxidata** (L.) Fr. (D. B., p. 201, with var. *pityrea* Flk.).**C. rangiferina** L. (D. B., p. 201, with var. *silvatica* Hoffm.).  
Greenland. G. Brit.**C. rangiformis** Hoffm.On earth among Empetrum, Seyðisfjord, O. Galløe, 1913. New to  
Iceland.**C. uncialis** (L.) Web. (D. B., p. 202, with var. *adunca* Wahlenbg.  
and *amaurocræa* Flk.).  
Greenland. G. Brit.

**C. turgida** (Ehrh.) Hoffm.

On earth, the mountain of "Sulur" near Öfjord, N. Iceland, O. Galloë, 1913. New to Iceland.

### **Stereocaulon.**

**S. condensatum** Hoffm. (D. B., p. 201).

Not found in Greenland. G. Brit.

**S. coralloides** Fr.

Empetrumheath, Seyðisfjord, O. Galloë, 1913. New to Iceland.

**S. denudatum** Flk. (D. B., p. 201, especially v. **pulvinatum** Schaer.)  
Greenland. G. Brit.

**S. evolutum** Graewe (D. B., p. 201).

Greenland. G. Brit.

**S. incrustatum** Flk.

On earth, Reyðarfjord, East Greenland, O. Galloë, 1913. New to Iceland.

**S. paschale** (L.) Fr. (D. B., p. 201).

Greenland. G. Brit.

**S. tomentosum** (Fr.) Th. Fr. (D. B., p. 200, *Ster. tom.* and var. *alpinum* Laur.).

Greenland. G. Brit.

### **GYROPHORACEÆ.**

(Gyrophara).

### **Gyrophora.**

**G. arctica** Ach. (D. B., p. 205, *G. hyperborea* v. *arctica* Ach.).  
Greenland. G. Brit.

**G. cylindrica** L. (D. B., p. 206).  
Greenland.

**G. erosa** Web. (D. B., p. 205).  
Greenland. G. Brit.

**G. hyperborea** Ach. (D. B., p. 205).  
Greenland. G. Brit.

**G. murina** D C (D. B., p. 206).  
G. Brit.

**G. polyphylla** L. (D. B., p. 206).  
Greenland. G. Brit.

**G. proboscidea** L. with var. **deplicans** (D. B., p. 205).  
Greenland. G. Brit.

**G. vellea** L. (D. B., p. 206).  
Greenland. G. Brit.

## ACAROSPORACEÆ.

(Acarospora, Biatorella).

**Acarospora.****Ac. discreta** (Ach.) Th. Fr.Pebbles and firm rock near Húsavík, N. Iceland, O. Galloë, 1913.  
New to Iceland.**Ac. fuscata** (Schröd.) Th. Fr. (D. B., p. 212, *Ac. fusc.* v. *rufescens*).  
Not found in Greenland. G. Brit.**Ac. Heppii** (Naeg.) Koerb.On basalt, Seyðisfjörður in E. Iceland; on lava, Havnefjörður in SW.  
Iceland; O. Galloë, 1913. New to Iceland.**Biatorella.****B. Morio** Flk. with var. *pallescent*. (D. B., p. 218).  
Greenland. G. Brit.

## EPHEBACEÆ.

(Ephebe, Polychidium).

**Ephebe.****E. pubescens** L. (D. B., p. 202).  
G. Brit.**Polychidium.****P. muscicola** Sw. (D. B., p. 206).  
Not found in Greenland. G. Brit.

## LICHINACEÆ.

(Lichina).

**Lichina.****L. confinis** O. F. Müller (D. B., p. 202).  
Greenland. G. Brit.

## COLLEMACEÆ.

(Collema, Leptogium).

**Collema.****C. crispum** L. (D. B., p. 206).  
Not found in Greenland. G. Brit.**C. flaccidum** Ach. (D. B., p. 206, *Synechoblastus*).  
Greenland. G. Brit.



**C. nigrescens** L. (D. B., p. 206, Synechoblastus).

Not found in Greenland. G. Brit.

**C. pulposum** Bernh. (D. B., p. 206).

Greenland. G. Brit.

**C. verrucaeforme** L. (D. B., p. 206).

Not found in Greenland.

### **Leptogium.**

**L. lacerum** Sw. (with v. **pulvinatum** Ach.) (D. B., p. 206).

Greenland. G. Brit.

**L. (Collemodium) plicatile** Ach.

On basalt, Seyðisfjörður, O. Galløe, 1913. New to Iceland.

**L. scotinum** Ach. (D. B., p. 206).

Greenland. G. Brit.

## **PANNARIACEÆ.**

(Massalongia, Placynthium, Pannaria, Psoroma).

### **Massalongia.**

**M. carnosa** (Dicks.) Koerb.

Almannagjá near Thingvellir, SW. Iceland, O. Galløe, 1913. New to Iceland.

### **Placynthium.**

**P. delicatulum** Th. Fr. (D. B., p. 207, Lecothecium).

Not found in Greenland. G. Brit.

**P. nigrum** Huds. (D. B., p. 207, Lecothecium).

G. Brit.

### **Pannaria.**

**P. brunnea** Nyl. (D. B., p. 207).

Greenland. G. Brit.

**P. elaeina** Wahlenbg. (D. B., p. 207).

Not found in Greenland.

**P. granatina** Sommerf. (D. B., p. 207).

Greenland.

**P. Hookeri** Sm. (D. B., p. 207).

Greenland. G. Brit.

**P. lepidiota** Sommerf. (D. B., p. 207).

Greenland. G. Brit.

**P. microphylla** Nyl.

On earth near the summit of the mountain of "Sulur" (Öfjörður in N. Iceland), O. Galløe, 1913, and on the mountains in the same place, east of the fjord, *idem*, 1913. New to Iceland.

**P. triptophylla** Ach. (D. B., p. 207).

Greenland. G. Brit.

**Psoroma.**

**P. (Lecanora) Hypnorum** (Hoffm.) Ach. (D. B., p. 209, Squamaria).  
Greenland. G. Brit.

**STICTACEÆ.**

(Sticta).

**Sticta.**

**St. scrobiculata** Scop. (D. B., p. 203).  
Greenland. G. Brit.

**PELTIGERACEÆ.**

(Nephroma, Peltigera, Solorina).

**Nephroma.**

**N. arcticum** L. (D. B., p. 203).  
Greenland.

**N. expallidum** Nyl. (D. B., p. 203).  
Greenland.

**N. laevigatum** v. **parile** Ach. (D. B., p. 203).  
Greenland. G. Brit.

**N. tomentosum** Hoffm. (D. B., p. 203).  
Greenland. G. Brit.

**Peltigera.**

**P. aphtosa** L. (D. B., p. 202).  
Greenland. G. Brit.

**P. canina** (L.) Fr. (D. B., p. 202).  
Greenland. G. Brit.

**P. horizontalis** L.  
Empetrum-heath, Seyðisfjord, O. Galloë, 1913. New to Iceland.

**P. lepidophora** Nyl.  
On volcanic tuff near Ljósavatn farm, N. Iceland; heaths near Einarstaðir, N. Iceland; heath near Myvatn, N. Iceland; mountain-heath near Húsavík, N. Iceland; mountain-heath near Ölfjord, N. Iceland. O. Galloë, 1913. New to Iceland.

**P. malacea** (Ach.) Fr. (D. B., p. 202).  
Greenland. G. Brit.

**P. polydactyla** f. **collina** Ach. (D. B., p. 202).  
Greenland. G. Brit.

**P. rufescens** Fr. (D. B., p. 202).  
Greenland. G. Brit.

**P. venosa** (L.) Hoffm. (D. B., p. 203).  
Greenland. G. Brit.

**Solorina.**

**S. bispora** Nyl. (D. B., p. 203).

Greenland. G. Brit.

**S. crocea** Ach. (D. B.), p. 203).

Greenland. G. Brit.

**S. saccata** L. (D. B., p. 203).

Greenland. G. Brit.

PERTUSARIACEÆ.

(Pertusaria).

**Pertusaria.**

**P. communis** D C. (D. B., p. 211).

Not found in Greenland. G. Brit.

**P. coriacea** Th. Fr. (D. B., p. 211).

Not found in Greenland.

**P. corallina** (L.) Arn.

On lava, Havnefjord in SW. Iceland, O. Galloë, 1913. New to Iceland.

**P. dactylina** Ach. (D. B., p. 211).

G. Brit.

**P. oculata** Dicks. (D. B., p. 210, Lecanora).

Greenland. G. Brit.

**P. rhodoleuca** Th. Fr. (D. B., p. 211).

Not found in Greenland.

**P. xanthostoma** (Sommerf.) Fr. (D. B., p. 211).

Not found in Greenland. G. Brit.

LECANORACEÆ.

(Haematomma, Lecania, Lecanora).

**Haematomma.**

**H. coccineum** (Dicks.) Koerb.

On lava near Havnefjord, SW. Iceland, O. Galloë, 1913. New to Iceland.

**H. ventosum** L. (D. B., p. 211, Lecania).

Greenland. G. Brit.

**Lecania.**

**L. athroocarpa** (Dub.) Nyl. (D. B., p. 211).

Not found in Greenland. G. Brit.

**L. cyrtella** Ach. (D. B., p. 211).

Not found in Greenland. G. Brit.

**Lecanora.**

**L. albescens** v. **dispersa** Pers. (D. B., p. 210).

Not found in Greenland. G. Brit.

**L. alphoplaca** Wahlenbg. (D. B., p. 209, Squamaria).  
Greenland. G. Brit.

**L. alpina** Sommerf.

On Liparite, Hlíðarfjall near Mývatn, N. Iceland; erratic blocks on the mountains east of Öfjörð; on stones in Almannagjá, SW. Iceland. O. Galloë, 1913. New to Iceland.

**L. atra** (Huds.) Ach. (D. B., p. 210).  
Greenland. G. Brit.

**L. atriseda** Fr. (D. B., p. 210).  
Not found in Greenland. G. Brit.

**L. atrosulphurea** (Wahlenbg.) Ach. (D. B., p. 210, *L. variæ* forma).

**L. badia** (Pers.) Th. Fr. (D. B., p. 210).  
Greenland. G. Brit.

**L. calcarea** (L.) Sommerf.

On basalt, Reyðarfjörð in E. Iceland, O. Galloë, 1913. New to Iceland.

**L. cartilaginea** Westr. (D. B., p. 208, Squamaria).  
Not found in Greenland. G. Brit.

**L. castanea** (Hepp.) Th. Fr. (D. B., p. 210).  
Not found in Greenland.

**L. chrysoleuca** Sm. (D. B., p. 209, Squamaria) f. *rubina* Vill. and *melanophthalma* Nyl.  
Greenland. G. Brit.

**L. cinerea** (L.) Sommerf. (D. B., p. 210).  
Greenland. G. Brit.

**L. cinereo-rufescens** Dicks. (D. B., p. 211).  
Greenland. G. Brit.

**L. coarctata** v. *ornata* Sommerf. (D. B., p. 210).  
G. Brit.

**L. frustulosa** (Dicks.) Koerb. (D. B., p. 209).  
Greenland. G. Brit.

**L. gelida** (L.) Ach. (D. B., p. 208, Squamaria).  
Greenland. G. Brit.

**L. gibbosa** (Ach.) Nyl. (D. B., p. 210).  
Greenland. G. Brit.

**L. Hageni** (Ach.) Koerb. (D. B., p. 209).  
Greenland. G. Brit.

**L. lacustris** Wither. (D. B., p. 211).  
Greenland. G. Brit.

**L. pallescens** (L.) Schær. (D. B., p. 211) with var. *parella* L. and *Upsaliensis* L.  
Greenland. G. Brit.

**L. poliophæa** Wahlenbg. (D. B., p. 209).  
G. Brit.

**L. polytropæa** Ehrh. (D. B., p. 210, *L. variæ* forma).

- L. protuberans** Sommerf. v. **carneopallida** Nyl. (D. B., p. 210).  
Greenland. G. Brit.
- L. saxicola** (Poll.) Stenh. (D. B., p. 209, Squamaria).  
Greenland. G. Brit.
- L. sordida** (Pers.) Th. Fr. v. **glaucoma** (Hoffm.) Th. Fr. (D. B., p. 209).  
G. Brit.
- L. straminea** Wahlenbg. (D. B., p. 209, Squamaria).  
Greenland.
- L. subfusca** (L.) Ach. (v. **coilocarpa** Ach., **Hypnorum** (Wulf.) Schaer.,  
**glabrata** Ach., **rugosa** Pers., **atrynea** Ach.) (D. B., p. 209),  
Greenland. G. Brit.
- L. tartarea** L. (D. B., p. 211).  
Greenland. G. Brit.
- L. varia** (Ehrh.) Nyl. (D. B., p. 210, with var. **symmicta** Ach., **polytropia** Ehrh., **intricata** Schrad., **atrosulphurea** Wahlenbg., **leptacina** Sommerf.).  
Greenland. G. Brit.
- L. verrucosa** Ach. (D. B., p. 211).  
Greenland. G. Brit.

## PARMELIACEÆ.

(Cetraria, Parmelia).

### Cetraria.

- C. aculeata** Fr. (D. B., p. 200).  
Greenland. G. Brit.
- C. cucullata** Bell. (D. B., p. 204).  
Greenland. G. Brit.
- C. Fahlunensis** (L.) Schaer. (D. B., p. 204).  
Greenland.
- C. hiascens** (Fr.) Th. Fr.  
On earth on mountains near Húsavík, N. Iceland; on mountains east of Öfjord, O. Galloe, 1913. New to Iceland.
- C. Islandica** Ach. with var. **crispa** Ach. and **Delisei** Bory. (D. B., p. 203).  
Greenland. G. Brit.
- C. nivalis** (L.) Ach. (D. B., p. 203).  
Greenland. G. Brit.
- C. sæpincola** (Ehrh.) Ach. with v. **chlorophylla** Humb. (D. B., p. 204).  
Greenland. G. Brit.

### Parmelia.

- P. alpicola** Th. Fr. (D. B., p. 205).  
Greenland. G. Brit.

*P. ambigua* Ach. (D. B., p. 204).

Greenland. G. Brit.

*P. encausta* Sm. (D. B., p. 204, *P. enc. v. intestiniformis* Vill.).

Greenland. G. Brit.

*P. incurva* Pers. (D. B., p. 204).

Greenland. G. Brit.

*P. lanata* (L.) Walbr. (D. B., p. 204).

Greenland. G. Brit.

*P. olivacea* L. (D. B., p. 204, f. *prolixa*, *fuliginosa*, *sorediata*, *aspidota*).

Greenland. G. Brit.

*P. physodes* L. (D. B., p. 204).

Greenland. G. Brit.

*P. saxatilis* L. with v. *omphalodes* (L.) Fr. (D. B., p. 204).

Greenland. G. Brit.

## USNEACEÆ.

(*Alectoria*, *Evernia*, *Ramalina*, *Thamnolia*, *Usnea*).

### **Alectoria.**

*A. divergens* Ach. (D. B., p. 200).

G. Brit.

*A. jubata* L. (D. B., p. 200, *Bryopogon*).

Greenland. G. Brit.

*A. nigricans* Nyl. (D. B., p. 200).

Greenland. G. Brit.

*A. ochroleuca* Nyl. (D. B., p. 200, with v. *cincinnata* Fr.).

### **Evernia.**

*E. furfuracea* L. (D. B., p. 204).

G. Brit.

### **Ramalina.**

*R. scopulorum* Retz (D. B., p. 200, "inclusis *cuspidata* Nyl. et formis inter *farinaceam* L. et *R. scop. intermediis*").

*R. subfarinacea* Nyl. (D. B., p. 200, probably included in *R. scop.*).

### **Thamnolia.**

*Th. vermicularis* Schær. (D. B., p. 202).

Greenland. G. Brit.

### **Usnea.**

*U. melaxantha* Ach. (D. B., p. 200).

Greenland.

CALOPLACACEÆ.

(Caloplaca).

**Caloplaca.**

- C. aurantiaca** Lightf. (D. B., p. 208, Placodium).  
G. Brit.
- C. cerina** (Ehrh.) Th. Fr. (D. B., p. 207, Placodium cer. f. stilli-  
cidiorum).  
Greenland. G. Brit.
- C. citrina** Ach. (D. B., p. 208, Placodium).  
G. Brit.
- C. diphyes** Nyl. (D. B., p. 208, Placodium).  
Not found in Greenland.
- C. elegans** (Link) Th. Fr. (D. B., p. 205, Xanthoria).  
Greenland. G. Brit.
- C. ferruginea** (Huds.) Th. Fr. v. **obscura** Th. Fr. (D. B., p. 208,  
Placodium).  
Greenland. G. Brit.
- C. Jungermanniae** (Vahl) Th. Fr. (D. B., p. 208, Placodium jung.  
and var. **leucoraeum**).  
Greenland.
- C. murorum** Hoffm. with var. **miniatum** Ach. and **obliteratum** Pers.  
(D. B., p. 207, Placodium).
- C. nivale** Koerb. (D. B., p. 208, Placodium).  
G. Brit.
- C. obscurella** Lahm. (D. B., p. 208, Placodium).  
Not found in Greenland.
- C. pyracea** (Ach.) Th. Fr. (D. B., p. 208, Placodium).  
Greenland. G. Brit.
- C. tetraspora** Nyl. (D. B., p. 208, Placodium).  
Not found in Greenland.
- C. vitellina** (Ehrh.) Th. Fr. (D. B., p. 207, Placodium).  
Greenland. G. Brit.

THELOSCHISTACEÆ.

(Xanthoria).

**Xanthoria.**

- X. lichnea** (Ach.) Th. Fr. (D. B., p. 205, X. par. v. lichnea).  
Greenland. G. Brit.
- X. parietina** L. (D. B., p. 205).  
Greenland. G. Brit.

## BUELLIACEÆ.

(Buellia, Rinodina).

**Buellia.****B. aethalea** (Ach.) Th. Fr.

Palagonite-tuff near Húsavík, N. Iceland, O. Galloe, 1913. New to Iceland.

**B. atroalba** Ach. (D. B., p. 218, with var. *chlorospora* Nyl.).**B. badia** Koerb. (D. B., p. 217).

Not found in Greenland.

**B. coniops** Wahlenbg. (D. B., p. 217).

Greenland. G. Brit.

**B. leptocline** Flot. (D. B., p. 217).

Not found in Greenland. G. Brit.

**B. myriocarpa** (D. C.) Mudd. (D. B., p. 217).

Greenland. G. Brit.

**B. parasema** (Ach.) Th. Fr. var. *muscorum* (Schær.) Th. Fr., *papillata* (Sm.) Th. Fr., *triphragmia* (Nyl.) Th. Fr., *albocincta* (D. B., p. 217).  
Greenland. G. Brit.**B. scabrosa** Koerb. (D. B., p. 212, *Karschia*).

G. Brit.

**B. stellulata** Tayl. (D. B., p. 218).

Greenland. G. Brit.

**B. tesserata** Koerb.

Cliffs, Seyðisfjord in E. Iceland, O. Galloe, 1913. New to Iceland.

**B. vilis** Th. Fr. (D. B., p. 217).

Not found in Greenland.

**Rinodina.****R. Conradi** Koerb. (D. B., p. 212, *Urceolaria*).

Greenland. G. Brit.

**R. mniaroea** (Ach.) Th. Fr. v. *cinnamomea* Th. Fr. (D. B., p. 212, *Urceolaria*).**R. sophodes** Ach. (D. B., p. 212, *Urceolaria soph.* and var. *confragosa* Ach., v. *exigua* Ach.).

Greenland. G. Brit.

**R. turfacea** Wahlenbg. (D. B., p. 212, *Urceolaria*).

Greenland.

## PHYSCIACEÆ.

(Physcia).

**Physcia.****P. aipolia** Nyl.

On basalt, Seyðisfjord in E. Iceland, O. Galloe, 1913. New to Iceland.



**P. aquila** Ach. (D. B., p. 205).  
G. Brit.

**P. caesia** (Hoffm.) Nyl. (D. B., p. 205, *P. stellaris* v. *caesia*).  
Greenland. G. Brit.

**P. ciliaris** L. (D. B., p. 205, *P. cil.* and v. *scopulorum* Nyl.).  
Greenland. G. Brit.

**P. pulverulenta** Nyl. v. *muscigena* Nyl. (D. B., p. 205).  
Greenland. G. Brit.

**P. obscura** (Ehrh.) Nyl. (D. B., p. 205).  
Greenland. G. Brit.

**P. stellaris** L. (D. B., p. 205).  
Greenland. G. Brit.

## II. THE MEANS OF PROPAGATION AND DISPERSAL OF THE ICELAND LICHENS.

---

After having considered, in the above, the composition of the Flora, the next point to be investigated is, by which means of propagation we can imagine that the species have been dispersed over the island, and have immigrated from the surrounding countries into Iceland, and *vice versa*.

Lichens are propagated by Ascospores, Pycnoconidia, Soredia, and detached portions of thallus.

Ascospores must be assumed to be the original means of propagation, which, as we know, has been handed down directly from the prototypes of the lichens, the Ascomycetes. Those lichens which still stand on a low, primitive phylogenetic stage, viz. the Crustaceous Lichens, have still, almost all, as a rule more or less numerous apothecia, usually with numerous well-developed spores. In the synoptic list of the chief biological conditions of the lichens of Iceland (see below) it will be seen that all the crustaceous lichens have been, and as a rule will be, found with apothecia. Among the Foliaceous Lichens there are several which often occur in great abundance, but are nevertheless rarely found with apothecia. This is for instance the case with *Cetraria aculeata*, *C. cucullata*, *C. hiascens*, *C. nivalis*, *Nephroma* spp., some *Pelligera* spp., *Physcia pulverulenta* v. *muscigena*, and perhaps a few other species. As will be seen, it is all the leaf-shaped earth-lichens which can undoubtedly be propagated by detached portions of thallus, which; when the plant is in a dry condition, are widely dispersed by the wind, or perhaps also, in part, by animals; but no thorough investigations are to hand as regards this point. What has been said of the foliaceous lichens is also frequently the case among the Fruticose Lichens, namely, that apothecia are rare, while other means of

propagation, soredia or detached portions of thallus, are extremely common. This is the case for instance with *Alectoria* and several *Cladonia* spp. Here there undoubtedly also exists a certain correlation between these means of propagation, vegetative means of propagation in several species being of far greater importance for the dispersal of the species, than ascospores. This phenomenon of vegetative propagation is known from several places; thus in Denmark *Cladonia rangiferina* is sterile as a rule, and is most frequently propagated there by detached portions of podetia, and the same is the case with *Cladonia uncialis*, etc.: this circumstance, however, has been exhaustively discussed by me previously (Galløe, 1913, p. 41, and under the different species in the same paper). As regards *Thamnolia vermicularis*, it never forms apothecia.

As to how the ascospores escape from the ascus and their mode of dispersal, are but little known. There is much which goes to show that in the majority of species the spores are dry bodies, which are carried away by the wind and thereby dispersed. But it is just possible that in some of the species they are sticky, and require other means of dispersal.

Pycnoconidia. At present very little is known as regards the extent to which pycnoconidia occur among the Crustaceous, Foliaceous and Fruticose Lichens, nor is it known what rôle they play as regards propagation. They have been regarded both as male reproductive cells, and as vegetative means of propagation. In some cases, investigators have succeeded in producing the lichen-thallus by bringing together pycnoconidia and gonidia in a pure culture, that is, have succeeded in propagating lichens vegetatively by pycnoconidia; this, however, does not necessarily compel us to regard the pycnoconidia of all species as vegetative means of propagation.

To regard pycnoconidia as male reproductive cells, is perhaps more disputable; their importance as such has not at any rate been proved; their entire biological importance is consequently rather problematic. To make investigations regarding this point will, no doubt, well repay the trouble. According to what has just been said, nothing can be stated at the present time as to whether there exists any correlation between the occurrence of pycnoconidia and the occurrence or absence, respectively, of other means of propagation.

Soredia, as is well-known, are small bodies which consist partly of hyphæ and partly of gonidia, and are formed sometimes in quite accidental places the on thallus, sometimes in fairly well-

defined patches, the so-called sorals. They have been regarded partly as a peculiar means of propagation produced recently, from a phylogenetic point of view, in the more differentiated (little primitive) species, partly as a pathological phenomenon, due to the fact that the gonidia, with abundant moisture, grow "wild," and burst the outer morphological frame, which the lichen-hyphæ would give to each species, as the one characteristic to the species.

That soredia-production may be pathological, and in many cases is exclusively so, I take for granted, but I am equally convinced that it is not so in all cases. Because in that case, *Cladonia pityrea*, for instance, which is always sorediiferous, must be regarded as a pathologically deformed form of another species, which, under normal conditions, has a quite different appearance. Something to that effect we were obliged to assume as regards the many other lichens, entirely or partially covered with soredia, which occur all over the world. But that such a view cannot be maintained, I consider as certain. It must, however, be pointed out that cultural experiments alone, can decide this question, and such experiments have not been made. It would be necessary, for instance to cultivate soredia in a place drier than that where the sorediiferous species in question has been collected, and try if such a culture would produce a totally different, non-sorediiferous individual, which might, perhaps, prove to be a species already known. Whether soredia-production is a pathological or a normal feature, at all events there is no doubt that it is promoted by dampness.

Soredia have also been regarded as a normal means of propagation in the species in question, and there is no reason whatever to doubt that they may be of this importance. In itself there is nothing to prevent soredia-production from being in some cases pathological, in others normal.

In the Crustaceous Lichens of Iceland soredia-production does not appear to be a common phenomenon. I did not find it widely distributed. *Lepraria* appears to be much less widely distributed in Iceland than in Denmark. Among the Foliaceous Lichens, soredia-production is met with in *Cetraria saepincola* v. *chlorophylla*, *Parmelia ambigua*, *incurva*, *physodes*, *saxatilis*, *stygia*, *Physcia cæsia*, *obscura* and *stellaris*.

Among the Fruticose Lichens it is found in several *Cladonia* species (*Floerkeana*, *pityrea*, *fimbriata*, etc.), *Ramalina subfarinacea* and *Usnea melaxantha*. In several of these species soredia appear

to be a very common means of propagation, and to occur where apothecia are rare, or not very frequent, (e. g. *Cladonia fimbriata*, *Ramalina subfarinacea* and *Usnea melaxantha*). The soredia are dispersed by the wind, or perhaps by adhering to the hair of animals.

Detached portions of thallus as a means of propagation are not known to occur with any certainty in a single Crustaceous Lichen. It is probable that this happens in the above-mentioned Foliaceous Lichens. In the Fruticose Lichens it has been demonstrated with certainty in several earth-lichens (*Cladonia*, etc., for instance *Cladonia rangiferina*, *uncialis*, *rangiformis*, etc.). In 1913 I fully mentioned and figured it in several species. It appears to be a very important and widely distributed means of propagation in several species, and largely replaces propagation by ascospores, which in such species usually occur rather rarely.

Dispersal takes place no doubt both by the agency of the wind and of animals.

If we consider the way in which lichens may be assumed to have been dispersed in Iceland itself, we must understand clearly that ascospores, pycnoconidia, soredia, and detached portions of thallus are, as far as we know at present, generally dispersed by the agency of the wind. But animals also no doubt, more or less, play their part in it. It may be regarded as certain that almost all animals that wander about in Iceland occasionally get lichen-spores, portions of thallus, etc. attached to them. Sheep that roam about almost everywhere, undoubtedly play no small rôle as disseminators, and the same, I dare say, applies to the majority of the other terrestrial animals, wild as well as tame. How far means of propagation such as ascospores and pycnoconidia, after having passed through the digestive organs of lichen-eating animals (sheep and reindeer), retain their power of germination, is not known in any single instance. Here, as everywhere in the lichen-biology, we stand at the present time just at the stage of asking questions, without as yet having got very many of them answered, because lichenologists do not, on the whole, occupy themselves with biological problems. But in a general way it may be said that species which play any essential part as articles of food for animals, namely the larger shrub-like earth-lichens, are generally little dispersed by ascospores, for they bear fruit rather sparingly, as mentioned above.



Species such as *Cladonia rangiferma*, *Alectoria ochroleuca*, *Cetraria aculeata*, and *Alectoria nigricans* are undoubtedly far more frequently propagated by detached portions of thallus, some carried away by the wind, and others adhering to the body of animals.

That portions of thallus should be able to pass through the digestive organs of animals uninjured, is *a priori* improbable, — if such were the case, they would be rather useless as fodder! Any possibility of such dispersal by means of herbivorous animals, is thus scarcely possible.

But water, also, plays a part in the dispersal of lichens. By the agency of water, the submerged *Verrucaria* spp. which live along the coasts, are undoubtedly dispersed. Then it is probable that the lichens which occur by water-falls, part of which live washed by the falling water (for instance *Staurothele clopima*), are dispersed by the downward-flowing water.

---

If we now consider the agencies which play or have played a part in the exchange of lichen-species with the surrounding countries, we must, as in the case of dispersal in Iceland itself, point out three different agencies: wind, water and animals.

The lichens which may be assumed to have immigrated, (respectively emigrated,) by the agency of the wind, are firstly all those that propagate by ascospores, consequently, practically all the crustaceous lichens, at any rate, by far the greater part of the species (about 65 %): then next, the majority of the foliaceous lichens, possibly all of them (there are altogether about 21 % of them); and lastly some fruticose lichens. As regards the latter, however, it must be taken for granted, that at least *Thamnolia vermicularis* did not migrate in the form of spores, as it never bears fruit.

Some of the species have probably also migrated by means of pycnoconidia, but as the occurrence of the latter in the species is very incompletely known, and as their importance as a means of propagation may be disputed, it is not possible to form any opinion as to what importance they are of or have been, in respect to immigration.

Lastly, some species have migrated as soredia. As mentioned above the soredium is not a very common means of propagation in the Icelandic species; in the crustaceous lichens it is extremely rare. I am not prepared to state with any certainty in how many

species it occurs, but if it be found in about 20 species, that is no doubt all, and does not form even one-tenth of the species. The chief means of propagation of crustaceous lichens is, as we know, ascospores.

In the foliaceous lichens it has been found in the species about 9 — mentioned above, that is to say, in about one-sixth of the total number of species.

In how many species of fruticose lichens it has been found, cannot be stated with any certainty, but doubtless, the number does not greatly exceed that of the foliaceous species.

Whether any immigration has taken place by means of detached portions of thallus which have been conveyed by the wind, it is impossible to decide. It has been mentioned above that this mode of dispersal plays a considerable part within the boundaries of the country, with regard to many of the fruticose and foliaceous lichens. But whether portions of thallus, capable of germination, are really transported through the air from the surrounding countries, cannot, of course, be known, but the possibility is scarcely precluded.

Judging from the above, the rôle which we must assume that the wind has played in the immigration and emigration of Iceland's species, is thus very considerable, as all the crustaceous lichens and the majority — perhaps even all — of the fruticose and foliaceous lichens have such means of dispersal (ascospores, pycnocodia, soredia and detached pieces of thallus) as justify us in believing that the wind in particular has transported them to the country.

Water has played a far less considerable part as a means of dispersal, in fact, it can be assumed only with regard to the few submerged *Verrucaria* spp., and the emergent *V. maura*, that they have immigrated by this means. They occur doubtless, over nearly the whole of the Arctic, and over great parts of the adjoining climate-areas, on cliffs out in the sea. They are common on the coasts of Greenland, Iceland, Norway, the Færøes, Denmark and Great Britain, consequently both in Arctic and in temperate regions. They constitute altogether not above 2—3 % of the flora of Iceland.

What importance animals have had as regards immigration is quite unknown. Here again it must suffice us to frame questions which will, perhaps, in the future, be taken up and answered by others.

Primarily it may be supposed that birds of passage which migrate backwards and forwards between Iceland and milder regions,

according to the season of the year, may transport lichen-“germs” capable of germination, to Iceland, but nothing is known regarding this point. At the present time it is not even possible to procure a list of the lichens, which grow on cliffs inhabited by sea-fowl in both Scotland and Iceland, from which an opinion could be formed as to how far such transport between these countries is probable. But even if there were a distinct agreement of flora between such localities, that would by no means prove that the transport had been made only by birds. We should be justified in assuming that the lichen-“germs” have been carried along by wind or perhaps water and that this agreement is due to the similarity of the substratum, i. e. one especially manured by birds, as regards the solution of this question, there is scarcely any other way out of the difficulty, than by a direct investigation of what migrating birds can possibly carry of lichen spores and parts along with them, adhering to their feet or to other parts of their bodies, when they arrive at the country in spring; but this will be a very minute and difficult investigation.

But whatever the result may be at which we arrive by that method, it will not be able to modify, to any degree worth mentioning, the view that all other means of migration taken together, scarcely play so great a part in the immigration, as does transport by wind. Even if we imagined all other means eliminated, the flora would, in all probability, have acquired the same essential composition, as that now existing, by the agency of the wind alone; all our knowledge of the means of dispersal of the species is suggestive of this. But this does not exclude the possibility that many species are transported into the country in more ways than one, for instance both by birds and by wind.

It is only with regard to the few submerged species, that the wind has probably played no part at all. Here I believe ocean-currents, and perhaps sea-fowl, have been the transporting agencies.

---



### III. THE BIOLOGY OF THE LICHENS OF ICELAND.

---

**L**ICHENS may be divided into the following biological types: — Bark, (Epiphyllous), Earth, Rock, (Parasitic) and (Saprophytic) lichens. The three enclosed in brackets are wanting in Iceland, (but possibly one or other of the last two groups may be found there), and therefore will not be discussed here. With regard to these it will suffice to refer the reader to my treatise “Forberedende Undersøgelser til en almindelig Lichenøkologi” (1913).

#### 1. BARK LICHENS.

To this group I refer not only those which grow on the bark of trees, but also such as grow on bare wood (telegraph poles, surfaces of wooden houses, etc.). These substrata have practically not been investigated as regards lichen-biology, whilst their anatomy has been investigated long ago.

The chemical properties of the bark and their importance to lichens, are as yet very superficially known. The bark always contains organic substances (suberin, cellulose, tannin, resin, etc.), inorganic salts, etc. Besides, it may be taken for granted, that the outside layer of bark is generally more decomposed than are the inner ones. That the bark differs distinctly as a substratum according to whether it is young or old, is evident from the investigations which Lotsy (1890) and I myself have made, regarding the immigration-history of the lichens on bark. These investigations have shown that the pioneer vegetation always consists of certain crustaceous lichens, and is not replaced until later by the permanent vegetation. I have no certain knowledge of this immigration-history as regards Iceland, but I have reason to believe that the rule mentioned above also holds good there.

Judging from what is known, the reason for this vegetation order is a fairly similar process of decomposition in the different kinds of bark, for barks even very different physically (smooth and

scaly) show quite analogous features in the development-history of the vegetation.

I am not aware of the existence of any thorough chemical investigation of the different kinds of bark, nor do I believe that such exists, except perhaps as regards the officinal barks.

Neither have, as yet, the physical conditions of bark been investigated. We can, upon a superficial survey, immediately distinguish between the two, well-known groups, smooth bark and scaly bark. They are easily distinguished from each other.

I have known, as a general fact, that the systematic species of the tree, is of no importance to the biological types which settle down on its bark, as crustaceous, foliaceous and fruticose lichens may be found on all of them. Which of these types is to dominate the vegetation when it is fully developed, depends on the degree of light to which the tree is exposed, and other meteorological circumstances, as I have shown in my work on "Danske Licheners Økologi" (1908).

On the other hand, the floristic composition of the vegetation varies essentially, according to the systematic species of the tree. Experience shows that certain lichens occur by preference on certain species of trees, (*Usnea* spp. on coniferous trees, etc.). It is possible that, by more thorough investigations, we shall also be able to find fixed rules for this association, but as yet nothing is known regarding this point. At present we must be content with the lists of lichens compiled for each species of tree, as has been done in "Danske Likeners Økologi," and as regards Iceland, when discussing the lichens of the Birch later on in this paper.

Wood. Many species which occur most frequently on bark, may occasionally be found on bare wood. Wood is chemically closely related to bark, and the lichens which occur on it can, as a matter of course, be classified among the bark lichens. It must, however, be mentioned with respect to the growth-tensions which occur in the bark during the growth of the tree, and which are inclined to stretch the crust-shaped lichens into elliptical or oval crusts, with the main axis of the ellipse at right-angles to the longitudinal axis of the tree, that these, of course, will not be found in dead wood. There, on the contrary, the crustaceous lichens grow parallel with the "fibres," i. e. parallel with the longitudinal axis of the stem, hence the reason why lichen-crusts which grow uninfluenced by neighbours and competitors, are very often oval or

elliptic in shape, with their main axis parallel with the longitudinal axis of the tree.

In Iceland there occurs rather a common wood-substratum, namely the old decomposed walls of the wooden houses. On such walls I found the following common species: —

Buellia myriocarpa.	Caloplaca vitellina.
Lecanora Hageni.	— pyracea.
— varia.	Phycia obscura.
— subfusca.	

Bark-lichens may be divided into Crustaceous, Foliaceous and Fruticose lichens.

Of Crustaceous bark-lichens there are two different types, hypophlæodal and epiphlæodal.

The hypophlæodal crustaceous-lichens (numerous *Graphidæ*, etc.) have, as regards their attachment to the substratum, been long ago investigated very thoroughly by Lindau (1895), to whose treatise I refer the reader.

Their thallus lives in the interior of the bark of trees, covered by its cells, which afford the lichen protection against evaporation. According to Lindau their hyphæ appear to be quite unable to dissolve the cellulose of the bark, so they probably live on its decomposition-products. They themselves, however, contribute towards decomposition by bursting asunder the cells by the tension of their growth, whereby air and water gain access to the bark. The thallus is otherwise homoiomerous in structure in several of the species, in others distinctly heteromerous; consequently, on the whole, very primitive, and only slightly removed from the purely mycelial fungal prototypes.

The hypophlæodal crustaceous-lichens stand extremely low both in respect to morphology and anatomy, and as regards their capacity for competition with other plants. They live exclusively on the bark of trees and have no analogues among the earth-lichens and only a few (and these even very disputable,) among the rock-lichens with endolithic thallus. Only where other bark-lichens are absent for various reasons, may these occur, but if the conditions are favourable to fruticose and foliaceous lichens, they are immediately expelled by these. They are most frequent on smooth bark — the numerous smooth-barked trees of the tropics house an abundance of them — and they remain there so long as the bark is not decomposed enough to house other, more pretentious types.

The course of development in the decomposition of the bark, and the consequent change of vegetation from hypophlœodal to epiphlœodal and other bark lichens, may be studied on almost every old tree.

How many of Iceland's bark lichens are hypophlœodal, has not been investigated.

The epiphlœodal crustaceous-lichens are fastened to the substratum like the hypophlœodal; they have been investigated by Lindau (1895). They have a hyphal tissue that sinks into the bark and ruptures the cells of the bark, but is not able to dissolve their cellulose. The gonidia-containing part of the thallus is on the surface of the bark, — hence their name — and is more or less distinctly covered with a cortex, showing all transitions between species with the thinnest and the thickest cortex.

In several crustaceous lichens soredia are formed which can propagate the plant, for instance in the *Variolaria* spp. This mode of propagation indicates a higher morphological stage than that of the hypophlœodals, in which anything like it appears to be rare.

With regard to competitive capacity, in most of the habitats the epiphlœodals stand above the hypophlœodals, but they generally appear to need a more advanced stage of decomposition of the bark, than do the latter, so that they frequently succeed to them as the bark gradually gets older. It is possible that they also require more light.

Of crustaceous bark-lichens Iceland has the following: —

<i>Arthonia proximella</i> Nyl.	<i>Lecania cyrtella</i> Ach.
— <i>punctiformis</i> Ach.	<i>Lecanora atra</i> (Huds.) Ach.
<i>Arthopyrenia analepta</i> Ach.	— <i>Hageni</i> (Ach.) Koerb.
— <i>grisea</i> Schleich.	— <i>pallescent</i> (L.) Schaer.
<i>Bacidia abbrevians</i> Nyl.	— <i>protuberans</i> Sm.
— <i>arceutina</i> Ach.	— <i>subfusca</i> (L.) Ach.
— <i>atrosanguinea</i> Schaer.	— <i>tartarea</i> L.
— <i>Beckhausii</i> Koerb.	— <i>varia</i> (Ehrh.) Nyl.
— <i>rubella</i> Ehrh.	<i>Lecidea crustulata</i> (Ach.) Koerb.
— <i>sphaeroides</i> .	— <i>Diapensiæ</i> Th. Fr.
<i>Buellia myriocarpa</i> (D C) Mudd.	— <i>elaeochroma</i> (Ach.) Th. Fr.
— <i>parascema</i> (Ach.) Th. Fr.	— <i>erytrophæa</i> Flk.
<i>Caloplaca cerina</i> (Ehrh.) Th. Fr.	— <i>fuscescens</i> Sm.
— <i>citrina</i> Ach.	— <i>helvola</i> (Koerb.) Th. Fr.
— <i>ferruginea</i> (Huds.) Th. Fr.	— <i>Nylanderii</i> Anzi.
<i>Diploschistes scruposa</i> L.	— <i>Tornoensis</i> Nyl.
<i>Lecania athroocarpa</i> (Dub.) Nyl.	<i>Lepraria</i> .

*Microthelia micula* Flot.  
*Pertusaria communis* D C.

*Pertusaria xanthostoma* (Sm.) Fr.  
*Rinodina sophodes* Ach.

The Foliaceous bark-lichens appear to be far richer and more varied in structure, and probably comprise very different types, which have not yet, however, been investigated from a biological point of view. With regard to this point, it will suffice for me to draw attention to the striking difference between such species as are addressed to the substratum (*Phycia pulverulenta*), the surface of which the lichen follows along all its irregularities; and on the other hand *Parmelia physodes*, the greater part of which rises into the air, and lastly *Evernia Prunastri*, which hangs down in tufts from trunks and branches.

The thallus of the foliaceous lichens is dorsiventral, is covered by a cortex, and has rhizines on its under surface. The rhizines attach the lichen to the substratum in the way described by Lindau, for, on coming into contact with the bark, they spread out flat over the substratum and, when the bark is well decomposed, send hyphæ down into its cracks for further attachment. The rhizines are unable to dissolve the cellulose, but it may be presumed that they absorb the salts set free by the decomposition of the bark.

The gonidia-containing thallus itself is, as is well-known, indented in various ways, and grows centrifugally over the substratum, for which reason it often dies away in the centre, a fact commonly observed, especially in *Parmelia saxatilis* and *Slicia pulmonacea*. The edge of the thallus gradually forms new rhizines on the side turned downwards. The gonidia are situated just below the cortical layer of the morphological upper-surface.

Propagation takes place by means of spores, possibly by pycnoconidia and soredia, which are extremely common in several species (*Parmelia* and *Evernia* spp.).

In their competitive capacity the foliaceous lichens stand, in many habitats, far above the crustaceous lichens. They generally require more thoroughly decomposed bark than do the latter, therefore (with a few exceptions) they do not live on young branches. In addition, they generally demand more light. Consequently, where abundant light and well-decomposed bark are found, the vegetation of the bark of the tree consists of foliaceous lichens, which easily grow over and exterminate the original vegetation of crustaceous lichens. In the birch coppices of Iceland this may be observed here and there on older trunks and branches, especially in parti-



cularly wind-affected coppices of which the tops of the shoots are dead.

The conditions pertaining to propagation in the foliaceous lichens do not appear to differ from those in the crustaceous lichens.

Iceland has the following foliaceous bark-lichens: —

<i>Cetraria sæpincola</i> (Ehrh.) Arn.	<i>Parmelia olivacea</i> L.
<i>Collema flaccidum</i> L.	— <i>physodes</i> L.
— <i>nigrescens</i> L.	— <i>saxatilis</i> L.
<i>Evernia furfuracea</i> L.	<i>Physcia ciliaris</i> L.
<i>Leptogium plicatile</i> Ach.	— <i>obscura</i> (Ehrh.) Nyl.
<i>Nephroma laevigatum</i> .	— <i>stellaris</i> L.
— <i>tomentosum</i> .	<i>Sticta scrobiculata</i> Scop.
<i>Pannaria triptophylla</i> Ach.	<i>Xanthoria lichnea</i> (Ach.) Th. Fr.
<i>Parmelia ambigua</i> Ach.	— <i>parietina</i> L.

Fruticose bark-lichens (*Usnea*, *Ramalina*, *Bryopogon*) are not found in Iceland, so they will not be discussed more fully here. They are described in my treatise of 1913, pp. 19 et seq.

## 2. EPIPHYLLOUS LICHENS.

are not found in Iceland. They require evergreen leaves as a substratum. These extremely interesting plants received brief mention in my paper of 1913. The chief work on them is Ward's treatise of 1893.

## 3. EARTH LICHENS.

Three types may be distinguished: Crustaceous, Foliaceous and Fruticose lichens, all three of which are found in Iceland.

In all Crustaceous earth-lichens there is a distinct demarcation between that part of the thallus which is buried in the ground (subterranean, hypogaeal thallus) and that which rests upon the surface of the ground (epigaeal thallus). The subterranean thallus may vary fairly markedly in appearance: it may be composed of small, more or less loosely connected grains (*Lecidea uliginosa*, *L. alpestris*, *L. arclica*, *Gyalecta geoica*), or it may consist of a homogeneous crust (*Bilimbia sabuletorum*, *Lecidea Diapensiae*, etc.), or of small, somewhat scale-like parts coherent at the base (*Sphyridium byssoides*). The biological importance of these forms has not yet been investigated.

The gonidia occur sometimes evenly distributed in the whole of the epigaeal thallus, sometimes arranged in a definite layer immediately beneath the cortex.

The subterranean thallus normally is free of gonidia (barring foreign-gonidia). It may be very strongly developed, and it pushes its way down among the particles of soil, which may gradually become entirely enclosed by its hyphæ. I have sometimes observed shapeless enclosed lumps of black humus (*Lecidea decolorans*, *Bilimbia sabuletorum* (D. Lik. Ø., pl. 4, fig. 15), *Bacidia citrinella*), sometimes organic remains with the cell-structure preserved (*Lecidea decolorans*), and sometimes grains of mineral matter (*Buellia scabrosa*). In no case has it been possible to demonstrate whether solution takes place by the agency of the lichen-hyphæ. It is almost incomprehensible that something of this kind should not happen, but it has not been proved. It is possible that what is set free of the enclosed organic remains, or of the mineral grains by purely chemical decomposition, suffices for the lichens.

In some few cases (*Lecidea decolorans* (D. Lik. Ø., pl. 10, fig. 53, c), *Pannaria brunnea*) I found, enclosed in the subterranean thallus, an undetermined species of green algæ. The gonidia were dead and decoloured, but the lichen-hyphæ had not sent haustoria into them (nor do they do so as a rule to their normal gonidia). The death of the gonidia was undoubtedly due to contact with the hyphæ, and possibly some use had been made of their contents. The whole thing must be regarded as a *Cephalodium*-formation, a "hypogæan" cephalodium or perhaps a "pseudocephalodium."

About the mode of propagation of the crustaceous lichens very little is known. Ascospores, perhaps pycnoconidia, are probably their most common means of propagation, I have not observed soredia or detached portions of thallus in them, as in the fruticose lichens. It is a very interesting fact, that these means of propagation appear to be at any rate rare in the primitive, crustaceous lichens.

Crustaceous lichens are very weak in competition with other plants, as these easily cover them over and exterminate them. They are most favourably situated in Iceland, and in other Arctic countries; this will be discussed more fully below.

Iceland has the following crustaceous earth-lichens: —

<i>Bacidia arceutina</i> Ach.	<i>Baeomyces byssoides</i> (L.) Th. Fr.
— <i>caudata</i> Nyl.	— <i>placophyllum</i> Wahlenbg.
— <i>flavo-virescens</i> Dicks.	<i>Buellia badia</i> Koerb.
— <i>herbarum</i> Hepp.	— <i>parasema</i> (Ach.) Th. Fr.
— <i>milliaria</i> Fr.	— <i>scabrosa</i> Koerb.
— <i>obscurata</i> (Sm.) Th. Fr.	<i>Caloplaca cerina</i> (Ehrh.) Th. Fr.
— <i>squalescens</i> Nyl.	— <i>Jungermannia</i> (Vahl) Th. Fr.



<i>Caloplaca</i> <i>nivale</i> Koerb.	<i>Lecidea</i> <i>granulosa</i> (Ehrh.) Schaer.
— <i>tetraspora</i> Nyl.	— <i>limosa</i> Ach.
— <i>vitellina</i> (Ehrh.) Th. Fr.	— <i>lurida</i> Sw.
<i>Catillaria</i> <i>cumulata</i> Sm.	— <i>neglecta</i> Nyl.
— <i>Jemtlandica</i> Th. Fr.	— <i>rubiformis</i> Wahlenbg.
<i>Collema</i> <i>verrucaeforme</i> L.	— <i>ramulosa</i> Th. Fr.
— <i>pulposum</i> Bernh.	— <i>uliginosa</i> Schrad.
<i>Coniocybe</i> <i>furfuracea</i> L.	— <i>vernalis</i> (L.) Ach.
<i>Gyalecta</i> <i>cupularis</i> Ehrh.	<i>Lepraria</i> .
— <i>foveolaris</i> Ach.	<i>Lopadium</i> <i>fuscoluteum</i> Dicks.
<i>Lecanora</i> <i>castanea</i> (Hepp.) Th. Fr.	— <i>pezizoideum</i> (Ach.) Koerb.
— <i>Hageni</i> (Ach.) Koerb.	<i>Massalongia</i> <i>carnosa</i> (Dicks.) Koerb.
— <i>pallescens</i> (L.) Schaer.	<i>Microglaena</i> <i>sphinctrinoides</i> Nyl.
— <i>subfusca</i> (L.) Ach.	<i>Pannaria</i> <i>brunnea</i> Nyl.
— <i>tartarea</i> L.	— <i>lepidiota</i> Sm.
— <i>varia</i> (Ehrh.) Nyl.	<i>Pertusaria</i> <i>coriacea</i> Th. Fr.
<i>Lecidea</i> <i>alpestris</i> Sm.	— <i>dactylina</i> Ach.
— <i>arctica</i> Sm.	— <i>oculata</i> Dicks.
— <i>assimilata</i> Nyl.	<i>Placynthium</i> <i>delicatulum</i> Th. Fr.
— <i>atrorufa</i> Dicks.	<i>Psoroma</i> <i>Hypnorum</i> (Hoffm.) Ach.
— <i>Berengeriana</i> Mass.	<i>Rinodina</i> <i>Conradi</i> Koerb.
— <i>crassipes</i> Th. Fr.	— <i>miniaraea</i> (Ach.) Th. Fr.
— <i>cuprea</i> Sm.	— <i>turfacea</i> Wahlenbg.
— <i>decepiens</i> Ehrh.	<i>Toninia</i> <i>squalida</i> (Ach.) Nyl.
— <i>decolorans</i> Hoffm.	— <i>syncomista</i> (Flk.) Th. Fr.
— <i>elæochroma</i> (Ach.) Th. Fr.	— <i>vesicularis</i> Hoffm.
— <i>fusca</i> Schaer.	

The Foliaceous earth-lichens may be divided into at least two groups, procumbent and erect. To the procumbent group belong, e. g. *Peltigera* (*canina*, *horizontalis*, *venosa*, *aphotosa*, *lepidophora*), *Solorina* (*crocea*, *saccata*, *bispora*), *Physcia* (*pulverulenta* v. *musci-gena*, *stellaris*), *Dermatocarpon* (*hepaticum*, *dædaleum*, *cinereum*). To the erect group belong *Cetraria* (*islandica*, *odontella*, *cucullata*, *nivalis*, *glauca*, *lacunosa*) and some of the species of *Collema* and *Leplogium*. It is possible that some of the species may be procumbent under certain circumstances, and erect under others. It is clear that these species differ essentially as regards their competitive capacity against other plants. The erect species must be regarded as the best equipped in that respect, and are also those which are most frequent and most numerous in nature. As is well-known the *Cetraria* spp. are much more numerous than are any of the procumbent earth-lichens.

The Procumbent foliaceous lichens grow centrifugally from the centre of the plant, and are provided with scattered bundles of rhizines on their under surface. The rhizines attach themselves

gradually to the substratum, as they come in contact with it. How they attach themselves, and how far they are of any other importance than to fix the plant in the substratum, is not known. The thallus itself is always dorsiventral and in some species it dies away in the middle, its single lobes thus becoming isolated. Zukal (1895) has shown that several of the earth-lichens "wander" by a kind of mycelium, which proceeds from their rhizines, and run horizontally below the surface of the ground, forming new thalli here and there, as in *Peltigera venosa* and *Solorina saccata*. This mode of propagation corresponds exactly with that by which crustaceous lichens with a mycelium of radiating, centrifugal growth, form numerous small balls of gonidia, which by their abundance fuse into a granulate thallus; or with that by which *Cladonia* forms its centrifugally-growing scales (primary thallus) or *Stereocaulon* its scales which afterwards develop into podetia (Danske Likeners Økologi, fig. 91); it is no doubt the most natural explanation of the fact, that the form of many foliaceous lichens is that the thallus consists of one or more lobes, which have a base on the surface of the earth itself, and grow from thence unilaterally forward away from that base.

The Erect foliaceous lichens are, although erect, very commonly dorsiventral. So far as my investigations go, they die away below (the spot corresponding with the centre of the procumbent lichens) and keep on growing at the apex. They escape being blown away by being fastened by their "haptera" each to the other or to other things (Sernander, 1901). These haptera, which have not been investigated more closely, have been found by Sernander in *Cetraria islandica*, *cucullata*, *hiascens* and *nivalis*, and are transformed cilia, which, as is well-known, are extremely common in this genus.

The means of propagation in the foliaceous earth lichens appear to be ascospores, or perhaps pycnoconidia. On the other hand, soredia and detached portions of thallus do not appear to play any part in the dispersal of these species either. Otherwise, the whole class has been as yet very little investigated. It is evident that procumbent foliaceous lichens are weak competitors, and are easily covered by other plants. As regards abundance of individuals they also play but a slight rôle in nature. They have far better chances on stones and trees, and are very common in such stations. The erect foliaceous lichens have far greater advantages in competition, and are much richer in individuals than are the others.

Iceland has the following foliaceous earth lichens: —

<i>Cetraria cucullata</i> Bell.	<i>Peltigera aptosa</i> L.
— <i>hiascens</i> (Fr.) Th. Fr.	— <i>canina</i> (L.) Fr.
— <i>nivalis</i> (L.) Ach.	— <i>horizontalis</i> L.
<i>Dermatocarpon cinereum</i> Pers.	— <i>lepidophora</i> Nyl.
— <i>hepaticum</i> Ach.	— <i>malacea</i> (Ach.) Fr.
— <i>rufescens</i> Ach.	— <i>polydactyla</i> (Neck.) Hoffm.
<i>Leptogium lacerum</i> Ach.	— <i>rufescens</i> Fr.
— <i>scotinum</i> Ach.	— <i>venosa</i> (L.) Hoffm.
<i>Nephroma arcticum</i> L.	<i>Physcia pulverulenta</i> Nyl.
— <i>expallidum</i> Nyl.	(v. <i>muscigena</i> ).
— <i>tomentosum</i> (Hoffm.) Nyl.	<i>Solorina bispora</i> Nyl.
<i>Pannaria microphylla</i> Nyl.	— <i>crocea</i> Ach.
<i>Parmelia lanata</i> Wallr.	— <i>saccata</i> L.

The Fruticose earth-lichens. Three types may be distinguished, which are however connected by intermediate forms, namely, *Hypothallus*-wanderers, *Podetium*-wanderers and *Primary-scale*-wanderers, which have been exhaustively described and for the first time established by me in 1913. From these groups I quote as examples: —

*Hypothallus*-wanderers: *Stereocaulon condensatum*, *Cladonia papillaria*, *C. pyxidata*, *C. pityrea*, *C. fimbriata*, *C. squamosa*, *C. crispata*, *C. cornuta*, *C. macilenta*, *C. Floerkeana*, *C. coccifera*, *C. deformis*, *C. verticillata* (see figs. in Forb. Unders., 1913).

*Podetium*-wanderers: *Stereocaulon tomentosum*, *S. evolutum*, *S. coralloides*, *S. paschale*, *Dufourea arctica*, *D. muricata*, *Siphula ceratites*, *Cladonia degenerans*, *C. gracilis*, *C. furcata*, *C. rangiformis*, *C. uncialis*, *C. rangiferina*, *Thamnolia vermicularis*, *Alectoria ochroleuca*, *Cornicularia aculeata*, *Bryopogon jubatus* v. *nitidulus*, *Sphærophorus fragilis* (see figs. in Forb. Unders., 1913).

*Primary-scale*-wanderers: *Cladonia foliacea* (see figs. in Forb. Unders., 1913).

As an example of the structure of a *hypothallus*-wanderer, a description of *Cladonia pyxidata* will suffice. When the spore in this species germinates, it gives rise to a mycelium which spreads out radially in the ground (Dan. Lik. Øk., fig. 39 a), and is called a *hypothallus*. Wherever these purely mycelial hyphæ encounter *Pleurococcus*-algæ on the surface of the ground, they establish — as has already been described by Krabbe (1891) and Wainio (1898), — a connection with these latter, and form lichens. We may then, on a somewhat older *hypothallus*, distinguish between the purely mycelial hyphæ, which have not as yet begun their lichen-formation, and within these (nearer to the germinating point) a belt, where the

primary scales are fully formed, and in the centre, still older scales with podetia, which are frequently placed distinctly in a circle ("fairy ring"). The hypothallus can wander in the ground for years, exactly as a fungal mycelium wanders; the podetia, on the other hand, live a few years only, and are gradually replaced by new ones. They are erect as long as they are alive, and end by dying away at the base, so that, ultimately, they rot and fall down, as they very rarely cohere with one another by haptera.

This type is the most primitive of the fruticose lichens, as is shown by the fact that it is still the vegetative thallus which keeps on living, while the podetia, the curiously transformed apothecia-stalks, die away and are destitute of all the peculiar contrivances which are found in the type of podetium-wanderers, such as prostrate, creeping podetia, haptera, etc.

It is, however, a type which is well-adapted to live on the ground, which the hypothallus can easily penetrate. On the other hand they are ill-adapted for life on the bark of trees or on stones, which can only with great difficulty be penetrated by the hypothallus. Nor do there occur, as far as is known, any species among the bark or rock lichens which may be included among the hypothallus-wanderers. On the other hand, they are more unfavourably situated in regard to competition than are the podetium-wanderers, which die away below and keep on growing at the apex, by which means they can outgrow several other species. They are also far rarer as regards individuals than are the excellently equipped podetium-wanderers, *Alectoria ochroleuca*, or *Cladonia rangiferina*.

*Cladonia rangiferina* is the most highly developed of all the podetium-wanderers we know. When the spore germinates, a crust-shaped thallus is formed, but this is very rarely obtained, and has been observed only by a few lichenologists, (Krabbe, Wainio and Galløe), as it is very small and disappears very quickly. Upon it the first podetia are developed, and they branch rapidly. The primary thallus dies away and from henceforward the podetium is left to look after itself; it gradually dies away at the base, but keeps on growing "per secula" (Wainio) at the apex, so that it gradually comes to rest upon a cake of lichen-peat made by itself. By the dying away of the podetium, its lateral branches become gradually isolated from one another; those that are placed somewhat horizontally come gradually into touch with the surface of the ground, and take hold of it at their apices by sending pencil-shaped haptera



into it (Mentz, 1900; Sernander, 1901; Galløe, 1908 and 1913). The podetium-branch thus anchored forms new vertical branches, which in turn also die away below, etc. All the vertical podetium-branches and podetia, which are naturally very slightly attached to the ground (by the decaying bases), are mutually connected by numerous haptera, which hold them so closely together, that it is impossible to obtain uninjured any isolated podetium from a tuft.

The characteristic features of this type are, that the primary thallus (here crustaceous) very soon dies, and that the podetia (at the edge of the tuft) may lie down horizontally and wander in this way, attached to the ground and to one another by haptera, while they die away at the base, and keep on living perhaps for centuries at their apex.

The podetium-wanderer is an excellent earth-lichen-type, capable of competition beyond any of the others, by the fact of its dying away at the base, and keeping on growing at the apex, which enables it to grow above both crustaceous and foliaceous lichens, and also above hypothallus- and primary-scale-wanderers. The type is consequently exceedingly rich in individuals in nature; reindeer moss, as is well-known, is the most abundant earth-lichen in the world. But the type is poor in species. It is not adapted to life on rocks and trees, for its dying away at the base would deprive it of its substratum.

The primary-scale wanderers are represented by *Cladonia foliacea*, which is in reality intermediate between a fruticose and a foliaceous lichen. The spore, on germinating, quickly forms a primary thallus consisting of large, well-developed lobes, which spread out in a tuft-formation over the ground, while the hypothallus decays quickly. Along the edge of the tuft the lobes lie horizontally, but towards the centre they stand upright. They die away at the base, and keep on growing at the apex, exactly as in *Cetraria*, for instance. They are closely connected with one another by numerous haptera, which prevent them from being scattered to the winds. Consequently, so far, *C. foliacea* is a foliaceous lichen, but podetia may also be developed on the lobes of the thallus — although not frequently in Denmark or in Iceland — which makes it impossible to include it, as a matter of course, among the foliaceous lichens. The primary-scale wanderers, as regards their competitive capacity, are like the lower species of the erect foliaceous lichens; they are few in number both as regards individuals and species. The fact

that they die away at their base make them unfit for life on the bark of trees and on stones, and consequently they do not occur there.

Some fuller data concerning the biology of the fruticose lichens will be given here: —

The hypothallus is the purely mycelial lichen-tissue, free of gonidia, which is formed by the germination of the spore (the soridium or perhaps the pycnoconidium). It has been observed in all the species of the genus *Cladonia*, and in *Stereocaulon condensatum*; but as to all the other species of the latter genus it has, in some, never been observed, and in others, is very insignificant, and is then, only for a time, of importance to the life of the species, as it dies away early. It lives long in all hypothallus-wanderers, and constitutes — as suggested by the name — their only means of wandering. On the other hand, it disappears very early in the primary-scale wanderers, and in the majority of the podetium-wanderers.

It is always formed of very loosely woven hyphæ, which grow centrifugally from the germination-centre. Wherever green algæ suitable for the species, is encountered by it on the surface of the ground, it weaves its hyphæ round them, and forms thereby the first beginning either of primary scales (*Cladonia*) or of direct podetia (*Stereocaulon*). This process has, as regards *Cladonia*, been described by Krabbe (1891) and Wainio (1898).

Some of the hypothallal hyphæ are often formed as fairly thick, dark hyphal bundles, almost devoid of intercellular spaces, especially where they are continued up into the base of the primary scale (*Cladonia cornuta*, *C. verticillata*). The hyphæ easily come into contact with mineral-grains, humus-particles, plant-remains with their structure still intact, and earth algæ. About this the following is to be noted: —

Mineral-grains, especially sand-grains, adhere to the hyphæ of several species. I believe that this happens through the cell-walls being covered with a slight (microscopically-invisible) covering of mucus. The sand-grains themselves are always finely striated on the surface, no doubt from weathering, for it cannot be proved that the hyphæ exercise any chemical influence upon them, and we must be careful not to state definitely that the roughnesses are marks of corrosion.

The humus-particles are opaque under the microscope. Where

they are lying interwoven with the hyphæ-bundles, it cannot be shown that the hyphæ affect them. I have observed them very commonly in *Cladonia pilyrea*, *squamosa*, *crispata* and *Floerkeana*.

Plant-remains, with their structure intact, occur very commonly in the hypothallus. Thus I have found *Cladonia pilyrea* adhering to the bark of a dead heather-twigg. The hyphæ of the hypothallus behave here exactly as does the hypophloedal hyphal system in the bark-lichens: The cork-lamellæ were split from one another into small-scales, but the cork could not be proved to have been corroded by the hyphæ. The same lichen often spreads out its hypothallus over dead moss-leaves on the ground, but these have, as a rule, turned so brown and are so broken, that it cannot be shown whether the hyphæ have had any part in their disintegration.

Very commonly the hyphæ encounter various green algæ and *Cyanophyceæ* (*Gloeocapsa*, etc.); in no case did I find haustoria in the algæ, nor did I, on the whole, see the hyphæ attach themselves to the algæ, or by their mode of branching, etc. show the least interest in the algæ in question. They appear almost always to be of no importance whatever to the lichen-hyphæ, even if they are lying encysted amongst them. The fact that dead specimens may be found amongst them does not show with any certainty that death is due to any influence exerted by the lichens, although the possibility of it is not excluded.

The primary thallus (in *Cladonia*) consists, as is well-known, of small, leaf-shaped thallus-scales of dorsiventral structure, which proceed directly from the hypothallus, and are developed in centrifugal succession from it. In all hypothallus-wanderers the primary scales live very long as "nutrition-shoots," co-equal with the podetia. They are of far less importance to the more primitive podetium-wanderers (*Cladonia gracilis*, *furcata*, *rangiferina*) in which the podetia, at an early stage in the plant's life, become its chief, and finally its only assimilatory organ; finally, in the more advanced podetium-wanderers (*Cladonia rangiferina*, *uncialis*), they are so insignificant, that they form quite a crust-shaped thallus, which perishes so early, that the majority of the lichenologists have not even seen it. Moreover, several podetium-wanderers are, as a rule, propagated in quite a different manner (by fragments of podetia, etc.) and thus have, on the whole, very rarely any opportunity of developing a primary thallus.



In *Cladonia foliacea* the primary thallus is the chief assimilatory organ of any length of duration.

Consequently, three types may be distinguished: (1) Permanent primary thallus, which keeps on growing along the edge and dies away at the base; this is found in the primary-scale-wanderers (*Cladonia foliacea*). (2) Permanent primary thallus, which does not die away behind, found in the hypothallus-wanderers and in the more primitive podetium-wanderers (*Cladonia papillaria*, *pyxidata*, *pityrea*, *fimbriata*, *squamosa*, *crispata*, *cornuta*, *macilenta*, *Floerkeana*, *coccifera*, *deformis*, *verticillata*, *gracilis*, *rangiferina*, *furcata*). (3) Quickly perishing, crust-shaped primary thallus, found in the most decided podetium-wanderers (*Cladonia uncialis* and *rangiferina*).

From the under surface of the primary scales, in several cases, hyphæ may proceed from the cortical layer. Sometimes it is difficult to decide with any certainty, whether they are simply hypothallal hyphæ or — which may be the case — secondary hyphæ, which from the medullary layer, push their way into the soil, and attach themselves to it, and are therefore, properly speaking, haptera. Undoubted haptera I have found in *Cladonia foliacea*, where they occur in the form of a hyphal pencil, in *C. pityrea*, where they are similar in form, in *C. squamosa*, where they form solid hyphal bundles, and in *C. pyxidata*, *macilenta* and *furcata*, in which they consist of scattered hyphæ, produced from the under surface of the scales.

The haptera attach themselves to mineral-grains, humus-lumps, etc., in exactly the same manner as do the hypothallal hyphæ, and it is true also with regard to them, that it has not been possible to demonstrate microscopically that they have any chemical influence. Interwoven in a hapteron of *Cladonia foliacea* I found green algæ, which were apparently uninfluenced by the proximity of the hyphæ.

Another type of primary-scale haptera I found in *Cladonia foliacea* and in *C. cornuta*. By means of these the scales attached themselves to one another or to podetia of the same species.

Podetia. Of these, four types may be distinguished, which differ in duration of life and in mode of growth. All the fruticose earth-lichens are erect, and their thalli are, as a rule, called "podetia," but these, however, differ greatly in the history of their development. Here the term is used as a biological conception to indicate the subærial thallus, mainly of a radiating form; (consequently not the primary scales of *Cladonia*). Of this I have set up four types, viz. (1) erect, radial, permanent podetia; (2) erect, radial podetia, dying

away at the base; (3) procumbent, dorsiventral, hapteron-producing podetia, dying away at the base behind; (4) procumbent, dorsiventral, hapteron-free podetia, dying away at the base behind.

Type 1 is found only in the hypothallus-wanderers, and in the majority of these.

Type 2 is found in some of the hypothallus-wanderers, and in all the podetium-wanderers. As a rule, we may take for granted that podetia of type 1, when they become old, ultimately pass over to type 2 for a short time, before they die away entirely. But even if the boundary line between the two types is thereby made very uncertain, it is advisable to maintain both of them, as there are undoubtedly species which never die away below or, at any rate, very rarely do so (e. g. *Stereocaulon condensatum*, *Cladonia papillaria*, *C. pyxidata*, *C. pityrea* and possibly others).

Type 3 like type 4 is commonest in the podetium-wanderers, in which the edge of the tuft usually grows in circumference by the marginal podetia lying down and creeping over the surface of the ground, and like runners spreading out on the substratum. By this the podetia often become somewhat dorsiventral and, in addition, send in some cases haptera into the ground (the majority of the podetium-wandering *Cladonias*); in other cases nothing like this happens (*Stereocaulon*, *Dufourea*).

Consequently, in the same tuft and in the same species more than one type of podetium may be found, so that types 1 and 2 are united, in that the old podetia may belong to type 2, and the young, on the other hand, to type 1; but, as already mentioned, in some species type 1 is the dominant one.

Types 2 and 3 are, as a rule, united in the same species and in the same tuft, in that type 3 forms the runners of the tuft, and type 2 the old erect shoots in the middle of the tuft.

In the same way, types 2 and 4 are as a rule united in the same tuft.

It is evident, that all species which have on the whole erect, permanent podetia, are less adapted to grow on the earth, because they are so dependent on the substratum for their attachment, and are therefore easily overgrown and crowded out by other species. Their apical growth also is very limited, which in addition reduces their capacity for competition.

Podetium-wanderers, on the other hand, are excellent competitors. With regard to these I shall add some further notes about

the relation of the podetia to the substratum and mutually to one another.

As already mentioned, the oldest podetia die away below, and form thereby a peaty mass, while they keep on growing at their apex "per secula" as Wainio writes.

The question now arises how the podetia, on a century-old cake of lichen-peat, obtain their mineral food. So long as the lichens are in somewhat close contact with mineral soil, every shower will saturate the upper layers of earth, and the water will become nutritive to a certain extent. But later on, when the cakes of lichen-peat are formed, they will no doubt gradually become washed free from minerals, and the water which the lichens can absorb from the substratum (which is, as is well-known, very little, because they lead the rainwater down into the ground much more easily than upwards from it, as demonstrated by Zukal, 1891—96) must become poorer and poorer in nutriment. Can this ultimately bring about the result that the lichen-covering, by its continued growth, brings about its own destruction? It is a question which lichenologists, who have easy access to Alpine lichen-heaths, ought to take up for investigation.

Haptera have been first demonstrated and described by Sernander (1901) in a small and very interesting, but unfortunately only too brief, treatise. Sernander distinguishes several types (*Cladonia*-type, *Alectoria*-type, etc.). I prefer another classification, because haptera of several different types occur on the same plant, and cannot therefore be named after different genera. Sernander does not describe them anatomically. In my "Forberedende Under-søgelse" (1913) they have been very fully treated and figured, and the chief points will now be recapitulated here.

According to my classification the types to which the haptera may be referred, are the following: —

- (1) Apical haptera,
- (2) Lateral haptera,
- (3) Primary-scale haptera,
- (4) Podetium-scale haptera.

Some of these, especially the two last, have not been mentioned at all by Sernander.

The haptera may attach themselves to the ground (when the podetia are procumbent); or to other individuals of the same species (but no parasitic relation ever arises from this contact); or to other

species of lichens (again no parasitic relation appears to arise), or, lastly, to quite other plants, e. g. moss, heather, etc.

Apical haptera put into the ground I have found in the more differentiated podetium-wanderers, with distinctly procumbent marginal podetia, the apices of which occasionally come into contact with the ground, and are then immediately transformed into pencil-shaped bundles of hyphæ, which penetrate into the ground, and fix the podetia for the time being, and absorb water and nourishment. The hyphæ are frequently H-shaped by attachment to one another (fusions), and they behave exactly like hypothallal hyphæ; they attach themselves to mineral-grains, humus-particles, and dead plant-remains with the structure intact, nor can it be microscopically proved that they affect these bodies chemically. In one single case I have seen earth-algæ (*Zygogonium*-filaments) entangled and attacked by the haustoria of the hyphæ, namely in *Cladonia rangiferina*; otherwise earth-algæ do not appear to be attacked by them. Apical haptera put into the ground I have found in *Cladonia furcata*.

Apical haptera which attach themselves to individuals of the same species, I have observed in *Cladonia crispata*, *coccifera*, *rangiformis*, *rangiferina*, *Cornicularia aculeata*.

Apical haptera which attach themselves to the podetia of other species, I have found in *Cladonia degenerans*, *rangiformis*, *uncialis*, *rangiferina*, *Alectoria ochroleuca*, *Cornicularia aculeata*, *Bryopogon jubatus* v. *nitidulus*. In none of these cases does the part attacked appear to sustain any damage. The haptera appear to be exclusively organs of attachment, not suckers.

The lateral haptera put into the ground (in *Cladonia gracilis*, *furcata*, *rangiformis*, *uncialis*, *rangiferina*) are biologically identical with the apical haptera put into the ground.

Lateral haptera between podetia of the same species (in *Cladonia papillaria*, *crispata*, *coccifera*, *Dufourea arctica*, *muricata*, *Cladonia gracilis*, *rangiformis*, *uncialis*, *rangiferina*, *Thamnolia vermicularis*, *Cornicularia aculeata*, *Sphærophorus fragilis*) are widely distributed. The cortical layer of the podetia grow mutually together, but the gonidium- and the medullary layers are not at all influenced by this.

A totally different kind of haptera is found in *Siphula ceratites*, where the podetia grow completely together, cortex with cortex, medulla with medulla, etc.; Sernander has described this (1901).

Lateral haptera put into other species (heather, moss and other lichens) I have seen in *Dufourea arctica*, *Siphula ceratites*, *Cladonia*



*degenerans*, *uncialis*, *Thamnolia vermicularis*, *Cornicularia aculeata*, *Bryopogon jubatus* v. *nitidulus*, *Sphaerophorus fragilis*; they play exactly the same rôle as do apical haptera put into other species.

Primary-scale haptera I found only in *Cladonia foliacea*. By means of them the primary scales of long duration which die away at the base, are attached to one another; no parasitic relation arises by this attachment.

Podetium-scale haptera I found only in *Cladonia cornuta*. By means of them the podetia are attached to one another, the scales of the one podetium attaching themselves to the wall of another podetium of the same species; no parasitic relation arises by this attachment.

When procumbent podetia are buried in the ground, they die. No species known to me can endure being covered with earth for a long time. First the gonidia appear to die, sometimes after a short period of intense division, which is probably occasioned by the increased dampness. Then the lichen-hyphæ die, the walls, as a rule, turning brown.

The fruticose earth-lichens are propagated in a widely different manner according to their morphological structure. Hypothallus-wanderers very commonly bear fruit, and are propagated, no doubt as a rule, by ascospores. Some of them are propagated far more frequently by soredia, and in that case apothecia are much rarer in them (*Cladonia fimbriata*, *deformis*), so that in such species there appears to exist a correlation between these two modes of propagation. In others again these two modes of propagation appear to be equally common, a quantity of soredia and apothecia being developed on the same individual. However it requires to be more closely investigated, whether the asci in strongly soredia-bearing individuals are empty, as they frequently are in *Cladonia*.

In the podetium-wanderers propagation takes place in several cases by the breaking off of fragments of podetia which are then carried away by the wind to other places where they form new tufts. This has already been described by Wainio (1898) and afterwards mentioned by Mentz (1900) and Galløe (1913 and 1918).

Species of *Stereocaulon* do not appear to be able to propagate themselves in this way, as podetia-fragments have not yet been observed to put out haptera into the ground. On the other hand, they are often found bearing apothecia.

Of fruticose earth-lichens Iceland has the following: —

<i>Alectoria divergens</i> Ach.	<i>Cladonia pityrea</i> .
— <i>jubata</i> L.	— <i>pyxidata</i> .
— <i>nigricans</i> Nyl.	— <i>rangiferina</i> .
— <i>ochroleuca</i> Nyl.	— <i>rangiformis</i> .
<i>Cetraria aculeata</i> Fr.	— <i>turgida</i> .
<i>Cladonia amaurocraea</i> .	— <i>uncialis</i> .
— <i>bellidiflora</i> .	— <i>verticillata</i> .
— <i>cariosa</i> .	( <i>Polychidium muscicola</i> Sw., dwarf-
— <i>coccifera</i> .	formed).
— <i>decorticata</i> .	<i>Sphærophorus fragilis</i> L.
— <i>fimbriata</i> .	<i>Stereocaulon condensatum</i> Hoffm.
— <i>Floerkeana</i> .	— <i>incrustatum</i> Flk.
— <i>foliacea</i> .	— <i>paschale</i> (L.) Fr.
— <i>furcata</i> .	— <i>tomentosum</i> (Fr.) Th. Fr.
— <i>gracilis</i> .	<i>Thamnolia vermicularis</i> Schaer.

These and numerous other species have been specially treated in "Forberedende Undersøgelser" (1913), to which the reader is referred.

#### 4. ROCK LICHENS.

When the climatic conditions are favourable to the growth of lichens, a lichen-vegetation may eventually develop on a rocky substratum. But other demands also must be satisfied, namely those which have regard to the physical and chemical conditions of the substratum.

Many different rocky substrata may be distinguished, and some differences in their lichen-vegetation may also be pointed out.

The most important physical conditions are, as far as is known, the following: —

Stahlecker has observed that on stratified rocks lichens first choose those surfaces which are perpendicular to the stratification. How this phenomenon is to be explained is yet unknown but, *à priori*, we might be tempted to believe, that the lichen-hyphæ more easily penetrate the rock parallel with the stratification, than transverse to it (compare with this the fact that wood-lichens are best able to grow parallel with the "fibres" of the wood). Perhaps such surfaces disintegrate also more quickly.

The importance of the chemical conditions are far better known, owing to investigators like Krempelhuber, Fuisting, Steiner, Zukal, Zahlbruckner, Hulth, Bachmann, Fünfstück, Lang, Friederich and Stahlecker.

The researches of these investigators have proved that there is a distinct anatomical difference between lichens from primitive rocks,

(silica-lichens), and those from calcareous rocks, (calcareous lichens), although the observers disagree somewhat among themselves as regards the explanation of this phenomenon.

Stahlecker has shown that rocks composed of different kinds of mineral-grains, are affected by the lichens so that the basic grains are the first to be corroded, then the acid. The physical and mineralogical qualities of the mineral-grains are, on the other hand, of no importance. The same author maintains that lichens are able to corrode quartz; this is denied by Bachmann.

On the other hand, how rocks with glassy structure, without distinct, separate grains of mineral matter, as for instance obsidian, the ground-mass in porphyries, pumice, etc., are affected, is not known.

The corrosion must be assumed to take place in part actively on the part of the hyphæ, by their excreting acids. But nothing is known regarding this point.

The degree to which the rock is disintegrated is, as I have shown (1908, p. 300), of great importance, the freshest, recently-bared rock-surfaces being devoid of lichens, while progressive disintegration is accompanied by the presence of crustaceous, foliaceous and fruticose lichens in fixed succession.

As far as my knowledge and that of other investigators goes, I must assume that a floristic difference will be proved to exist in the lichen-vegetation found on different kinds of rock, especially between that found on calcareous and siliceous rocks — a circumstance which is already partially known.

It is thus seen that both floristically and biologically the chemical condition of the substratum is the determining factor, whilst its physical condition appears to be less important (compare above on bark-lichens). But as yet exhaustive lists of lichens from different kinds of rock are wanting, and these alone can give a closer insight into this floristic difference. That species exist which are confined to one particular substratum, for instance lichens which are exclusively "calcareous lichens," is quite certain, but I do not think it has been definitely proved.

Rock-lichens may be divided into three groups: crustaceous, foliaceous and fruticose lichens.

In the crustaceous lichens two sub-groups may be recognized: the epilithic and the endolithic.

The epilithic crustaceous lichens have a hyphal layer



devoid of gonidia, which is sunk into the substratum and which corrodes the individual grains of mineral matter. According to A. Friederich this hyphal layer is thin in the silicolous lichens, and cannot at all be compared, as regards size, with the corresponding tissue in the calcareous lichens. Besides, according to Friederich, it is never furnished with oil-hyphæ or sphæroid-hyphæ; but according to Bachmann, such are said to occur. At any rate, Fünfstück's investigations show that where the same lichen grows both on calcareous and on siliceous rocks, the individuals from the calcareous rocks contain oil, while those from the siliceous rocks do not. Fünfstück, whose results have since been strongly supported by E. Lang's renewed investigations, appears to differ somewhat from Bachmann as regards the occurrence of oil-hyphæ in the silicolous lichens; this disagreement need not, however, be a fundamental one, as there will probably be various degrees with regard to the oil-contents connected with the larger or smaller amount of lime contained in the rock-species in question. At any rate, it is certainly an undisputable fact that the amount of oil is greatest in the calcareous lichens.

The biological importance of the oil-contents is much contested. Zukal is of opinion — but quite wrongly, according to Fünfstück's investigations, — that the oil is a supply stored for fruit-setting. Hulth also, regards the oil-containing tissue as reservoirs for reserve food-material. Fünfstück shows that there exists no connection between the fruit-setting and the oil-contents, and is of opinion, that the oil is an excretion formed owing to the accumulation of the carbon dioxide, which is set free by the hyphæ penetrating into the calcium carbonate.

As mentioned by Bachmann and Stahlecker the hyphæ affect the mineral grains in various ways. According to Stahlecker they corrode quartz. This is denied by Bachmann. Basic mineral-grains are affected before the acid mineral-grains, according to Stahlecker. When there is a decided cleavage-plane in the mineral-grains (as in mica), the hyphæ, according to Bachmann, follow the direction of the cleavage, whereby the existing cleavages are widened and filled with hyphæ.

The epilithic part of the thallus contains gonidia. It frequently consists of a growing lichen-mycelium produced centrifugally from the centre of germination, bearing on the thallus numerous small, rounded or irregularly angular areas containing gonidia; according

to Friederich, these gonidia-areas have come into existence in places where the gonidia (algæ) have accidentally fallen on the lichen-mycelium. According to Stahlecker each area has originally been an independent thallus, which, by coming into contact with similar neighbouring thalli, forms with these a "Gesamtthallus," which may afterwards grow as a unity, starting from a common centre. This interpretation sounds quite incredible, and I think it is very rarely, if ever, in accordance with fact. Can it, on the whole, be understood that these smaller thalli are "independent," as they have all been produced by the same lichen-mycelium?

It is quite another question, whether a group of really independent thalli, produced each from its own ascospore, on meeting, can alter and carry on a joint growth. About this nothing is known, *à priori*, it does not seem very probable.

In reality, these small thallus-patches containing gonidia, mentioned by Stahlecker, must quite naturally be regarded as analogous, for instance, to the primary scales in *Cladonia*, which are also small green gonidia-containing thalli on a common mycelium; or with the exactly corresponding balls of gonidia in numerous crustaceous earth-lichens (*Lecidea alpestris*, *L. uliginosus*, etc.).

Quite another separation into patches may moreover take place by existing patches splitting asunder into separate parts by growth-tensions (or by drying?) (see "Dan. Lik. Øk.," fig. 19, a, b, c, d).

When the thallus is smooth and non-partitioned, Stahlecker is of opinion that it is an old, formerly partitioned thallus. I cannot believe this interpretation of the condition.

Friederich has found the gonidia-layer of the silicicolous lichens to be thicker than that of the calcareous lichens, Fünf-stück has also found this to be the case.

The mode of propagation has been investigated by Beckmann, who found that some species (*Lecanora badia*, *L. cenisea*), the thalli of which are partitioned, may reproduce by means of detached portions of the thallus, whereas soredia are absent. On the other hand, the partitioned thalli of the *Rhizocarpon* spp. do not appear to be able to reproduce in this way.

Thin, cohering (non-partitioned) thalli do not appear to be able to reproduce in this way. Whether this mode of propagation, on the whole, plays any important part in nature, compared with propagation by spores, I regard as doubtful.

With regard to capacity for competition, the crustaceous lichens

have no equals when the surface of the substratum is fresh, i. e. has been recently bared or is non-disintegrated. They cannot, however, live on very recently bared rock; a slight inorganic disintegration must first take place, and then they make their appearance. They themselves contribute towards disintegration whereby they prepare the substratum for other, more pretentious forms (foliaceous and fruticose lichens) and so bring about their own destruction, as mentioned in "Dan. Lik. Øk.," p. 360.

The endolithic crustaceous lichens appear to occur only on calcareous rocks. As an example may be mentioned *Biatora immersa* (Web.) Arn., which is exhaustively treated by Fünfstück. There is in this species a slightly developed epilithic thallus, containing gonidia, which at the base passes over into a more vigorous endolithic thallus, with a great abundance of oil-cells of various forms. There is evidently a certain connection between the great abundance of oil in the thallus, and the chemical nature of the substratum, especially its wealth of carbonates. This class and the calcareous lichens richer in gonidia, that is to say, on the whole, the endolithic and the epilithic species, are connected by a series of intermediate forms; and there is hardly any lichen which is endolithic in the sense that the whole of the thallus is hidden in the substratum and covered over by it. For the rest, there are many points in the natural history of the endolithic lichens, which still remain to be explained. With regard to special modes of propagation, nothing is known.

At the point of transition between crustaceous and foliaceous lichens there stands a group of "placoid" species (Beckmann, 1907), for instance, *Placodium* (*Lecanora*) *saxicola*, *Caloplaca murorum*, *Dimelæna oreïna*, all of which have along their edges leaf-like thallus-lobes, devoid of cortex on their under surface.

In *Placodium saxicola* there may occasionally be found an indication of a cortical layer on the under surface, when it is growing on a smooth, polished rock-surface (Dan. Lik. Øk., fig. 62, b). Beckmann has shown that the species mentioned here may be propagated by the thallus-lobes becoming detached, and sprouting out into new individuals.

Of crustaceous lichens Iceland has the following species: —

<i>Acarospora discreta</i> .	<i>Arthonia ruderalis</i> .
— <i>fuscata</i> .	<i>Bacidia caudata</i> .
— <i>Heppii</i> .	— <i>coprodes</i> .

Bacidia milliaria.	Lecanora polytropa.
— sphæroides.	— saxicola.
— subfuscula.	— sordida.
Bæomyces hyssoides.	— straminea.
Biatorella Morio.	— subfusca.
Buellia æthalea.	— tartarea.
— atroalba.	— varia.
— badia.	Lecida aglaea.
— coniops.	— arctogena.
— leptocline.	— atrobrunnea.
— myriocarpa.	— atrorufa.
— stellulata.	— auriculata.
— tesserata.	— cinereoatra.
— vilis.	— confluens.
Caloplaca aurantiaca.	— contigua.
— cerina.	— convexa.
— citrina.	— crustulata.
— diphyes.	— cyanea.
— elegans.	— Dicksonii.
— ferruginea.	— elata.
— murorum.	— elæochroma.
— pyracea.	— erratica.
— vitellina.	— fuscoatra.
Catillaria athallina.	— furvella.
— lenticularis.	— impavida.
Diploschistes scruposa.	— lapicida.
Gyalecta cupularis.	— lithophila.
Hæmatomma coccineum.	— lugubris.
— ventosum.	— panæola.
Lecania athroocarpa.	— pantherina.
Lecanora albescens.	— paupercula.
— alphoplaca.	— Siebenhaariana.
— alpina.	— speirea.
— atra.	— subconfluens.
— atriseda.	— tenebrosa.
— atosulphurea.	— vernalis.
— badia.	Lepraria.
— calcarea.	Pannaria elæina.
— cartilaginea.	— granatina.
— chrysoleuca.	— Hookeri.
— cinerea.	— microphylla.
— cinereorufescens.	Pertusaria corallina.
— coarctata.	— rhodoleuca.
— frustulosa.	Placynthium nigrum.
— gelida.	Polyblastia Henscheliana.
— gibbosa.	— hyperborea.
— Hageni.	Rhizocarpon alboatrum.
— lacustris.	— calcareum.
— pallescens.	— geminatum.
— poliophæa.	— geographicum.

Rhizocarpon petræum.	Verrucaria margacea.
— viridiatrum.	— mucosa.
Staurothele elopima.	— nigrescens.
Verrucaria maura.	— rupestris.

As regards a few of these species it is true that they not only occur on common rocks, but also on disintegrated, bleached bones of various animals, usually on bones of sheep, which are rather commonly found lying out in the open air. With regard to this point further particulars will be found in the table of the chief biological conditions of the different species.

The Foliaceous rock-lichens. The numerous species of *Umbilicaria*, *Gyrophora*, *Parmelia*, etc., may be sub-divided into at least two types, viz. the *Gyrophora*-type and the *Parmelia*-type.

The *Gyrophora*-type (*Gyrophora*, *Umbilicaria*), as we know, consists of lichens which are attached to the substratum at a single point on the under surface of the thallus — the “umbilicus”. This is the reason why the lichens cannot die away in the centre and form “fairy rings.” With regard to absorption of food from the substratum, such species are differently conditioned from the *Parmelia*-like-lichens which are attached to the substratum at various points. With regard to capacity for competition, all the species stand very high, as they very easily grow across their competitors. Hence, in many places in Arctic regions, they form, on the rocks, growths very conspicuous and rich in individuals.

The *Parmelia*-type. Its many species are attached to the substratum by numerous rhizines, and die away in the centre, forming “fairy rings,” without thereby losing their foothold. This feature is very commonly seen in *Parmelia saxatilis*.

The ordinary anatomical structure has already been long known from the investigations of Schwendener and others. I shall only draw attention to the fact that there are cortical layers on both sides, as also a gonidial and a medullary layer.

The morphological structure still requires much investigation, especially from a biological point of view.

The means of propagation are, in addition to ascospores, in some species soredia also. How widely distributed the latter are, is not known. Propagation by means of detached portions of thallus, does not appear to have been observed in any of the species.

In competition the foliaceous lichens are far superior to the crustaceous lichens, when the substratum has, in some measure,



been prepared by the growth of the latter. I have never observed any foliaceous lichens on a quite recently bared surface. The crustaceous lichens appear always to be the first to arrive, and are afterwards succeeded and exterminated by the foliaceous lichens.

Of Foliaceous rock-lichens Iceland has the following: —

<i>Cetraria</i> <i>Fahlunensis</i> .	<i>Leptogium</i> <i>plicatile</i> .
<i>Collema</i> <i>crispum</i> .	<i>Parmelia</i> <i>alpicola</i> .
— <i>flaccidum</i> .	— <i>encausta</i> .
— <i>pulposum</i> .	— <i>incurva</i> .
<i>Dermatocarpon</i> <i>miniaturum</i> .	— <i>lanata</i> .
<i>Evernia</i> <i>furfuracea</i> .	— <i>olivacea</i> .
<i>Gyrophora</i> <i>arctica</i> .	— <i>physodes</i> .
— <i>cylindrica</i> .	— <i>saxatilis</i> .
— <i>erosa</i> .	— <i>stygia</i> .
— <i>hyperborea</i> .	<i>Physcia</i> <i>aipolia</i> .
— <i>murina</i> .	— <i>aquila</i> .
— <i>polyphylla</i> .	— <i>caesia</i> .
— <i>proboscidea</i> .	<i>Xanthoria</i> <i>lychnea</i> .
— <i>vellea</i> .	— <i>parietina</i> .

The Fruticose lichens are not numerous. As I have previously shown, they rest almost exclusively on a substratum prepared by other lichens, and consequently are not really true rock-lichens, as they are dependent on the peat-formation, which the first inhabitants of the rocks leave behind them on their decay. Consequently, if we investigate more closely such apparently rock-inhabiting species of *Stereocaulon* and others, we shall find under them — not rock — but first a thin layer of peat, and under that, the rock. Consequently, they are in reality earth-lichens.

A few species are, however, undoubtedly true inhabitants of rocks, for instance *Usnea melaxantha*, *Roccella*, *Ramalina* and a few *Stereocaulon* spp. They have at their base a permanent thallus, which is thread-shaped (*Usnea*) or ribbon-shaped (*Ramalina*) and isolateral. Formation of haptera between the individuals (see under earth-lichens) is unknown, and would appear also to be rather superfluous, as they do not die away at the base. Consequently, as regards these two points, they appear to differ greatly from their fruticose relatives among the earth-lichens, — which is quite in harmony with the different substratum.

Special modes of propagation — by detached portions of thallus, etc., are not known.

With regard to competitive capability the fruticose lichens generally stand very high. In Denmark species of *Ramalina* can form

continuous, almost pure growths on rocks (*Ramalina*-belt) on the cliffs of Bornholm. Species of *Roccella* appear to form similar carpets on the cliffs of the sub-tropical and perhaps tropical regions.

Of Fruticose rock-lichens the following are found in Iceland: —

<i>Alectoria ochroleuca</i> .	<i>Sphærophorus coralloides</i> (?).
<i>Coenogonium ebeneum</i> .	— <i>fragilis</i> (?).
<i>Ephebe pubescens</i> .	<i>Stereocaulon coralloides</i> (?).
<i>Lichina confinis</i> .	— <i>denudatum</i> .
<i>Racodium rupestre</i> .	— <i>evolutum</i> .
<i>Ramalina scopulorum</i> .	<i>Usnea melaxantha</i> .
— <i>subfarinacea</i> .	

With regard to these it should be remarked that it is somewhat doubtful how far *Racodium* and *Coenogonium* should, on the whole, be reckoned among the fruticose lichens: they have a thread-shaped, somewhat procumbent-ascending thallus. Also a query has been placed against several of the other species, to indicate that it is doubtful whether they are true rock-lichens occurring on bare rock because, at any rate when older, they are rarely, in fact very rarely, attached to the rocky substratum.

## 5. SYNOPSIS OF THE CHIEF BIOLOGICAL CONDITIONS OF THE LICHENS OF ICELAND.

Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Acarospora discreta</i> .....				+	+			+		
— <i>fuscata</i> .....				+	+			+		
— <i>Heppii</i> .....				+	+			+		
<i>Alectoria divergens</i> .....			+		+					+
— <i>jubata</i> .....			+							+
— <i>nigricans</i> .....			+							+
— <i>ochroleuca</i> .....			+	+	+					+
<i>Arthonia proximella</i> .....	+				+			+		
— <i>punctiformis</i> .....	+				+			+		
— <i>ruderalis</i> .....				+	+			+		
<i>Arthopyrenia analepta</i> .....	+				+			+		
— <i>grisea</i> .....	+				+			+		
<i>Bacidia abbrevians</i> .....	+				+			+		



Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Bacidia arceutina</i> .....	+		+		+			+		
— <i>atrosanguinea</i> .....	+				+			+		
— <i>Beckhausii</i> .....	+				+			+		
— <i>caudata</i> .....			+	+	+			+		
— <i>coprodes</i> .....				+	+			+		
— <i>flavo-virescens</i> .....			+		+			+		
— <i>herbarum</i> .....			+		+			+		
— <i>milliaria</i> .....			+	+	+			+		
— <i>obscurata</i> .....			+		+			+		
— <i>rubella</i> .....	+				+			+		
— <i>sphaeroides</i> .....	+			+	+			+		
— <i>squalescens</i> .....			+		+			+		
— <i>subfuscata</i> .....				+	+			+		
— <i>umbrina</i> .....				+	+			+		
<i>Bæomyces byssoides</i> .....			+	+	+			+		
— <i>placophyllum</i> .....			+		+			+		
<i>Biatorella Morio</i> .....				+	+			+		
<i>Buellia æthalea</i> .....				+	+			+		
— <i>atroalba</i> .....				+	+			+		
— <i>badia</i> .....				+	+			+		
— <i>coniops</i> .....				+	+			+		
— <i>leptocline</i> .....				+	+			+		
— <i>myriocarpa</i> .....	+			+	+			+		
— <i>parasema</i> .....	+		+		+			+		
— <i>scabrosa</i> .....			+		+			+		
— <i>stellulata</i> .....				+	+			+		
— <i>tesserata</i> .....				+	+			+		
— <i>vilis</i> .....			+		+			+		
<i>Caloplaca aurantiaca</i> .....				+	+			+		
— <i>cerina</i> .....	+		+	+	+			+		
— <i>citrina</i> .....	+			+	+			+		
— <i>diphyes</i> .....				+	+			+		
— <i>elegans</i> .....				+	+			+		
— <i>ferruginea</i> .....	+			+	+			+		
— <i>Jungermanniæ</i> .....			+		+			+		
— <i>murorum</i> .....				+	+			+		
— <i>nivalis</i> .....			+		+			+		
— <i>obscorella</i> .....	+				+			+		
— <i>pyracea</i> .....	+			+	+			+		
— <i>tetraspora</i> .....			+		+			+		
— <i>vitellina</i> .....	+		+	+	+			+		
<i>Catillaria athallina</i> .....				+	+			+		

Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Catillaria</i> <i>cumulata</i> .....				+	+			+		
— <i>Jemtlandica</i> .....			+		+			+		
— <i>lenticularis</i> .....				+	+			+		
<i>Cetraria</i> <i>aculeata</i> .....			+		+					+
— <i>cucullata</i> .....			+		+		?		+	
— <i>Fahlunensis</i> .....				+	+		?		+	
— <i>hiascens</i> .....			+		+		?		+	
— <i>nivalis</i> .....			+		+		?		+	
— <i>sæpincola</i> .....	+				+		?		+	
<i>Cladonia</i> <i>amaurocraea</i> .....			+		+					+
— <i>bellidiflora</i> .....			+		+		?			+
— <i>cariosa</i> .....			+		+		?			+
— <i>coccifera</i> .....			+		+		?			+
— <i>decorticata</i> .....			+		+	+	?			+
— <i>fimbriata</i> .....			+		+	+	?			+
— <i>Floerkeana</i> .....			+		+	+	?			+
— <i>foliacea</i> .....			+		+	+	?		+	+
— <i>furcata</i> .....			+		+		+			+
— <i>gracilis</i> .....			+		+		+			+
— <i>pityrea</i> .....			+		+	+	?			+
— <i>pyxidata</i> .....			+		+		?			+
— <i>rangiferina</i> .....			+		+		+			+
— <i>rangiformis</i> .....			+		+		+			+
— <i>turgida</i> .....			+		+		+			+
— <i>uncialis</i> .....			+		+		+			+
— <i>verticillata</i> .....			+		+		?			+
<i>Coenogonium</i> <i>ebeneum</i> .....				+	+					+
<i>Collema</i> <i>crispum</i> .....			+	+	+				+	
— <i>flaccidum</i> .....	+			+	+				+	
— <i>nigrescens</i> .....	+				+				+	
— <i>pulposum</i> .....			+	+	+				+	
— <i>verrucæforme</i> .....			+		+				+	
<i>Coniocybe</i> <i>furfuracea</i> .....	+				+			+		
<i>Dermatocarpon</i> <i>cinereum</i> .....			+		+				+	
— <i>hepaticum</i> .....			+		+				+	
— <i>miniatum</i> .....				+	+				+	
— <i>rufescens</i> .....			+		+				+	
<i>Diploschistes</i> <i>scruposus</i> .....	+			+	+			+		
<i>Ephebe</i> <i>pubescens</i> .....				+	+					+
<i>Evernia</i> <i>furfuracea</i> .....	+			+	+				+	
<i>Gyalecta</i> <i>cupularis</i> .....			+	+	+			+		
— <i>foveolaris</i> .....			+		+			+		

Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Gyrophora</i> <i>arctica</i> .....				+	+				+	
— <i>cylindrica</i> .....				+	+				+	
— <i>erosa</i> .....				+	+				+	
— <i>hyperborea</i> .....				+	+				+	
— <i>murina</i> .....				+	+				+	
— <i>polyphylla</i> .....				+	+				+	
— <i>proboscidea</i> .....				+	+				+	
— <i>vellea</i> .....				+	+				+	
<i>Hematomma</i> <i>coccineum</i> .....				+	+	+		+		
— <i>ventosum</i> .....				+	+	?		+		
<i>Lecania</i> <i>athroocarpa</i> .....	+			+	+			+		
— <i>cyrtella</i> .....	+			+	+			+		
<i>Lecanora</i> <i>albescens</i> .....				+	+			+		
— <i>alphoplaca</i> .....				+	+			+		
— <i>alpina</i> .....				+	+			+		
— <i>atra</i> .....	+			+	+			+		
— <i>atriseda</i> .....				+	+			+		
— <i>atrosulphurea</i> .....				+	+			+		
— <i>badia</i> .....				+	+			+		
— <i>calcareæ</i> .....				+	+			+		
— <i>cartilaginea</i> .....				+	+			+		
— <i>castanea</i> .....			+		+			+		
— <i>chrysoleuca</i> .....				+	+			+		
— <i>cinerea</i> .....				+	+			+		
— <i>cinereorufescens</i> .....				+	+			+		
— <i>coarctata</i> .....				+	+			+		
— <i>frustulosa</i> .....				+	+			+		
— <i>gelida</i> .....				+	+			+		
— <i>gibbosa</i> .....				+	+			+		
— <i>Hageni</i> .....	+		+	+	+			+		
— <i>lacustris</i> .....				+	+			+		
— <i>pallescens</i> .....	+		+	+	+			+		
— <i>poliophæa</i> .....				+	+			+		
— <i>polytropæa</i> .....	+			+	+			+		
— <i>protuberans</i> .....				+	+			+		
— <i>saxicola</i> .....				+	+			+		
— <i>sordida</i> .....				+	+			+		
— <i>straminea</i> .....				+	+			+		
— <i>subfusca</i> .....	+		+	+	+			+		
— <i>tartaræa</i> .....	+		+	+	+			+		
— <i>varia</i> .....	+		+	+	+			+		
<i>Lecidea</i> <i>aglaea</i> .....				+	+			+		

Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Lecidea alpestris</i> .....			+		+					
— <i>arctica</i> .....			+		+				+	
— <i>arctogena</i> .....				+	+				+	
— <i>assimilata</i> .....			+		+				+	
— <i>atrobrunnea</i> .....				+	+				+	
— <i>atrorufa</i> .....			+	+	+				+	
— <i>auriculata</i> .....				+	+				+	
— <i>Berengeriana</i> .....			+		+				+	
— <i>cinereoatra</i> .....				+	+				+	
— <i>confluens</i> .....				+	+				+	
— <i>contigua</i> .....				+	+				+	
— <i>convexa</i> .....				+	+				+	
— <i>crassipes</i> .....			+		+				+	
— <i>crustulata</i> .....	+			+	+				+	
— <i>cuprea</i> .....			+		+				+	
— <i>cyanea</i> .....				+	+				+	
— <i>decipiens</i> .....			+		+				+	
— <i>decolorans</i> .....			+		+				+	
— <i>Diapsisæ</i> .....			+		+				+	
— <i>Dicksonii</i> .....				+	+				+	
— <i>elata</i> .....				+	+				+	
— <i>elæochroma</i> .....	+		+	+	+				+	
— <i>erratica</i> .....				+	+				+	
— <i>erythrophæa</i> .....	+				+				+	
— <i>fusca</i> .....			+		+				+	
— <i>fuscescens</i> .....	+				+				+	
— <i>fuscoatra</i> .....				+	+				+	
— <i>furvella</i> .....				+	+				+	
— <i>granulosa</i> .....			+		+				+	
— <i>helvola</i> .....	+				+				+	
— <i>impavida</i> .....				+	+				+	
— <i>lapidica</i> .....			+		+				+	
— <i>limosa</i> .....			+		+				+	
— <i>lithophila</i> .....				+	+				+	
— <i>lugubris</i> .....				+	+				+	
— <i>lurida</i> .....			+		+				+	
— <i>neglecta</i> .....			+		+				+	
— <i>Nylanderii</i> .....	+				+				+	
— <i>panæola</i> .....				+	+				+	
— <i>pantherina</i> .....				+	+				+	
— <i>paupercula</i> .....				+	+				+	
— <i>rubiformis</i> .....			+		+				+	

Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Lecidea ramulosa</i> .....			+		+			+		
— <i>Siebenhaariana</i> .....				+	+			+		
— <i>speirea</i> .....				+	+			+		
— <i>subconfluens</i> .....				+	+			+		
— <i>tenebrosa</i> .....				+	+			+		
— <i>Tornoënsis</i> .....	+				+			+		
— <i>uliginosa</i> .....			+		+			+		
— <i>vernalis</i> .....			+	+	+			+		
<i>Lepraria</i> .....	+		+	+				+		
<i>Leptogium lacerum</i> .....			+		+				+	
— <i>plicatile</i> .....	+			+	+				+	
— <i>scotinum</i> .....			+		+				+	
<i>Lichina confinis</i> .....				+	+					+
<i>Lopadium fuscoluteum</i> .....			+		+			+		
— <i>pezizoideum</i> .....			+		+			+		
<i>Massalongia carnosa</i> .....			+		+			+		
<i>Microthelia micula</i> .....	+				+			+		
<i>Microglæna sphinctrinoides</i> .....			+		+			+		
<i>Nephroma arcticum</i> .....			+		+				+	
— <i>expallidum</i> .....			+		+				+	
— <i>lævigatum</i> .....	+				+				+	
— <i>tomentosum</i> .....	+		+		+				+	
<i>Pannaria brunnea</i> .....			+		+			+		
— <i>elæina</i> .....				+	+			+		
— <i>granatina</i> .....				+	+			+		
— <i>Hookeri</i> .....				+	+			+		
— <i>lepidiota</i> .....			+		+			+		
— <i>microphylla</i> .....			+	+	+			+		
— <i>triptophylla</i> .....	+				+			+		
<i>Parmelia alpicola</i> .....				+	+				+	
— <i>ambigua</i> .....	+				+	+			+	
— <i>encausta</i> .....				+	+				+	
— <i>incurva</i> .....				+	+	+			+	
— <i>lanata</i> .....			+	+	+				+	
— <i>olivacea</i> .....	+			+	+				+	
— <i>physodes</i> .....	+			+	+	+			+	
— <i>saxatilis</i> .....	+			+	+	+			+	
— <i>stygia</i> .....			+		+				+	
<i>Peltigera aptosa</i> .....			+		+				+	
— <i>canina</i> .....			+		+				+	
— <i>horizontalis</i> .....			+		+				+	
— <i>lepidophora</i> .....			+		+				+	

Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Peltigera malacea</i> .....			+		+				+	
— <i>polydactyla</i> .....			+		+				+	
— <i>rufescens</i> .....			+		+				+	
— <i>venosa</i> .....			+		+				+	
<i>Pertusaria communis</i> .....	+				+			+		
— <i>corallina</i> .....				+	+			+		
— <i>coriacea</i> .....			+		+			+		
— <i>dactylina</i> .....			+		+			+		
— <i>oculata</i> .....			+		+			+		
— <i>rhodoleuca</i> .....				+	+			+		
— <i>xanthostoma</i> .....	+				+			+		
<i>Physcia aipolia</i> .....				+	+				+	
— <i>aquila</i> .....				+	+				+	
— <i>cæsia</i> .....				+	+				+	
— <i>ciliaris</i> .....	+				+				+	
— <i>obscura</i> .....	+				+	+			+	
— <i>pulverulenta</i> .....			+		+				+	
— <i>stellaris</i> .....	+				+	+			+	
<i>Placynthium delicatulum</i> .....			+		+			+		
— <i>nigrum</i> .....				+	+			+		
<i>Polyblastia Henscheliana</i> .....				+	+			+		
— <i>hyperborea</i> .....				+	+			+		
<i>Polychidium muscicola</i> .....			+		+					+
<i>Psoroma hypnorum</i> .....			+		+				+	
<i>Racodium rupestre</i> .....				+	+			+		
<i>Ramalina scopulorum</i> .....				+	+					+
— <i>subfarinacea</i> .....				+	+					+
<i>Rhizocarpon alboatrum</i> .....				+	+					+
— <i>calcareum</i> .....				+	+			+		
— <i>geminatum</i> .....				+	+			+		
— <i>geographicum</i> .....				+	+			+		
— <i>petreum</i> .....				+	+			+		
— <i>viridiatrum</i> .....				+	+			+		
<i>Rinodina Conradi</i> .....			+		+			+		
— <i>mnieræa</i> .....			+		+			+		
— <i>sophodes</i> .....	+				+			+		
— <i>turfæa</i> .....			+		+			+		
<i>Solorina bispora</i> .....			+		+				+	
— <i>crocea</i> .....			+		+				+	
— <i>saccata</i> .....			+		+				+	
<i>Sphærophorus coralloides</i> .....				+	+					+
— <i>fragilis</i> .....			+	+	+					+



Names	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens	Propagation by			Thallus		
					Ascospores	Soredia	Thallus fragments	Crust-like	Leaf-like	Shrub-like
<i>Staurothele clopima</i> .....				+	+			+		
<i>Stereocaulon condensatum</i> .....			+		+					+
— <i>coralloides</i> .....				+	+					+
— <i>denudatum</i> .....				+	+					+
— <i>evolutum</i> .....				+	+					+
— <i>incrustatum</i> .....			+		+					+
— <i>paschale</i> .....			+		+					+
— <i>tomentosum</i> .....			+		+					+
<i>Sticta scrobiculata</i> .....	+				+				+	
<i>Thamnolia vermicularis</i> .....			+				+			+
<i>Toninia squalida</i> .....			+		+			+		
— <i>syncomista</i> .....			+		+			+		
— <i>vesicularis</i> .....			+		+			+		
<i>Usnea melaxantha</i> .....				+	?		?			+
<i>Verrucaria maura</i> .....				+	+			+		
— <i>margacea</i> .....				+	+			+		
— <i>mucosa</i> .....				+	+			+		
— <i>nigresens</i> .....				+	+			+		
— <i>rupestris</i> .....				+	+			+		
<i>Xanthoria lichneæ</i> .....	+			+	+				+	
— <i>parietina</i> .....	+			+	+				+	

## IV. THE CLASSIFICATION OF THE LICHENS INTO ASSOCIATIONS.

### 1. BARK-LICHEN ASSOCIATION.

#### EPIPHYTIC-LICHEN ASSOCIATION (BARK-LICHENS).

**I**N Iceland there is only one kind of tree which bears a lichen-vegetation worth mentioning, viz. the birch, *Betula odorata*.

This, like all other kinds of trees, runs through a fixed development as regards its lichen-vegetation, as I have formerly shown in my treatise "Danske Likeners Økologi" (1908). When quite young it is devoid of lichens, after which crustaceous lichens make their appearance, and later on foliaceous, and eventually fruticose lichens.

The bark of the birch, as is well-known, is smooth and arranged in layers; it contains plenty of birch-resin which helps to preserve it, so that it is but slightly liable to decomposition and rotting; it is especially for this reason that it is used for covering wooden houses, for soles of boots, etc.

When the trunks become old, the bark bursts and is thrown off in thin sheets, and at the foot of the trunk more or less distinctly radial cracks are formed in the bark, so that the bark becomes "scaly" in that part. Moreover, fissures, wounds from fallen-off branches, and cracks due to old lenticels, etc., are abundantly formed on the persistent parts of the bark.

Generally, the rule holds 'good that the lichen-vegetation begins on damaged, rough bark, in bark-cracks, lenticels, etc., while the smooth, undamaged bark is devoid of lichens.

As is well-known birches form coppices of very varying extent in Iceland. The highest are found in Hallormstaðskogur (see Thor-oddson's fig. 36 in Part I of this work) and in South Iceland, while the coppices of North Iceland are of lower growth (Hálsskogur, etc.). I myself have unfortunately seen the coppices of North Iceland only.

The light-conditions in almost all the coppices are favourable

enough for lichen-vegetation, in that the foliage of the birch casts a very light shade, and the trees stand a fair distance apart. Lichens are also frequently found on the ground under the trees.

The wood-floor is sometimes occupied by heather-moor, sometimes by grass- or moss-vegetation. But a "herb-vegetation" (i. e. a vegetation in which dicotyledonous flowering-plants are dominant) may also occur.

In Hálsskogur the bottom, which is of fine sand, is covered by a carpet consisting of grass, dwarf-birches, *Vaccinium uliginosum*, *Empetrum*, *Rubus* and *Galium*, with here and there intervening patches bare of vegetation covered with fallen birch-leaves. The trees stand close together, are 1—3 metres high, and the stems are thin, being 8—10 cm. in diameter; the bark is smooth. Both the wood-floor and the trees are devoid of lichens. This is probably due, as regards the bottom, to the too great competition of other plants, while as regards the bark, it is undoubtedly due to its not being sufficiently decomposed.

On the road between Hál and Einarstaðir (North Iceland) I passed by a coppice, quite similar in appearance, where the stems were below or about the height of a man, and devoid of lichens, while the ground, in only one spot, bore some *Cladonia pityrea*.

In some places, according to H. Jónsson's observations, a rich vegetation of lichens occurs on birches, for instance in South Iceland, and probably also in other places, where the birches are old enough to have decomposed bark. Thus, there is frequently found a rich vegetation of

<i>Parmelia olivacea</i> v. <i>aspidota</i> .	<i>Pertusaria xanthostoma</i> .
<i>Biatora Tornoënsis</i> .	<i>Lecanora protuberans</i> .
<i>Lecanora symmicta</i> .	

There is also found a rich lichen-vegetation on the dead top shoots of birches.

Deichmann Branth (D. B., 1903, p. 198) has compiled a list of more than 34 species, which have been found on Icelandic birches, namely the following: —

<i>Cladonia pyxidata</i> .	<i>Lecanora subfusca</i> (with var. <i>coilocarpa</i> , <i>albella</i> , <i>glabrata</i> , <i>rugosa</i> ).
<i>Cetraria sepincola</i> .	<i>L. varia</i> (with var. <i>symmicta</i> ).
<i>Parmelia olivacea</i> .	<i>L. protuberans</i> .
<i>Placodium ferrugineum</i> .	<i>L. verrucosa</i> .
<i>P. vitellinum</i> v. <i>octosporum</i> .	<i>Pertusaria communis</i> .
<i>Lecanora hypnorum</i> .	

<i>Pertusaria xanthostoma</i> .	<i>Lecidea enteroleuca</i> (with var.
<i>Urceolaria sophodes</i> v. <i>orbata</i> .	<i>Laureri</i> ).
— <i>exigua</i> .	<i>Gyalecta Beckhausii</i> .
<i>Lecidea vernalis</i> .	<i>Buellia myriocarpa</i> .
— <i>erythrophæa</i> .	<i>Arthonia proximella</i> .
— <i>Berengeriana</i> .	<i>Sagedia analepta</i> .
— <i>Tornoënsis</i> .	— <i>grisea</i> .
— <i>fuscescens</i> .	— <i>kentrospora</i> .
— <i>Nylanderi</i> .	<i>Pyrenula micula</i> .

If we compare the birches of Iceland and Denmark with reference to their lichen-vegetation, a characteristic difference will be seen as regards the species. In Denmark *Evernia Prunastri*, *E. furfuracea*, *Cetraria glauca*, *Usnea barbata* and *Ramalina fastigiata* form the dominant feature of the vegetation. In Iceland they do not appear to be of any importance, or are quite absent. The number of the species is greater in Iceland, yet I cannot depend upon this not being due to insufficient investigation of the birches of Denmark.

How the matter stands as regards "mass-occurrence" and "frequency-number" in Iceland and Denmark, I am not prepared to say, because, as I have already mentioned, I myself have not seen lichen-bearing birches in Iceland.

## 2. THE EARTH-LICHEN ASSOCIATIONS.

In the previous pages we have made a survey of the general biology of the earth lichens. Here we shall consider more closely the special Icelandic conditions, viz. the characteristic qualities of the Icelandic soil, and, finally, the lichen vegetation found in the plant-associations.

In a preceding part of this work Professor Thoroddsen has given an exhaustive description of the Icelandic soil, and of its geological and agricultural qualities. To this I refer the reader, and it will suffice here merely to point out such features of it as are of importance to the lichen-vegetation.

As stated by Thoroddsen, the Icelandic soil consists entirely of a finely divided mass, derived from the fundamental rock of the island, or of the same chemical and mineralogical composition as the latter. In other words it is the Basalt, in grains of every possible size, ranging from enormous blocks of rock to particles as fine as dust, which constitutes the soil available to the lichens all over Iceland. The liparite which occurs here and there is, ac-

according to Thoroddsen, of no importance as far as soil-formation is concerned.

Consequently, whether the soil is of the one or the other geological origin — glacial soil, or soil deposited in water, or deposited by wind, (aeolian deposits) — its chemical or mineralogical composition is essentially the same in all cases.

The circumstances which are of importance, regarding the soil as a lichen-substratum are therefore essentially the following: —

(1) The chemical composition (mineral earth or earth rich in humus), (2) the size of the grains, (3) thermal conditions, (4) the water-contents, (5) drifting soil, (6) burrowing animals, (7) leaf-fall, (8) and the snow-covering.

To these must be added, what is perhaps the most important, (9) competitive relations with other plants.

(1) The chemical composition of the loose soil is, as a whole, somewhat different in Iceland from that in Denmark, as was first pointed out by P. Feilberg (see Thoroddsen, in vol. 1, p. 252, of the present work). With regard to the amount of nutrition present, the difference is doubtless of very little consequence as regards lichens. On the other hand, it is indirectly a highly important fact, that the great amount of iron-salts and humus characteristic of the soil of Iceland, conditions a plant-growth which, taken as a whole, is very widely different from that of Denmark, and causes a competition among the plant-species which is highly conducive to the wide distribution of lichens all over Iceland.

(2) The size of the grains (fineness, respective coarseness) of the soil is, as mentioned above, hardly of any direct importance, but no doubt of indirect importance by being the means of bringing about various conditions of heat and moisture in the finer and coarser kinds of soil.

(3) The thermal conditions are far more unfavourable in Iceland than in Denmark, far greater tracts of ground being frozen, during a greater part of the year. As long as the upper soil-layers are frozen, the plant-covering also will frequently be thoroughly chilled, and the lichens will therefore lie dormant. On the other hand, it hardly has a direct influence upon the lichens if the ground is frozen farther down, as they are attached to the ground only very superficially, frequently only a few millimetre at the uppermost part near the surface. Quite another and far greater but indirect rôle is played by the frozen ground, owing to the fact



that the conditions of moisture are essentially dependent upon it. When the ground thaws in spring, there is a time in which the upper soil-layers are, for the time being, very wet, because the melting snow and ice cannot sink into the ground, owing to the sub-surface ice. We may be justified in saying that, taken as a whole, the yearly growth-period as compared, for instance, with that in Denmark, is considerably shortened by the low temperature of the soil. How long this period lasts, upon the whole, as regards the lichens, which, as we know, assimilate as soon as the temperature is above freezing-point, has not been investigated. But I assume that it is far shorter than in Denmark, where it lasts almost all the year round.

(4) The water-contents of the soil in Iceland, owing to the great amount of precipitation and the slight evaporation, are far greater than in Denmark. In the surface features of the landscape this is shown by the frequent occurrence of bogs. But, naturally, there is a great difference in the amount of water contained in the various soils, all conditions being found intermediate between boggy soil saturated with water, and dry sandy soil, and soil fine as dust which is so dry in numerous places that it drifts with the wind at every opportunity. The wettest soil, which is continually saturated with water (the bogs), is devoid of lichens; this is also the case with the driest, drifting soil, not on account of its dryness — for it is well-known that lichens chiefly imbibe directly-precipitated moisture, and are fairly independent of other water-supplies, — but on account of the unstability of the drifting soil. Lichens grow on soil intermediate, with regard to dampness, between these two extremes: they grow in association with other plants, as will be fully described below.

(5) All drifting soil is devoid of lichens.

(6) The rôle which burrowing animals play in Iceland is not known very particularly; it is however in all probability quite insignificant, while in Denmark, as is well-known, it is very great, especially in the woods.

(7) Leaf-fall. The layer of decaying leaves which in Denmark, during autumn, buries all the small plants of the wood-floor, plays, as a matter of course, a similar rôle in Iceland. When the trees or the shrubs (willow, birch) stand very close, the ground is frequently devoid of lichens, and this is no doubt partially due to this leaf-covering.



(8) The snow-covering has a very great influence, especially in the mountains. Where there is a perpetual snow-covering, lichens naturally cannot live. But lichens can live even on soil which is free from snow for only a few weeks during the summer. Thus I observed in several places on the mountains around Ölfjord that lichens grew abundantly at considerable elevations, which are not freed of snow until July. Taken as a whole it may be said, that the snow-covering in Iceland, by shortening the annual growth-period, plays a far greater rôle than it does in Denmark.

(9) The competitive relations with other plants are, on the whole, more favourable to the lichens in Iceland than in Denmark, because the higher plants — in consequence of the soil and climate — are not generally of so quick a growth there as in Denmark; but this I must naturally discuss more fully under each particular plant-association. For the present I shall only point out that the lichen-vegetation in Iceland plays physiognomically a more dominant rôle than in Denmark, more particularly because the competition on the part of other plants is not so keen there as it is in the more temperate regions.

The combined result of all the factors, climatic and edaphic, which we have been considering above, shows itself in the form of plant-associations as they occur in nature. I shall therefore go through these one by one, and, as far as our present knowledge of the subject makes it possible, occupy myself more closely with what has given them their appearance.

With regard to the plant-associations of loose soil, it is difficult to carry out any single logical systematization — merely to find proper names for them, such as are characteristic and to the point, is difficult. To do this we can proceed in any one of three essentially different ways: we can (1) name the association after the soil (e. g. "sandy shore," "dunes," etc.), or (2) after the conspicuous, dominant plants found therein (e. g. "beech wood," "birch coppice," etc.), or lastly (3) we may combine these two, as ecologists frequently do, and as people do in common language, naming some associations after the characteristic features of the soil, and others after conspicuous, characteristic plants.

In reality it is extremely difficult to decide upon one of these methods in particular, for the following reasons: If there existed

absolute agreement as regards a fixed terminology for the naming of the different kinds of soil, and in addition, if it were possible, out in the field, immediately to identify to which category the soil belonged which supported the association we were just then investigating, then it would be an excellent method consistently to name the association after the soil. But this cannot be done, owing to the nature of the subject. There does not exist, and will hardly ever be created, any descriptive soil-term, which will win universal acceptance. Nor will it ever be possible, out in the field to identify each kind of soil with any certainty. This requires thorough chemical and physical investigations, which must be made in the laboratory.

It appears to be far easier to name the association after the dominant plants, — when such occur. A beech wood is easy to recognize as such, but a “fell-field” (rocky-flat) a “mat-herbage” (herb-flat) which are not characterized by any one individual species, how are we to know them?

Here we find ourselves in reality placed before a fundamental question in ecology, — the definition and naming of the plant-association: partly, how we shall precisely define the individual association, so that it is recognizable wherever it may be met with on the surface of the earth, and may be determined, at any rate, with as great certainty as we determine a systematic species: and partly, how we shall name it, after the soil, or after dominant species of plant, or perhaps after dominant “growth-forms” (see Warming and Raunkiær).

On this question, first and foremost the founder of ecology, E. Warming, and afterwards C. Raunkiær, have contended that the associations ought to be analyzed with regard to “growth-forms,” so that we may thereby define them. What we shall afterwards call them is a point of less importance, as different names for the same association may be used synonymously, even although a uniform nomenclature would facilitate the survey considerably when we are occupying ourselves with the systematising of the associations.

Which classification of the growth-forms of the plant-world we are to use, must be dependent on the object we have in view in the investigation of the associations. In itself there is nothing to prevent our using several different classifications in the same investigation, for instance, we could enumerate the “geophytes,” “hemiptophytes,” “chamæphytes,” etc. (according to Raunkiær’s clas-

sification), or the "summer-annuals," "caespitose plants," "creeping-herbs," "shrubs," etc., etc. (according to Warming's classification).

It is in reality a hopeless task to try to describe a plant-association without such an analysis. I have experienced this, time after time, during my studies in Iceland when, in my notes, I was to give a name to an association. I was often uncertain as to how far I was now using the old, long-established terms "heaths," "fell-fields," "mat-herbages," etc., etc., with exactly the same meaning as the creators of these terms themselves gave to them. I did my best to use the correct terms, but I cannot deny that it often occurred to me, that it would have been much easier if the terms had been defined somewhat more precisely. For instance, had the term "heath" been defined as a plant-association in which dwarf shrubs or chamæphytes had a definite degree of frequency, it would have been far easier for me to have recognized the association in question, in the field: also remembering the fact, that the same association may perhaps be named sometimes in one way, and sometimes in another, according as the investigator in question received a more strong, subjective impression of this or the other species: It is possible that a lichenologist would occasionally speak of a "lichen-heath," which a bryologist would call a "moss-heath," and a phanerogamologist an "*Empetrum*-heath"!

I see no other solution of the difficulty than that the investigator — be he bryologist, lichenologist, algologist, phanerogamologist or what else, should define the association, as far as possible, from his own point of view, and then afterwards eventually agree upon how the whole association is to be named, and how the divergent names given by the investigators, may be reconciled with one another.

In the following pages I shall define the associations according to the dominant growth-forms. I shall go through the chief plant-associations, adopting in the main the division briefly given by Thoroddsen in this work (vol. I, pp. 317 et seq.), from which, however, in some points I shall differ.

Besides this analysis of the association as regards the various growth-forms it contains, there are several other matters which will be discussed, first among which comes the mass-occurrence of the different species, or growth-forms, contained in the association.

Various methods have been used for this purpose; they have been described and compared by C. Ferdinandsen (1918). Their

value varies greatly, and at the outset we may say that, for an exhaustive description, it is necessary to use several methods. Nature is too many-sided to be described in a few words, or by tabular methods.

Among the chief methods may be mentioned Raunkiær's valency-method (Raunkiær, 1916) which consists in the following: In an association a number of equally large sample-areas (e. g.  $\frac{1}{10}$  square metre) are demarcated, with equally large intermediate spaces between them, and the vegetation in them is investigated. Any plant-species (or any growth-form) which occurs in all the sample-areas is said to have the frequency-percentage (F. %) 100, in half of the samples F. % 50, etc.

By means of this method an idea is obtained of the frequency of the occurrence of the species (or growth-form) in the association.

Investigators have also tried to express by figures the size of the space occupied by each single species, (or growth-form) in the area of the association; the mode of procedure is similar to that used in the determination of frequency, in so far that samples are taken, the area occupied by every single species in the sample is determined, and on the basis of this, the total amount of area occupied by the species in the whole association, is calculated. Lagerberg, Raunkiær, H. E. Petersen and C. Ferdinandsen recommend and employ this method (see these authors in the Bibliography).

It is evident that it is very much to be wished, that we could give figures, which would be reliable for the areas occupied by the individual species. In the mean time it must be said, that the attempts made by the above-mentioned authors, to make such calculations, have proved an utter failure, and are quite worthless although, unfortunately, we must expect the method to be in vogue for some time, and to be employed by others.

The unreliability of the results obtained by this method, is due to the following fact: Even if we take a sample, ever so small, it is impossible to decide with any certainty how large a part of it is occupied by this or that species, unless it actually happens that only one species occurs in the sample. As soon as there are several species more or less entangled in each other, the conditions pertaining to the space occupied, are incapable of accurate description. How are we to determine, for instance, in a Danish *Calluna*-heath, how much of a sample is occupied by *Calluna*, and how much by



the reindeer moss entangled with it. The task is simply impossible, the question cannot be answered. The fact cannot be emphasized too sharply, that the figures which have hitherto been given for the areas occupied, and which have been obtained by the method of the above-mentioned authors, do not at all possess the numerical, the mathematical authority which numbers ought to have in order to be useful for purposes of statistical comparison. They are in short an illusion.

Add to this, that even if the figures for the area occupied could be fixed fairly accurately, that would not give us any great knowledge of the abundance with which the species (or growth-form) in question occurs in an association. A ten-years-old beech-wood will frequently cover as large an area as one of a 100 years, whilst the figures for the area occupied would not give any idea of the enormous difference as regards masses in the two growths. It is true, anything like this need not be demanded of the figure in question, but then they are not very enlightening in any respect, and are therefore superfluous.

In connection with the frequency percentage (F. %) (frequency-number), a far better method can be more advantageously employed, a method which science — as far as I know — has not employed very largely, but which practical men discovered decennia ago. It cannot be employed on excursions, with note-book and squared paper, or on expeditions on horse-back; it requires a sojourn on the spot, and some patience. It is simply this: The mass of a wood is determined by the forester by its timber-contents in cubicmetres (it may be expressed in terms of weight!); the crop of a rye-field may be given in weight (straw and grain); and quite similarly could the natural vegetation of any place be treated by a man of science: but then it would be necessary to reap the plants, the masses of which are wanted to be known.

This method has the advantage that — of course in connection with other descriptive means (frequency-numbers, etc.) — it can be employed to characterize both the whole association, and its individual species. Thus, it is really a valuable piece of information concerning an association, to know, for instance, that on a square metre there grow, on an average, let us say 2 kilograms of plants, while another association perhaps bears 200 kilograms. It must be admitted that this gives quite a striking impression of the plant-producing power in two such localities. I wonder how the tropical

rain-forest, and the lichen-covered heaths of Iceland, would appear when thus compared according to relative weights of produce! It would be extremely interesting to ascertain.

But also the luxuriance of the individual species or growth-form in an association, would be able to be characterized by this method. It would be very interesting to see, for instance, the result of comparing a piece of Danish heath with an Icelandic heath, in respect to the lichen-vegetation. How many kilograms of lichens each sample-area contains up there in the North and down here in Denmark.

Unfortunately I have not been able to employ such a "weight" method in my investigations in Iceland, nor had I at that time considered this matter more closely. But I am convinced that we have here an exceedingly valuable means of description, by which to characterize the difference between the masses, be it of the individual species, the growth-form or the whole association; and, as already mentioned, practical men have long ago used it in pursuit of their object.

#### a. The Deserts.

Large tracts of Iceland have a desert-vegetation, i. e. a very open vegetation consisting of scattered individuals. Where to draw the boundary line between the desert and the closed vegetations, i. e. vegetations which cover the ground completely, is entirely a matter of opinion, and the boundary can only be an artificial one. We may for instance decide, according to Raunkiær's method, to take a large number of equally large sample-areas, and note down their vegetation separately. It will then be seen that many of the areas are entirely devoid of plants, and such areas may be designated 0 (*nil*); and then resolve that a tract of land in which 75 % of the sample-areas were devoid of vegetation, should be designated "desert." But, as already mentioned, whether this "percentage of voidness" is chosen, or an entirely different one, for the designation "desert," it is and must be a matter of opinion. Such an analysis of "voidness" would be interesting for purposes of comparison, for instance between the Arctic cold-deserts, and the sub-tropical heat-deserts. But such an analysis has not yet been made, nor have the deserts of Iceland been, as yet, sufficiently investigated in this respect.

In Iceland many different kinds of deserts are found, the best-



known are the fell-fields of the plateaux; but others exist also, as for instance vast sandy tracts with drifting sand, both in the highlands and in the lowlands. We shall now consider these deserts more closely, leaving out those with a rock-substratum, which will be discussed elsewhere.

According to the substratum we can divide the deserts into stony, gravelly, sandy and clayey deserts. A division according to the principles of plant-ecology, cannot be undertaken, as the vegetation has not been sufficiently investigated, from a statistical point of view.

Stony Deserts are the stone-covered ridges (holt) of the lowlands, and the talus of fallen blocks and débris (Urd) of the highlands. The lichens growing directly on the stone-substratum, do not concern us here, but between the stones on the ridges there grow as chasmophytes, *Dryas octopetala*, *Thymus Serpyllum*, *Silene acaulis*, *Potentilla verna*, *Cerastium alpinum*, *Arabis petraea*, *Saxifraga caespitosa*, *Juncus trifidus*, *Luzula spicata*, *Achimilla alpina*, *Poa glauca*, *Elyna Bellardi*, and a number of less frequent species (according to Jónsson). Interspersed in the moss-carpet occur (according to Jónsson's list in "Vegetationen paa Snæfellsnæs," p. 41) the following species: —

Cladonia rangiferina	(podetia-wandering fruticose lichen).
Thamnolia vermicularis	—
Cladonia uncialis	—
Sphærophorus coralloides	—
Cetraria aculeata	—
Sphærophorus fragilis	—
Cladonia pyxidata	(hypothallus-wandering fruticose lichen).
— cornucopioides	—
Cetraria islandica	(erect foliaceous lichen).
Peltigera canina	(horizontal foliaceous lichen).
— rufescens	—
— aphtosa	—

Jónsson does not mention having found any crustaceous lichens, therefore these will hardly occur in conspicuous abundance, whilst it may be expected that, on future investigations, some or other of the small, inconspicuous species may be found, at any rate on decaying moss.

Jónsson also mentions the fact that here and there *Cladonia* and *Sphærophorus* spp. may occur as dominants in a sub-vegetation of mosses, in addition to more sparsely occurring *Gramineæ*.

The taluses of fallen blocks and débris (Urd) in the

highlands, are either very poor in, or entirely devoid of, phanerogams, and between the stones mosses (*Grimmia hypnoides*) chiefly occur, in part together with lichens; this will, however, be discussed more fully under the vegetation of the moss-carpets of the island.

The Gravelly flats in the lowlands bear a scanty vegetation of herbs, (see e. g. Thoroddsen in vol. I, p. 326 of the present work; Jónsson's lists are exhaustive, but, like Thoroddsen, he makes no mention of finding lichens).

In river-gravel in the lowlands *Chamaenerium* is common. The river-flats are occasionally inundated in spring, and are devoid of lichens.

The gravelly flats of the plateau are "the parts of the rocky flat poorest in plants" (Jónsson). Here and there grow *Luzula spicata*, *Oxyria digyna*, *Cerastium alpinum*, *Silene acaulis*, *Arabis petraea*, *Galium silvestre*, *Saxifraga caespitosa*, etc. Moss-cushions (*Dicranum falcatum*) occur also, and, — as "collars" around larger stones, — small carpets of *Grimmia hypnoides* intermixed with lichens (*Cetraria islandica* and *Cladonia*) and phanerogams; this will be mentioned more fully under the moss-vegetation. The gravelly flats which I traversed just below the summit of the mountain "Sulur," near Eyjafjörður, were still, on the 5th of July, supersaturated with the down-trickling snow-water, and were quite bare of vegetation.

Sandy flats. Several kinds of sandy flats of various geological origin occur, partly in the lowlands, and partly in the highlands. Many of them are quite bare of plant-growth along such great tracts, that days intervene before a few individuals are again met with. The commoner types of sandy flats are: beach-sand (with a halophilous herb-vegetation), which is devoid of lichens (owing to its contents of chloride of sodium); Jökul-sand (which is often inundated by Jökul-rivers) either devoid of, or with a very poor, herb-vegetation, and without lichens (on account of inundations possibly followed by drifting sand); and lastly tracts of blown sand (Sander) of various origin, but more or less wind-affected on the surface by frequent and violent sand-storms. The different kinds of sand mentioned here are devoid of lichens, owing to three essentially different reasons: (1) the occurrence of chloride of sodium in the soil (beach-sand), (2) frequent inundations (the sandy tracts below the Jökuls) or (3) drifting sand, (in the sandy tracts of the plateaux and elsewhere).

I traversed, in several places, such extensive sandy tracts, as

for instance Hólasandr (north of Mývatn), the "Sanders" in the delta of the Jökulsá (at the head of Axarfjörður), and the dunes between Mývatn and the Jökulsá.

The first of these tracts (Hólasandr) consists of black sand, in which are numerous stones with worn edges. It is very poor in vegetation; there occurred however, scattered uniformly over the entire surface, some grass, in tufts, at stated intervals of about  $\frac{1}{3}$ — $\frac{1}{2}$  metre. All other kind of vegetation was absent, for instance — owing to the strong sand-drifts prevailing everywhere — not a single moss or lichen was found.

As mentioned above, the stones were highly worn by the action of sand, and bore no mosses and hardly any lichens; scarcely a hundred out of the thousands of stones I passed by during a two-hours' ride, bore any vegetation at all, and even that of these few stones was extremely scanty. The following species were found: —

Stereocaulon spp.	(fruticose lichen).
Parmelia lanata	(foliaceous lichen).
Gyrophora arctica	—
— erosa	—
Lecidea pantherina	(crustaceous lichen).

The dune terrain east of Mývatn bore in numerous places a scattered vegetation of *Elymus arenarius*, which looked very remarkable against the dark background of black sand. Here also strong sand-drifts prevailed, and the ground was, in consequence, quite devoid of lichens.

As regards their vegetation and other external conditions, the blown-sand areas in the delta at the mouth of the Jökulsá, greatly resemble, for instance, Hólasandr. The sand, which is mixed with stones with worn edges, drifts very much. In stormy weather it was not possible for us to see even a few hundred metres in front of us on account of the sand-clouds, which filled the air near the ground.

In this place, a little grass, some *Silene acaulis*, and a few other phanerogams, formed an extremely poor and scattered vegetation. Mosses and lichens were totally absent, on account of the drifting sand.

Desert-like, clayey-flats with a poor or scattered vegetation, have been described more fully by Jónsson from East Iceland, Snæfellsnæs and South Iceland. They are, however, frequently more luxurious, and can bear a vegetation which forms a kind of transi-

tion to heath-vegetation. An instance of this is also given below under the description of heaths (Type III).

We shall elsewhere — under the description of Iceland's moss-carpet and their lichens, — have an opportunity of discussing the competition between moss and lichen. Here it will suffice to state, that lichens, in the loose soil of mountain-highs, in mountain-deserts, rarely occur on quite bare, purely inorganic soil. They show a peculiar tendency to seek company with mosses or other plants, without its being always possible to state precisely, which have been the first to arrive on the spot.

The species which appear to be most common on loose soil in mountain-deserts are the following: —

- |               |                |  |  |
|---------------|----------------|--|--|
| Cladonia      | turgida        | (fruticose lichen), frequently sterile.                        |  |
| —             | pyxidata       | —  | —, on humus.                                   |
| —             | rangiferina    | —  | —  |
| —             | coccifera      | —  | —  |
| Stereocaulon  | denudatum      | —  | —  |
| Alectoria     | nigricans      | —  | —  |
| Thamnia       | vermicularis   | —  | , sterile.                                     |
| Cetraria      | hiascens       | (foliaceous lichen), frequently sterile.                       |  |
| —             | islandica      | —  | —  |
| —             | Fahlunensis    | —  | —  |
| —             | aculeata       | (fruticose lichen),  | —  |
| Solorina      | crocea         | (foliaceous lichen),   | —  |
| Pannaria      | microphylla    | —  |  |
| Peltigera     | aphtosa        | —  | —  |
| —             | lepidophora    | —  | —  |
| Dermatocarpon | hepaticum      | —  | , on moor-soil.                                |
| Lecanora      | tartarea       | (crustaceous lichen), fertile; on moss, moor-soil and lichens. |  |
| Bacidia       | flavovirescens | (crustaceous lichen), often sterile; on purely inorganic soil. |  |
| Pertusaria    | oculata        | (crustaceous lichen), often fertile.                           |  |
| Buellia       | parasema       | —  |  |
|               |                | v. papillata, fertile; on moor-soil.                           |  |
|               |                | v. triphragmia, fertile.                                       |  |
| Rinodina      | miniaria       | (crustaceous lichen)   |  |
|               |                | v. cinnamomea, fertile; on moor-soil.                          |  |
| Lecidea       | assimilata     | (crustaceous lichen), fertile; on dead moss.                   |  |
| Caloplaca     | Jungermanniae  | —  | , fertile; on moor-soil.                       |
| Psoroma       | hypnorum       | —  | , fertile; on moss.                            |
| Lecanora      | castanea       | —  | , fertile; on moor-soil.                       |
| Bæomyces      | byssoides      | —  | , often sterile; on moor-soil rich in mineral. |

This is by no means an exhaustive list of the earth-lichens of the plateau; it must be supplemented by several other species, the occurrence of which is not known very accurately, and also by some which will be mentioned under the description of the moss-carpet of Iceland; these, as we know, partially extend upwards into the most desolate wastes of mountain heights, and are there found interspersed with various species of lichens.

### b. Lichen-heaths

of wide extent do not appear to occur in Iceland. In the above a couple of instances have been mentioned showing that lichens can, in patches, dominate the physiognomy of a *Grimmia*-carpet or of a poorly-developed chamæphyte-heath. But beyond this, no lichen-heaths proper are known, as they are described from other places in Arctic Regions.

### c. Moss-vegetations.

Whilst chamæphyte-heaths, grass-areas and coppices all have their own fairly distinct horizontal limits, this is not the case as regards the moss-areas. These are found at all altitudes, right up to the snow-limit, both in the low land and in the highest plant-bearing high land. The moss-vegetation itself has been exhaustively described elsewhere in this work (Hesselbo, 1918). I shall therefore occupy myself exclusively with those parts of it which are of importance to lichen-growth.

Mosses differ (in a higher degree than do lichens) in their requirements as regards moisture, in that several are hydrophytes (*Fontinalis*, *Sphagnum* spp., etc.), whilst others suffice with intermittent supplies of water, and some are distinctly xerophytic.

The vegetation of all areas of perpetual water-containing mosses, (in bogs and the like) is always devoid of lichens.

Here therefore, only that vegetation will be discussed which, during a shorter or longer period of the year, is dry and contains lichens. This refers, consequently, almost exclusively to the *Grimmia*-vegetation in both the high and low land. But before mentioning these more closely I shall say a few words about the *Philonotis*-bogs on the mountain slopes. They are seen in the landscape as bright-green patches on mountain declivities, where springs appear on the surface of the ground, and are extremely common every-



where along the sides of the fjords. Owing to their great water-contents they are always devoid of lichens.

*Grimmia*-heaths are found, as mentioned, at all altitudes right up to the snow-line, but differ somewhat according to the altitude.

The substratum which supports the *Grimmia*-carpet is sometimes solid rock, sometimes loose soil. My own observations are derived almost exclusively from carpets upon lava.

On mountain heights (fell-fields) the carpets are often small in extent, but further down in the low land they may cover large continuous tracts.

The plant-carpet is a few centimetres high and the moss-shoots stand erect. Whatever may be the nature of the deeper-lying substratum, at the bottom of the carpet there is always found, as a matter of course, a peat-formation consisting of the dead remains of the mosses, as soon as the moss-covering is only a few years old. The deeper-lying soil is evidently of no direct importance, or concern to the lichens; they are connected with the peat and the dust-particles, which always occur on it, and amongst the mosses.

With regard to the amount of water contained amongst the mosses, very little is mentioned in the literature. It may, however, be taken for granted that all *Grimmia*-vegetation in Iceland is dry enough to bear lichens. My own observations show this distinctly enough. For the rest, there is, as usual, the great defect, that we have no fixed method to indicate the degree of dampness of the plant-association, as far as emergent associations are concerned. We are constantly reduced to the entirely relative, and consequently almost useless terms, "dry," "damp," etc., without any fixed statement as regards measured amount.

Jónsson states that there is an essential difference in the accompanying phanerogams in high and in low land, in that only a few occur on the rocky flat, whilst they are found far more numerous further down. He states, in addition, as a general fact, that lichens are found more abundantly in the *Grimmia*-carpets of the rocky flat, than in those of the low land. How far this is quite right can only be proved by frequency-numbers, and statements of mass-occurrences (in weight), and such are not found in sufficient numbers. I must, however, say that Jónsson's statement sounds very reasonable, and is supported by Hesselbo. It can undoubtedly be explained by the fact that the climatic conditions are more unfavourable to the mosses in the high land, and relatively more



favourable to the lichens. Whether the absolute amount of lichens (in weight per unit of area) is really greater in the high land than in the low land is perhaps doubtful. But there is nothing to prevent the assumption that the amount, in proportion to the mosses, is greatest at a high altitude, not because the climate of mountain-heights is favourable to lichens, and is more agreeable to them than the climate of the low land, but because it is more inimical to the mosses than to the lichens, and thereby causes the latter to grow in apparently greater luxuriance. It is absolutely necessary to warn against a too strong belief in one's first-hand and direct impression as regards this matter; only actual measurements can give real information.

As an instance of a decided *Grimmia*-heath I shall describe more fully a stretch of land near Havnefjord (South-west Iceland).

The substratum is an older lava-field consisting of highly vesicular and porous post-glacial lava, the surface of which varies greatly, in that there occur level plains of small-sized lava-débris, strewn here and there with a little soil, large blocks of rock of varied appearance, vertical faces of rock, and caves, all mixed together in great confusion.

The *Grimmia*-carpet extends chiefly over the level plains covered with lava-débris. An enumeration of the characteristic plants gave the following results: — *Grimmia* occurred in all the sample-areas (F % 100), crustaceous lichens (F % 65), fruticose lichens (F % 15), bare ground (F % 10), grass (F % 65), *Galium* (F % 60), and some *Silene acaulis*.

The numbers may lead us to believe that crustaceous lichens highly dominate the plant-physiognomy of the carpet; this is, however, not the case.

The following species of lichens have been found: —

*Cetraria aculeata*, fruticose.  
*Cladonia coccifera*, —

*Pertusaria corallina*, crustaceous.  
Sterile crustaceous lichens.

But several other species may occur. If we enumerate all the species which have hitherto been recorded, we get the following: —

<i>Alectoria ochroleuca</i> v. <i>cinnamomea</i> , podetia-wandering fruticose lichen.	
<i>Cladonia rangiferina</i> ,	—
<i>Thamnolia vermicularis</i> ,	—
<i>Cladonia uncialis</i> ,	—

Stereocaulon denudatum,	podetia-wandering	fruticose lichen.
Sphaerophorus fragilis,	—	—
— coralloides	—	—
Cetraria aculeata,	—	—
Cladonia pyxidata,	hypothallus-wandering	fruticose lichen.
— gracilis,	—	—
— cornucopioides,	—	—
Cetraria islandica,	erect	foliaceous lichen.
Peltigera canina,	procumbent	foliaceous lichen.
— rufescens,	—	—
— aphota,	—	—
Solorina crocea,	—	—
Pertusaria corallina,	crustaceous	lichen.
Sterile crustaceous	lichens.	

Altogether about 18 species. Quantitatively, as far as it appears, the fruticose lichens are decidedly dominant in some places. Thus, Jónsson has seen them in such abundance amongst *Grimmia*, that he calls them "indicative of Lichen-heaths." But this appears to be only true of patches here and there. I myself have not met with this phenomenon. In Denmark we have nothing that can be compared with the Icelandic *Grimmia*-carpets, as regards superficial extension. Where we, here and there, find *Grimmia*-bogs scattered in our heaths, they are generally small, and appear to be wetter at the bottom, than are those in Iceland, and are consequently practically devoid of lichens. The difference no doubt chiefly depends on the fact, that in Denmark the *Grimmia*-bogs usually occur in damp hollows, where stagnant ground-water furnishes them with the necessary moisture, whilst the *Grimmia*-carpets in Iceland are, in a higher degree, directly furnished with this by rain. The *Grimmia*-carpets in Denmark have, as a rule, undoubtedly a quicker vertical growth, and deeper peat-substratum, which explains the characteristic paucity of lichens in our *Grimmia*-carpets, and the lichen-wealth in those of Iceland. It is consequently, in the first instance the competition which is stronger and more inimical to lichens in Denmark than in Iceland.

Besides this, it is strange that the Iceland *Grimmia*-carpets can contain quantitatively, such an abundance of crustaceous lichens, whilst ours are quite devoid of them.

A Table will render the difference plain: —

	Fruticose lichens	Foliaceous lichens	Crustaceous lichens	Number of species
Icelandic <i>Grimmia</i> carpets . .	61 %	28 %	11 %	18
Danish — — . .	100 %	00	00	5

I have no means of determining with certainty the quantitative difference, frequency and mass-occurrence (in weight). But a first-hand, direct consideration shows clearly enough, that the Danish bogs are very poor in lichens, whilst the lichen-wealth is far more considerable in Iceland.

#### d. The Grass Vegetation.

The majority of the grasses of Iceland belong probably to the same growth-form and are hemicryptophytes. The grass-covered areas — the grass-vegetation — may consequently be defined as areas containing a hemicryptophyte-vegetation with a very high frequency-percentage, in favourable cases — perhaps even most frequently — with a grass-frequency percentage (F %) 100. But consequently the areas contain many other plants besides grasses, for instance a larger or smaller number of chamæphytes, mosses, lichens, etc.

The grass-vegetation occurs abundantly everywhere on the island; no horizontal limit (compare wood-limit) towards the Arctic regions occurs.

On the other hand, there is a vertical limit, which, however, I cannot state precisely in metres, as I myself have not any definite measurements, nor have I seen any in the works of other authors. This much however is known, that it is chiefly the low-lying parts of the mountains and the lowlands which can support grass-carpet, while the high land is devoid of continuous grass-carpet.

With regard to the relation between the grassland and the ground-water level, the investigations published are not exhaustive enough to be able to give us a clear view on the subject. It is known, for instance from H. Jónsson's investigations, that low-lying, clayey sea-shores are in many cases covered with *Glyceria maritima* provided the ground is occasionally inundated by the sea.

Such a Glycerietum is often abundantly mixed with *Agrostis alba* and as regards growth-form, is consequently, on the whole, a grass-land, but differs in many respects so widely from the other grass-areas inland, that its associates are very different from those of these inland grass-areas.

This example is mentioned here merely to emphasize the commonly-existing rule which I demonstrated several years ago, that soil containing chloride of sodium is devoid of lichens. Not only would the presence of this substance, poisonous to lichens, but also the very high level of the ground-water undoubtedly, in itself, suffice to exclude lichens.

When the ground-water is fresh (lakes, etc.) a fixed succession of associations is no doubt developed in Iceland as with us in Denmark; those of Denmark are excellently set forth in Mentz's (Mentz, 1913) work on the recent vegetation of the Danish bogs, in which he demonstrates the transition from reed-swamp through mud-meadows to grass-bogs or *Paludella*-bogs and on to other vegetations (*Sphagnum*-bogs, etc.). With regard to Iceland we have not as yet such exhaustive descriptions; it is however already known that reed-swamps occur, passing into wet *Cyperaceae*-meadows, etc., and thence transitional forms to grassland.

But whether the ground-water is fresh or salt, it must be emphasized as a common feature, that lichens are absent everywhere where the ground-water, even during a shorter period of the year only, stands up to the level of the plant-covering or even above it, as in Denmark. I have observed such extensive meadows, devoid of lichens, in several places near Eyjafjörður and elsewhere.

The drier, lichen-containing grassland will be treated more fully in the following pages.

There exist no statistical investigations of the frequency-number of the grass species which occur in the grass-carpets, from which the various types of grass-areas could be designated or named. It is mentioned in the literature on the subject that the list of species from the different substrata (level land, mountain sides, home-fields, etc.) differs, but an exhaustive statistical verification is still wanting, and is also difficult to obtain, as the grasses are usually closely grazed by sheep so that it is a difficult or at any rate a slow work to determine them in the field. But even now an orientation may be had. It is for instance known that not only highly mixed carpets of both *Gramineae* and *Cyperaceae* are found, but also purer carpets

of sometimes one, sometimes another species; for instance, as Jónsson has shown, there often occurs a fairly pure vegetation of *Nardus* on slopes (Lier); also a rather pure *Agrostis (vulgaris)*-vegetation, and *Nardus-Agrostis*-slopes (Lier).

Consequently, it is not possible to give a more detailed division according to associations, but from a lichen-ecological standpoint this is of no consequence, because the different species of grass differ only slightly as competitors with lichens, and can therefore very well be treated collectively.

On the other hand, we have good knowledge of the substrata which support the grass, which is usually divided into associations according to the substrata — at least partially.

Thoroddsen discusses this exhaustively and instructively (vol. I, pp. 335—36), stating that

Grass-slopes (Græs-li) occur on sloping ground with loose soil and a level surface (not knolly) at the foot of mountains, both when the mountain is tuff and when it is basalt.

Knolly grassland (Græs-Mo) is extremely knolly, clayey ground, intermixed with humus.

A third type ("dry uncultivated grassland" loc. cit. p. 337) is without knolls and has a sandy, gravelly or pebbly substratum and an open plant-covering.

Home-field (Tun) is the cultivated, manured grassland around the farm-buildings.

The conditions afforded the lichens in the grass-vegetation are chiefly characterized by the fact that the plant-carpet is quite low, being only a few centimetre high; besides this the shoots, and especially the leaves, frequently stand more or less erect, so that abundant light usually falls between them. The amount of light is very favourable to lichens even in the most luxuriant carpet; on the other hand, the vertical direction of growth of the grass is a very grave hindrance to the crustaceous earth-lichens, which cannot of course force their way athwart this. On the other hand, as regards the fruticose and the erect foliaceous lichens this hindrance is of no great importance. Consequently, it will be easily understood, that crustaceous lichens can occur in abundance only in places, where the grass-carpet is open, so that they can grow directly on the surface of the ground, or here and there, where the grass is closely cropped (by grazing sheep, etc.), they can grow across the tufts.



As examples of lichen-vegetation in grass-carpets, I shall mention a few observations which are typical: —

On sloping ground on the sides of Reyðarfjörður (East Iceland) heaths and grass-carpets grow mixed with one another. The latter, seen from a distance, have a light greyish-green colour and consist mainly of *Festuca ovina* mixed with a small amount of *Calluna*, *Empetrum*, *Dryas*, *Silene acaulis*, *Cassiope hypnoides*, *Betula nana*, some mosses and *Lycopodium*. When I visited the place the grass was very short (3—6 centimetres), being closely grazed by sheep whose dung was found everywhere. Here and there was an extremely small number of lichens, which played a very subordinate part both as regards abundance and degree of frequency.

The degree of frequency was determined neither here nor in any other of the grass-carpets investigated by me, because the lichens were so exceedingly unevenly distributed that, in order to obtain a fairly reliable frequency-number, a far larger number of sample-areas would be required, than I had time to investigate.

The following species were found: —

Stereocaulon coralloides.	Cladonia fimbriata.
— tomentosum f. campestre.	Thamnolia vermicularis.
— incrustatum.	Cetraria aculeata.
Cladonia pityrea.	Peltigera canina.
— uncialis.	— aphtosa.
	Bacidia flavo-virescens.

In quite similar localities, and in an exactly similar vegetation, I found near Seyðisfjörður the same scanty lichen-vegetation supplemented by a few other species, viz.

Psoroma hypnorum.  
Dermatocarpon hepaticum.  
Collema spp.

I found on extensive, very knolly grassland, on mountain-slopes on each side of Eyjafjörður, a somewhat different vegetation, in that the top of the knolls bore *Dryas*, *Betula nana* or *Empetrum* — an indication of heath-vegetation. Upon these dwarf-shrubs and the dead portions of the grass-tufts on the top of the knolls, occurred masses of *Lecanora tartarea*, and here and there a solitary *Cetraria aculeata*. The former crustaceous lichen is, as is well-known, extremely common on the stunted plant-carpets of the Arctic regions, for instance in Lapland and Greenland.

I found near Eyjafjörður, just below the summit of Sulur-



mountain, extensive flats covered with heaths, knolly grassland, bogs and *Cyperaceæ* bogs.

The grass-flats contained a great quantity of lichens, very unevenly distributed, but in great numbers and well-developed specimens. The following species were found: —

<i>Alectoria ochroleuca</i> .	<i>Leeanora subfusca</i> v. <i>hypnorum</i> .
<i>Cladonia turgida</i> .	— <i>tartarea</i> .
<i>Sphærophorus fragilis</i> .	<i>Pertusaria oculata</i> .
<i>Cetraria aculeata</i> .	<i>Lecidea elæochroma</i> v. <i>muscorum</i> .
<i>Peltigera aphthosa</i> .	<i>Coenogonium ebeneum</i> .
— <i>malacea</i> .	Sterile crustaceous lichens.

The lichens occurred not only on the top of the knolls, but also on their sides. On the other hand, quite flat grass-areas (consisting of *Nardus*, *Anthoxanthum* and some *Carex* spp.) were quite devoid of lichens and very bright-green: they were probably too damp for lichens.

The species which have hitherto been found in grass-areas are the following: —

<i>Alectoria ochroleuca</i> (fruticose).	<i>Peltigera malacea</i> (foliaceous).
<i>Cladonia turgida</i> —	<i>Collema</i> spp. —
— <i>pityrea</i> —	<i>Dermatocarpon hepaticum</i> —
— <i>uncialis</i> —	<i>Coenogonium ebeneum</i>
— <i>fimbriata</i> —	(crustaceous).
<i>Thamnolia vermicularis</i> —	<i>Lecanora tartarea</i> —
<i>Sphærophorus fragilis</i> —	— <i>subfusca</i> v. <i>hypnorum</i>
<i>Stereocaulon coralloides</i> —	(crustaceous).
— <i>tomentosum</i> f. <i>campestre</i> (fruticose).	<i>Psoroma hypnorum</i> —
— <i>incrustatum</i> —	<i>Pertusaria oculata</i> —
<i>Cetraria aculeata</i> —	<i>Lecidea elæochroma</i> v. <i>muscorum</i>
<i>Peltigera canina</i> (foliaceous).	(crustaceous).
— <i>aphthosa</i> —	<i>Bacidia flavovirescens</i> —
	Sterile crustaceous lichens.

Consequently, in all, 24 species: 11 fruticose lichens (46 %), 5 foliaceous lichens (21 %) and 8 crustaceous lichens (33 %).

Here, as in the case of the heath, is a want which has not yet been supplied; the mass-occurrence (given in weight) of the lichens has not been determined. Nor is the average frequency-number known, for reasons which have been mentioned above. It is therefore difficult to give any comparison between the lichen-vegetation of the grass-areas of Denmark and Iceland, as regards quantity, so far as this is manifested by mass-occurrence and frequency-number. As regards quality, i. e. with respect to growth-form and systematic species, a comparison can more easily be made.

It must be borne in mind that Iceland is peculiar owing to its great abundance of natural, free-growing pastures, both damp meadows, devoid of lichens, and drier lichen-bearing areas, whilst Denmark is almost devoid of uncultivated pastures, for damp meadows are frequently more or less cultivated (drained, etc.), and most of the other grasses are under intensive culture, entering into the regular rotation of crops. Consequently, the lichen-bearing areas in Denmark are very small and contain, according to my observations, only about 16 lichen-species, viz. 12 fruticose (*Cladonia rangiferina*, *C. rangiformis*, *C. uncialis*, *C. furcata*, *C. gracilis*, *C. squamosa*, *C. pyxidata*, *C. fimbriata*, *C. Floerkeana*, *C. coccifera*, *Cetraria aculeata*, and *Stereocaulon paschale*), 2 foliaceous (*Cetraria nivalis* and *Peltigera canina*) and 2 crustaceous (*Sphyridium byssoides* and *Lecidea uliginosa*).

The relationship according to percentage is consequently as follows: —

	Fruticose lichens	Foliaceous lichens	Crustaceous lichens
Danish lichen-bearing grass-areas (in dunes, etc.)	75 %	13 %	13 %
Icelandic — — — — —	46 %	*21 %	33 %

As seen from the lists, the species are not the same, although several are common to both countries. But the most conspicuous difference is that which has regard to the growth-forms, Iceland having a very great number of crustaceous lichens — which appear to play rather an important part as regards the plant-physiognomy — viz. 33 %. This undoubtedly indicates that the competition between grass and lichen results rather in favour of the lichens in Iceland, than of those in Denmark; that is to say, the presence of the great number of crustaceous lichens is not due either to climate or soil, but to a less keen competition.

Consequently, if we are to sum up in a few words a comparison between the lichen-vegetation of the Danish and Iceland grass-areas, we must say, that Iceland has the greater number of species, 24 as against 16 Danish, Iceland has 11 fruticose lichens, 5 foliaceous lichens, and 8 crustaceous lichens, while Denmark has 12, 2, 2

respectively. The numerical preponderance as regards Iceland is due to the foliaceous and especially the crustaceous lichens.

The mass-occurrence (in weight) in both countries is unknown, as is also the frequency-number in both countries. For a first-hand and direct consideration the difference does not appear to be great in these two respects, but we ought not to remain standing at this point.

#### e. Heaths.

Under this name I include all such associations as are identified in the field by the fact that all, or at any rate almost all, the sample-areas contain chamæphytes, mainly dwarf-shrubs. A phanerogamologist will hardly suffice with so short and summary a characteristic, and it is his task to investigate partly which growth-forms the heath contains, and what percentage of each (chamæphytes, hemicryptophytes, etc.) and partly what frequency-degree each of these growth-forms has. A vegetation of which some of the sample-areas contain *Empetrum* only, others *Calluna* only, and others again a mixture of both is, according to the diagnosis used here, a heath as entirely as a vegetation which contains exclusively *Calluna* in all its sample-areas, because *Calluna* and *Empetrum* belong to the same growth-form. When I here mention as a kind of diagnosis, the characteristic that all or almost all the sample-areas must contain some or other chamæphyte, this should not be regarded as an analysis of the phanerogamic growth-forms of the Iceland heath -- such will no doubt be given elsewhere in this work -- but it is simply an easily recognizable feature whereby one can perhaps in the future recognize such Icelandic vegetations, of which the lichen-vegetation has been investigated by me and will be described more fully later on in this paper; in a similarly summary manner phanerogamologists describe lichen-vegetations, moss-vegetations, etc. in associations which interest them for the sake of the phanerogams. It is in addition a diagnosis of quite similar character as the diagnosis that a wood is an association in which every sample-area contains a tree or parts of a tree -- a diagnosis which does not involve anything whatever as to the entire biological aspect of the wood, when all its species are enumerated according to their growth-form.

I must add, that in the investigation of the heath-associations, I took, in the majority of the localities, sample-areas of 2 square

decimetres (dm.<sup>2</sup>) with intermediate spaces of equal size, viz. about 1 metre.

The majority of the heaths, regarded as landscapes, are easily recognizable in Iceland by their greenish-brown tone of colour, which makes them conspicuous even at a fairly long distance. They occur on mountain-sides up to a height of about 400 metres. It is stated that on slopes (mountain-sides) the ground and hence also the plant-covering is flat, whilst they are knolly and uneven on a horizontal substratum. These features agree exactly with my observations.

In the following I shall give some examples of the more frequent facies of the heath and their lichen-vegetation.

Type I. Dry heaths on level (not knolly) ground.

(a) Heaths rich in phanerogams but either poor in or devoid of lichens.

Near Háls parsonage in Fnjoskádalur (North Iceland) I noted down that there occur extensive heaths the character plants of which are *Empetrum*, *Betula nana* and various *Glumifloræ*, mostly grasses. Each of these occur in all the sample-areas, i. e. they have the frequency-percentage 100. The ground, which is gently sloping, consists of fine, reddish sand, and is covered by a continuous carpet of the above-mentioned character-plants and by a few others which have a lesser frequency-degree, e. g. *Dryas*, *Silene acaulis*, etc.

Both the open ground and the birch-clusters are devoid of lichens.

The reason of this phenomenon merits fuller discussion. As mentioned above, we can, on the whole, point out eight essential factors which determine the presence or absence of earth-lichens in a particular association, viz. the chemical composition of the soil, the size of its grains, thermal conditions, water-contents, drifting soil, burrowing animals, a layer of decaying leaves, snow-covering, and competitive relations with other plants. Among these eight factors we must consider more fully the layer of decaying leaves and the competitive relations with neighbours. It is impossible to believe that all the other factors mentioned above, could have an injurious influence on a lichen-covering on the heath-areas in question. But the two powerfully acting factors just mentioned are without doubt instrumental in the existing want of lichens. The fact is, that dwarf-birches, where they form dense growths, are fairly high in growth, cast rather a deep shade, and shed a considerable number

of leaves which cover and choke such lichen-germs as might possibly fall on the plant-carpet and try to hold their own there.

The frequency-percentage (100 %) of the dwarf-birch in this association does not, as a matter of course, give us any idea of the fact that it dominates the area to such a high degree and has such an exclusive influence as regards the lichens. It has not for instance a higher frequency-number than have the *Empetrum* and *Gramineæ* in the same association. Yet we shall see further on that both *Empetrum* and *Gramineæ* in purer growths — i. e. not at all or only slightly mixed with birches — are far more hospitable towards the lichens than is the association described here, whose want of lichens must therefore undoubtedly be attributed to the presence of the dwarf birch.

In itself it is a drawback of the method in question, that this quality cannot be deduced from the frequency-number — that the latter expresses so imperfectly the area covered by the species present; but I fear that this drawback will ultimately be found to be insurmountable, whatever method should be adopted. The word-description of the association must here supplement the statistical figures.

I found heaths of this kind or of very much the same composition on extensive tracts between the farms of Háls and Einarstaðir, lower down on the mountains; especially in Fljótshéiði, a locality near the latter farm, I noted down a vegetation of dwarf-birches (F % 95), i. e. frequency-number 95, *Empetrum* (F % 90), *Glumifloræ* (F % 85), *Vaccinium uliginosum* (F % 65), *Dryas* (F % 45), *Salix lanata* (F % 30) and *Calluna* (F % 10). The dwarf-birch was consequently somewhat less frequent and a little less dominant there. A few other species grew scattered in the plant-carpet, and there occurred also a small quantity of lichens, F % 20 (10 % crustaceous lichens, 0 % foliaceous lichens, 10 % fruticose lichens) and a small quantity of mosses (F % 5).

The lichens in question were *Alectoria ochroleuca* and *Thamnolia vermicularis*, both podetia-wandering fruticose lichens, and a few crustaceous lichens which were not determined more closely.

In large, extensive tracts of land along the left bank of the Jökulsá, and between the farms of Svinadalur and Ás, I observed heaths somewhat more luxuriant in composition and characterized by an abundant mixture of *Salix lanata*. The other species were *Betula nana* (F % 100), *Glumifloræ* (F % 100), *Empetrum* (F % 95),



*Vaccinium uliginosum* (F % 80), *Salix lanata* (F % 60), *Geranium silvaticum* (F % 26), *Betula pubescens* (F % 20), *Salix* spp. (F % 20), *Equisetum* (F % 20), a little *Calluna* (F % 7), a little *Lycopodium* (F % 7) and some mosses (F % 13). Consequently, these heaths contain considerable quantities of high, well-grown shrubs, viz. *Salix lanata*, some *Betula pubescens*, etc. The vegetation was very close and luxuriant, and the floor was entirely covered with decaying leaves. In correlation with this lichens were totally wanting in these heaths.

We have now seen some different examples of how both the lower and taller shrubs, which shed an abundance of leaves every year, are simply through this peculiarity inimical to the growth of lichens. The more frequently low-growing trees occur on a heath, the more difficult do the life-conditions of the lichens become. It cannot be doubted that there is correlation between the occurrence of these two growth-forms.

Type I. (b) Dry heath with drifting soil; devoid of lichens.

In the mountains between Fnjoskádalur and Öfjörð (North Iceland) I noted in some places a *Dryas*-heath on which the characteristic plants were *Dryas* (F % 100), *Glumifloræ* (F % 100), dwarf-birch (F % 50), *Empetrum* (F % 40), *Salix lanata* (F % 20), and *Vaccinium uliginosum* (F % 20). Peculiar to this heath was the total absence of lichens, which was evidently due to the shifting soil of the place in question, strong winds causing it to drift. It was evident that the plant covering and other conditions were not detrimental to the lichens, which in other places thrived excellently among the same competitors which occurred here.

Thus we have seen two essentially different factors which may be instrumental in excluding a lichen-vegetation from heaths: (1) certain shade-casting, deciduous chamaphytes and Nano-phanerophytes which may dominate so highly that lichen-growth is made impossible, and (2) drifting soil which may play exactly the same part, even if the plants present are not in themselves any hindrance to lichen-growth.

Type I. (c) Heaths poor in phanerogams and rich in lichens.

Other heaths may be rich, even very rich, in lichens. We shall now mention some specimens of them.

In the heaths near Einarstaðir (Aðalreykjadalr in North Iceland) were found scattered larger and smaller areas of *Dryas*-grass-heaths which were easily discernible even from a considerable



distance owing to their light greyish-green tone of colour. Their character-plants were *Dryas* (F % 100), *Glumifloræ* (F % 100) and *Empetrum* (F % 90), besides less important quantities of dwarf-birches (F % 10) and *Silene acaulis* (F % 10). As indicated by the names, the plant-covering is rather low; the soil was stable (not drifting) and no abundantly leaf-shedding plants were predominant in it.

Such areas were peculiar by the vegetation being — also physiognomically — highly dominated by lichens, especially crustaceous lichens, for lichens, taken as a whole, were found in all the samples (F % 100). Fruticose lichens (F % 100), do not play any dominant part physiognomically, in spite of their high frequency-percentage (F % 100), that is to say, they are not very conspicuous as masses. This is in a way also true of the foliaceous lichens (F % 33), whilst crustaceous lichens (F % 100) are dominant to an unusual extent. This is a very peculiar feature, as it must be remembered that crustaceous lichens, taken as a whole, have very great difficulty in holding their own amongst other competing plants, for they are very easily choked by being even very slightly covered over by larger neighbours. Taken as a whole, the association just described may be regarded as a characteristic Arctic association, poor in phanerogams and rich in lichens.

The following species occurred: —

	Fruticose lichens	Foliaceous lichens	Crustaceous lichens	F %	Fertile	Sterile
<i>Cetraria aculeata</i> .....	+			100		+
<i>Alectoria ochroleuca</i> .....	+			100		+
<i>Thamnolia vermicularis</i> .....	+					+
<i>Cetraria islandica</i> .....		+		20		+
<i>Solorina saccata</i> .....		+		10	+	
<i>Leptogium lacerum</i> .....		+				+
<i>Peltigera lepidophora</i> .....		+				+
<i>Lecanora tartarea</i> .....			+	100		+
<i>Bacidia flavovirescens</i> .....			+			+
<i>Caloplaca pyracea</i> .....			+		+	

Consequently, 3 sterile fruticose lichens, 4 foliaceous lichens (of which 1 sterile) and 3 crustaceous lichens (of which 1 sterile).

In the districts around Mývatn about Hlíðarfjall I noted similar *Dryas*-heaths covering large tracts alternating with bare sand. Here the characteristic plants were also *Dryas* (F % 100), *Empetrum* (F % 100), *Glunifloræ* (F % 100) and abundance of dwarf-birches (F % 70) and *Vaccinium uliginosum* (F % 50). What has been said above about the factors which conditioned the life of the lichens in the heaths near Einarstaðir holds also good as regards these heaths. A fairly rich lichen-covering occurred (F % 100), viz. fruticose lichens (F % 100), foliaceous lichens (F % 50) and crustaceous lichens (F % 90); but, as may be seen, the larger species preponderate slightly, perhaps in correlation with the fact that dwarf-birches are more dominant here and determine the character of the lichen-vegetation.

The following species were found: —

	Fruticose lichens	Foliaceous lichens	Crustaceous lichens	F %	Fertile	Sterile
<i>Cetraria aculeata</i> .....	+			100		+
<i>Alectoria ochroleuca</i> .....	+			90		+
<i>Thamnolia vermicularis</i> .....	+			100		+
<i>Alectoria nigricans</i> .....	+			60		+
<i>Cladonia rangiferina</i> .....	+			10		+
<i>Cetraria nivalis</i> .....		+		30		+
— <i>islandica</i> .....		+		20		+
<i>Lecanora tartarea</i> .....			+	90	+	

Consequently, 5 fruticose lichens, 2 foliaceous lichens and 1 crustaceous lichen.

The species of lichens are not everywhere the same, but they do not vary greatly. In the neighbourhood of Mývatn I traversed large tracts of heath, still poorer in phanerogams, where the frequency-percentage of the lichens was very great (F % 100) and where the landscape displayed dark patches of blackish-brown lichens (*Cetraria islandica*, *C. nigricans* and *C. corniculata*). Here we might perhaps be justified in speaking of "lichen-heaths," but I think that their contents of *Dryas*, F % 100, make such a name superfluous.

I shall describe one more specimen of a *Dryas*-heath which I investigated near Einarstaðir. The ground was slightly inclined and partially bared in many places. The plant-covering was 8—10 cm. high and consisted of *Dryas* (F % 100), *Empetrum* (F % 100), grasses (F % 100), dwarf-birch (F % 64), *Azalea procumbens* (F % 24), *Vaccinium uliginosum* (F % 16), *Polygonum viviparum* (F % 12) and *Thalictrum alpinum* (F % 4). In this low-growing, open vegetation a quantity of lichens was growing (F % 100), fruticose and foliaceous lichens and *Lecanora tartarea*. The species were: —

*Alectoria ochroleuca* (fruticose lichen).

— *nigricans* —

*Cetraria nivalis* (foliaceous lichen).

— *aculeata* (fruticose lichen).

*Thamnolia vermicularis* (fruticose lichen).

*Lecanora tartarea* (crustaceous lichen).

The types of heath described above are characterized by their level, partially sloping substratum, their open and low-growing vegetation, and chamæphytes and hemicryptophytes with slight leaf-fall which dominate, both physiognomically and ecologically. Consequently, the conditions are favourable to the lichens, and their frequency-percentage is everywhere 100 or thereabout, sometimes crustaceous lichens (mostly *Lecanora tartarea*), sometimes fruticose lichens dominating.

Type II. Dry, knolly heaths with phanerogams on the horizontal surface of the knolls, lichens on the sides of the knolls, and mosses, etc., in the narrow depressions or ruts between the knolls.

A third type of heath which is common in Iceland is the Knolly heath; it has fewer lichens than has the low-lying, level *Dryas*-*Empetrum*-grass-heath.

I noted some examples of this type of heath from different areas in North Iceland between Einarstaðir (in Aðalreykjadalur) and Mývatn, on Reykjaheiði (south of Axarfjörður, between the Jökulsá and the Laxá), along the left bank of the Laxá (which runs out into Skjalfandi) and in a few other places.

As already mentioned it is peculiar to these heaths that the ground is very knolly, i. e. it consists of mounds with deep intervening depressions. The heaths appear usually or perhaps exclusively to develop on level (not sloping) ground.

Between Einarstaðir and Mývatn (in the valley of the Laxá) heaths were found composed of *Empetrum* (F % 100), grasses (F % 100), dwarf-birch (F % 80), and a few other phanerogams with a

considerably less frequency-degree and physiognomical dominance. Lichens were found in all the samples (F % 100), but nevertheless played physiognomically a less considerable part than in the level *Dryas-grass-Empetrum*-heath. They all occurred on the sides of the knolls, while the horizontal surfaces of the knolls were covered by phanerogams.

The following species occurred: —

	Fruticose lichens	Foliaceous lichens	Crustaceous lichens	F %	Fertile	Sterile
<i>Alectoria ochroleuca</i> .....	+			All the species taken together constitute a frequency-percentage 100. The species were not determined on the spot.		+
<i>Stereocaulon paschale</i> .....	+					+
<i>Cladonia rangiferina</i> .....	+					+
— sp.....	+					+
<i>Thamnolia vermicularis</i> .....	+					+
<i>Cetraria aculeata</i> .....	+					+
— <i>islandica</i> .....		+				+
— <i>nivalis</i> .....		+				+
— <i>Fahlunensis</i> .....		+				+
<i>Peltigera rufescens</i> .....		+				+
— <i>lepidophora</i> .....		+				+
<i>Solorina saccata</i> .....		+			+	
<i>Caloplaca vitellina</i> .....			+		+	
<i>Lecanora tartarea</i> .....			+			+

*Alectoria ochroleuca* and *Lecanora tartarea* constituted the most conspicuous features of the landscape, while reindeer moss, which is so common in Danish heaths, was of very little importance there.

On a knolly heath, in the district around Åsbyrgi, sitting on the knolls themselves, I also noted down the following species: —

- Cladonia fimbriata* (fruticose lichen; sterile).
- *cariosa* ( — ; fertile).
- *pityrea* ( — ; sterile).
- Leptogium lacerum* (foliaceous lichen; sterile).
- Peltigera venosa* ( — ; fertile).
- Bacidia flavo-virescens* (crustaceous lichen; sterile).
- Psoroma hypnorum* ( — ; fertile).
- Lecidea assimilata* ( — ; fertile).

Upon the above-mentioned Reykjaheiði, over considerable tracts of land, I also observed a very knolly heath, with high mounds (reaching to the knee and upwards). Between the knolls there were deep, narrow depressions.

The vegetation of the knolls consisted of dwarf-birch (F % 100), *Vaccinium uliginosum* (F % 100), *Empetrum* (F % 100), *Juniperus* (F % 60), grasses (F % 60) and small quantities of *Salix lanata* and *Calluna* and a few other less dominant species.

Mosses and lichens were found to be equally abundant upon the knolls themselves, viz. about frequency-percentage 40 of each.

As for the rest, each individual knoll showed a characteristic vertical grouping of the species, in that the horizontal surface of the knolls was covered by *Empetrum*, dwarf-birch and *Vaccinium*, whilst *Calluna* grew further down towards the depressions. All the lichens occurred on the sides of the knolls, none upon the horizontal surfaces.

In the depressions between the knolls, a vegetation was formed consisting of an equal mixture of *Empetrum*, mosses and grasses, whilst lichens were practically absent. The shade was very deep in the depressions, and this is no doubt the reason why lichens were almost absent there.

On this very characteristic heath, I noted down the following lichens: —

<i>Cladonia fimbriata</i>	(fruticose lichen; sterile).
— <i>uncialis</i>	( — ; — ).
— <i>rangiferina</i>	( — ; — ).
— <i>gracilis</i>	( — ; — ).
<i>Alectoria ochroleuca</i>	( — ; — ).
— <i>nigricans</i>	( — ; — ).
<i>Stereocaulon paschale</i>	( — ; — ).
<i>Sphærophorus fragilis</i>	( — ; — ).
<i>Cetraria aculeata</i>	( — ; — ).
— <i>islandica</i>	(foliaceous lichen; sterile).
<i>Peltigera rufescens</i>	( — ; — ).
<i>Lecanora tartarea</i>	(crustaceous lichen; fertile).
<i>Psoroma hypnorum</i>	( — ; — ).
<i>Petusaria xanthostoma</i>	( — ; — ).
<i>Bæomyces byssoides</i>	( — ; sterile).
<i>Buellia scabrosa</i>	( — ; fertile).
<i>Bacidia umbrina</i>	( — ; — ).

In a locality on the left bank of the Laxá, and not far from where it flows into Skjalfandi, I observed a similar tract of heath with large, high knolls (about 60—70 cm.) and with a vegetation



similar to that in Reykjaheiði. The dominant phanerogamic vegetation upon the knolls consisted of *Empetrum*, grass and *Calluna*, together with small quantities of dwarf-birch, *Arctostaphylos uva ursi*, *Belula nana*, *Vaccinium uliginosum* and *Dryas*. On the sides of the knolls were found lichens with a frequency degree 80, viz.

<i>Cladonia pityrea</i>	(fruticose lichen; sterile).
— <i>coccifera</i>	( — ; — ).
— <i>rangiferina</i>	( — ; — ).
<i>Peltigera rufescens</i>	(foliaceous lichen; — ).
<i>Cetraria islandica</i>	( — ; — ).
<i>Pertusaria oculata</i>	(crustaceous lichen; fertile).
<i>Psoroma hypnorum</i>	( — ; — ).
<i>Lecidea assimilata</i>	( — ; — ).
<i>Bacidia flavovirescens</i>	( — ; sterile).
<i>Lecanora tartarea</i>	( — ; — ).

The depressions between the knolls were covered with grasses, mosses, *Calluna*, etc., but lichens were absent.

In a locality a few miles from the heath just mentioned a very knolly heath occurred on a lava substratum, with the same phanerogams as that just mentioned, and the lichens also almost exclusively covering the sides of the knolls; only about 15 F % lichens occurring upon the horizontal surface. The species were: —

<i>Alectoria ochroleuca</i>	(fruticose lichen; sterile).
<i>Cladonia pityrea</i>	( — ; — ).
<i>Peltigera venosa</i>	(foliaceous lichen; sterile).
<i>Pannaria brunnea</i>	(crustaceous lichen; fertile).
<i>Psoroma hypnorum</i>	( — ; — ).
<i>Lecidea helvola</i>	( — ; — ).
<i>Lecanora tartarea</i>	( — ; — ).
<i>Bæomyces byssoides</i>	( — ; sterile).

Consequently, it is common to the Knolly heaths we have been considering here, to have a very uneven substratum with an essentially different vegetation upon the knolls and in the depressions between them. Lichens occur in a highly varying frequency-degree (40—80—100 F %) and almost exclusively on the sides of the knolls.

### Type III. Wet Mountain-heaths.

Still another type of heath is found in Iceland on mountain heights, in places where the snow-covering lasts a long time. I investigated more closely some such heaths, for instance on the mountains east of Eyjafjörður on Vadalheiði, on July 3rd, 1913. The snow

had just disappeared from the greater part of the heath, but it was still lying in many small patches in the depressions. It was evident that both climate and soil here were distinctly wetter and colder than in those places where the heath-types discussed above, usually develop.

The substratum was very knolly moraine soil, with knolls reaching up to the knees, and with deep, narrow moss-grown depressions between the knolls. Lichens were abundantly present; they occurred chiefly on the sides and on the horizontal surface of the knolls. The latter phenomenon I have only met with on this type of heath, and it is no doubt to be explained as a result of the fact that, owing to the difficult conditions of vegetation, well-developed phanerogams do not occur on the top-surfaces of the knolls, as they occurred on the heaths situated on lower levels on the mountains.

The following phanerogams occurred on the knolls: — Dwarf-willow (F % 90), *Cyperaceæ* (F % 90), *Polygonum viviparum* (F % 90), *Empetrum* (F % 40), *Silene acaulis* (F % 70), *Cassiope hypnoides* (F % 40), *Salix lanata* (F % 20), and lastly there occurred, also on the knolls, 100 F % of lichens (i. e. 90 F % of crustaceous lichens, 60 F % of foliaceous lichens and 60 F % of fruticose lichens).

In the depressions between the knolls there grew dwarf-willows (F % 100), *Polygonum viviparum* (F % 100), a small amount of *Empetrum* and grasses (F % 40), a small amount of *Cyperaceæ*, large quantities of mosses (F % 100), but no lichens.

The reason of this absence of lichens must undoubtedly be sought in the fact that the depressions keep very wet during the short period of summer in which the heath is free from snow; this creates unfavourable conditions for the lichens.

The following lichens were found upon the knolls: —

<i>Stereocaulon paschale</i>	(fruticose lichen; sterile),
<i>Cladonia turgida</i>	( — ; — ).
— <i>coccifera</i>	( — ; — ).
— <i>pyxidata</i>	( — ; — ).
— <i>fimbriata</i>	( — ; — ).
— <i>rangiferina</i>	( — ; — ).
<i>Cetraria islandica</i>	(foliaceous lichen; sterile).
— <i>hiascens</i>	( — ; — ).
<i>Dermatocarpon hepaticum</i>	( — ; fertile).
<i>Peltigera aphtosa</i>	( — ; sterile).
— <i>rufescens</i>	( — ; — ).
— <i>lepidophora</i>	( — ; — ).

<i>Solorina saccata</i>	(foliaceous lichen: fertile).
<i>Psoroma hypnorum</i>	(crustaceous lichen; fertile).
<i>Lecidea clavochroma</i> v. <i>muscorum</i>	(crustaceous lichen; fertile).
<i>Bæomyces byssoides</i>	(crustaceous lichen; sterile).
<i>Lecanora tartarea</i>	( — ; sterile and fertile).
<i>Buellia parasema</i> v. <i>muscorum</i>	(crustaceous lichen; fertile).
<i>Caloplaca Jungermanniæ</i>	(crustaceous lichen; fertile).
<i>Lecidea vernalis</i>	( — ; — ).
— <i>assimilata</i>	( — ; — ).
<i>Rinodina mniaræa</i> v. <i>cinnamomea</i>	(crustaceous lichen; fertile).

In all, 9 crustaceous lichens, 7 foliaceous lichens and 6 fruticose lichens.

I observed a similar damp mountain-heath, but smaller in extent, on Husavíkrfjall near Skjalfandi (North Iceland). Here also the phanerogamic vegetation consisted mainly of *Empetrum* (F % 100) and *Cyperaceæ* (F % 100), as also of *Vaccinium uliginosum* (F % 80), *Azalea procumbens* (F % 80), *Salix* spp. (F % 40), grasses (F % 20), and some *Alchemilla alpina*, — also lichens (F % 100). Here also the heath was knolly, and all the lichens occurred upon the knolls. The crustaceous lichens were dominant.

The following species occurred: —

<i>Stereocaulon denudatum</i>	(fruticose lichen; sterile).
<i>Cetraria lasiocens</i>	(foliaceous lichen; sterile).
<i>Peltigera lepidophora</i>	( — ; — ).
— <i>aphthosa</i>	( — ; — ).
<i>Psoroma hypnorum</i>	(crustaceous lichen; fertile).
<i>Lecanora tartarea</i>	( — ; sterile).
<i>Bacidia flavovirescens</i>	( — ; — ).
<i>Lecidea assimilata</i>	( — ; fertile).
<i>Bæomyces byssoides</i>	( — ; sterile).
(An undeterminable, sterile crustaceous lichen).	
(Lepraria).	

There still remains to be mentioned a small tract of very wet heath which was observed on Vaðlaheiði, on the mountains between Eyjafjörður and Fjorskádalur, where the plant-growth on the 3rd of July, 1913 had recently been bared of snow and was just coming into leaf.

The soil was wet, peaty and springy from the roots of the plants, and was partially covered with *Cyanophyceæ*. The phanerogamic vegetation, which was very low in growth and poorly developed, consisted of dwarf willows (F % 95), *Cyperaceæ* (F % 85), *Cassiope hypnoides* (F % 45), *Alchemilla alpina* (F % 25) and a few others which were not very conspicuous (e. g. *Azalea procumbens*,

species of *Salix*, etc.); there occurred also a small amount of mosses (F % 20), and some lichens (F % 45).

It was distinctly seen, that here all vegetation, both phanerogamic and cryptogamic, was greatly retarded by the long-lasting snow-covering, and by the fact that the soil was very wet and cold during the growth-period.

The following species occurred: —

*Stereocaulon* spp. (poorly developed) (fruticose lichen; sterile).  
*Peltigera rufescens* (foliaceous lichen; sterile).  
 — *aphtosa* ( — ; — ).  
 — *lepidophora* ( — ; — ).  
*Leptogium lacerum* ( — ; — ).  
*Psoroma hypnorum* (crustaceous lichen; fertile).

In order to obtain a general view of the subject, some typical tables are given here in which the different kinds of heaths are presented in tabular form. They are resumé's of the preceding text.

### Type I a.

(Dry heaths on level (not knolly) ground: rich in phanerogams; devoid of, or poor in, lichens).

#### Ex. 1. Heath near Háls parsonage (North Iceland).

Dwarf birch .....	F % 100	<i>Dryas</i> .....	(a small amount)
<i>Empetrum</i> .....	F % 100	<i>Arctostaphylos</i> .	(a small amount)
Grasses .....	F % 100	Lichens .....	F % 0

#### Ex. 2. Heath between Svinadalr and Ás (North Iceland).

Dwarf birch .....	F % 100	<i>Salix</i> spp. ....	F % 20
<i>Glumifloræ</i> .....	F % 100	<i>Equisetum</i> .....	F % 20
<i>Empetrum</i> .....	F % 95	<i>Calluna</i> .....	F % 7
<i>Vaccinium uliginosum</i> .	F % 80	<i>Lycopodium</i> .....	F % 7
<i>Salix lanata</i> .....	F % 60	Mosses .....	F % 13
<i>Geranium silvaticum</i> ...	F % 26	Lichens .....	F % 0
<i>Betula pubescens</i> .....	F % 20		

#### Ex. 3. Heath near Einarstaðir (North Iceland).

Dwarf birch .....	F % 95	<i>Dryas</i> .....	F % 45
<i>Empetrum</i> .....	F % 90	<i>Salix lanata</i> .....	F % 30
<i>Glumifloræ</i> .....	F % 85	<i>Calluna</i> .....	F % 10
<i>Vaccinium uliginosum</i> ...	F % 65	Lichens .....	F % 20

**Type I b.**

(Dry heaths with drifting soil; devoid of lichens).

**Ex. 1. Heath on mountains between Fnjoskádalur and Eyjafjörður (North Iceland).**

Dryas .....	F $\frac{0}{100}$ 100	Salix lanata .....	F $\frac{0}{100}$ 20
Glumilloræ .....	F $\frac{0}{100}$ 100	Vaccinium uliginosum ..	F $\frac{0}{100}$ 20
Dwarf birch .....	F $\frac{0}{100}$ 50	Lichens .....	F $\frac{0}{100}$ 0
Empetrum .....	F $\frac{0}{100}$ 40		

**Type I c.**

(Dry heaths on level (not knolly) ground; heaths poor in phanerogams, but rich in lichens).

**Ex. 1. Heath near Einarstaðir (North Iceland).**

Dryas .....	F $\frac{0}{100}$ 100	Dwarf birch .....	F $\frac{0}{100}$ 10
Glumilloræ .....	F $\frac{0}{100}$ 100	Silene acaulis .....	F $\frac{0}{100}$ 10
Empetrum .....	F $\frac{0}{100}$ 90	Lichens .....	F $\frac{0}{100}$ 100

**Ex. 2. Heath near Mývatn (North Iceland).**

Dryas .....	F $\frac{0}{100}$ 100	Dwarf birch .....	F $\frac{0}{100}$ 70
Empetrum .....	F $\frac{0}{100}$ 100	Vaccinium uliginosum ..	F $\frac{0}{100}$ 50
Glumilloræ .....	F $\frac{0}{100}$ 100	Lichens .....	F $\frac{0}{100}$ 100

**Type II.**

(Dry, knolly heaths with phanerogams on the horizontal surfaces of the knolls, lichens on the sides of the knolls, mosses, etc., in the depressions between the knolls).

**Ex. 1. The vegetation of the knolls on the heaths near the Laxá (North Iceland).**

Empetrum .....	F $\frac{0}{100}$ 100	Dwarf birch .....	F $\frac{0}{100}$ 80
Grasses .....	F $\frac{0}{100}$ 100	Lichens .....	F $\frac{0}{100}$ 100

**Ex. 2. The vegetation of the knolls on the heaths near the Laxá, near Skjalfandi.**

Calluna .....	F $\frac{0}{100}$ 100	Dryas .....	F $\frac{0}{100}$ 40
Empetrum .....	F $\frac{0}{100}$ 100	Dwarf willow .....	F $\frac{0}{100}$ 20
Grasses .....	F $\frac{0}{100}$ 100	Cyperaceæ .....	F $\frac{0}{100}$ 20
Arctostophylos .....	F $\frac{0}{100}$ 80	Alchemilla alpina .....	F $\frac{0}{100}$ 20
Dwarf birch .....	F $\frac{0}{100}$ 80	Mosses .....	F $\frac{0}{100}$ 60
Vaccinium uliginosum ..	F $\frac{0}{100}$ 80	Lichens .....	F $\frac{0}{100}$ 80

**Ex. 3. The vegetation of the knolls on Reykjaheiði (North Iceland).**

Dwarf birch .....	F $\frac{0}{100}$ 100	Salix lanata ... (a small amount)	
Vaccinium uliginosum ..	F $\frac{0}{100}$ 100	Calluna .....	(a small amount)
Empetrum .....	F $\frac{0}{100}$ 100	Mosses .....	F $\frac{0}{100}$ 40
Juniperus .....	F $\frac{0}{100}$ 60	Lichens .....	F $\frac{0}{100}$ 40
Grasses .....	F $\frac{0}{100}$ 60		



Type III.

(Wet mountain heaths; level or knolly; snow-covering of long persistence; on the whole rich in lichens).

Ex. 1. Vaðlaheiði; the vegetation upon the knolls  
(North Iceland).

Dwarf willow . . . . .	F % 90	Cassiope hypnoides . . .	F % 40
Cyperaceæ . . . . .	F % 90	Salix lanata . . . . .	F % 20
Polygonum viviparum . .	F % 90	Mosses . . . . .	F % 100
Empetrum . . . . .	F % 40	Lichens . . . . .	F % 100
Silene acaulis . . . . .	F % 70		

Ex. 2. Vegetation upon the knolls on a heath on  
Husavíkrfjall (North Iceland).

Empetrum . . . . .	F % 100	Salix spp. . . . .	F % 40
Cyperaceæ . . . . .	F % 100	Grasses . . . . .	F % 20
Vaccinium uliginosum . .	F % 80	Alchemilla alpina . . . .	F % 20
Azalea procumbens . . .	F % 80	Lichens . . . . .	F % 100

Ex. 3. Not knolly, level heath on Vaðlaheiði  
(North Iceland).

Dwarf willow . . . . .	F % 95	Alchemilla alpina . . . . .	F % 25
Cyperaceæ . . . . .	F % 85	Lichens . . . . .	F % 45
Cassiope hypnoides . . . .	F % 45		

As may be seen from the above description, the conception "heath" is rather comprehensive, in that many kinds of vegetation of fairly different physiognomy can be comprised under this name. Heaths however — as defined by me here — have one feature in common: they are all dominated by chamæphytes (about F % 100), in that sometimes one, sometimes another chamæphyte predominates, and sometimes they occur fairly equally mixed. In the meantime all chamæphytes are not equally hospitable towards lichens, for some, e. g. *Salix lanata*, dwarf birches and a few others, sometimes when they are well-developed, cast a deep shade and cover the ground abundantly with fallen leaves, and so they prove detrimental to the lichen-vegetation. Consequently the latter, partly from this reason and partly from others, vary as regards frequency-degree and mass-occurrence without its being possible to understand this fact by simply regarding the frequency-number (F %) of the chamæphytes in the tables. Other peculiarities, viz. the special specific peculiarities (high or low growth, small-leaved or large-leaved, etc.), luxuriant or stunted growth and similar features, cannot at all be

expressed by means of the frequency-numbers. Therefore, properly regarded, these prove to be nothing else but a diagnosis whereby to identify the association in nature, in the same way as the systematical description of species serves to identify the systematical species.

The frequency-number, however, affords some guidance to the attainment of an idea of the physiognomy of the association. But certainly much more than this is necessary. An exhaustive word-description, concerning all the features which cannot be explained by the frequency-number, is quite indispensable. This applies more especially to the mass-occurrence of the individual growth-forms, where the frequency-number is a very imperfect means of description.

As the heath is defined here, it is defined by its characteristic, dominant phanerogams.

Instead of treating the lichens found in every single plant-association already-known, I could have proceeded along other lines, and have classified the lichen-associations exclusively according to the characteristic lichens found in them, putting aside all accustomed considerations with regard to the phanerogams. Lichenologists will perhaps reproach me for not having taken this course. But I regard it as fully justifiable to make use of the conceptions already familiar regarding associations and to widen these by setting forth what lichen-studies teach us regarding them, in addition to what we have already learned from the phanerogam-studies. If I were to start in a one-sided way along lichen-ecological lines, then, as a matter of course, the conception "heath" could not be maintained, for no mass-occurrence, no frequency-number nor any other means of definition enables us to define the conception "heath" lichenologically. We have seen that the frequency-number for the lichens of heaths ranges from 0 to 100, — consequently, a heath cannot be defined by the frequency-number. Neither will it be possible to do so by a statement of the abundance of lichens, nor by any other means can the term "heath" be defined lichenologically.

When I maintain the conception "heath," it is exclusively a phanerogamic conception which I maintain, because it is old-established and because the heath is easily recognizable in nature when it is defined as I have done it here (F % 100 chamæphytes), and because, everything considered, it is more particularly the phanerogams of the heath which are of importance as regards the luxuriance or the reverse of the lichens.

The following species have been found on the heaths of Iceland: —

<i>Alectoria ochroleuca</i>	(fruticose; podetia-wanderer).
— <i>nigricans</i>	( — ; — ).
<i>Thamnolia vermicularis</i>	( — ; — ).
<i>Cladonia rangiferina</i>	( — ; — ).
— <i>uncialis</i>	( — ; — ).
— <i>gracilis</i>	( — ; hypothallus-wanderer [usually]).
— <i>turgida</i>	( — ; — — ).
— <i>fimbriata</i>	( — ; — ).
— <i>cariosa</i>	( — ; — ).
— <i>pityrea</i>	( — ; — ).
— <i>coccifera</i>	( — ; — ).
<i>Stereocaulon paschale</i>	( — ; podetia-wanderer).
— <i>denudatum</i>	( — ; — ).
<i>Sphærophorus fragilis</i>	( — ; — ).
<i>Cetraria aculeata</i>	( — ; — ).
— <i>islandica</i>	foliaceous; erect).
— <i>nivalis</i>	( — ; — ).
— <i>Fahlunensis</i>	( — ; procumbent).
— <i>hiascens</i>	( — ; erect).
<i>Peltigera aptosa</i>	( — ; procumbent).
— <i>venosa</i>	( — ; — ).
— <i>rufescens</i>	( — ; — ).
— <i>lepidophora</i>	( — ; — ).
<i>Dermatocarpon hepaticum</i>	( — ; — ).
<i>Solorina saccata</i>	( — ; — ).
<i>Leptogium lacerum</i>	( — ; — ).
<i>Lecanora tartarea</i>	(crustaceous).
<i>Psoroma hypnorum</i>	—
<i>Pertusaria xanthostoma</i>	—
— <i>oculata</i>	—
<i>Caloplaca pyracea</i>	—
— <i>Jungermannii</i>	—
— <i>vitellina</i>	—
<i>Pannaria brunnea</i>	—
<i>Rinodina mniaræa</i> v. <i>cinnamomea</i>	—
<i>Bacidia flavovirescens</i>	—
— <i>umbrina</i>	—
<i>Baeomyces byssoides</i>	—
<i>Buellia scabrosa</i>	—
— <i>parasemia</i> v. <i>muscorum</i>	—
<i>Lecidea vernalis</i>	—
— <i>helvola</i>	—
— <i>clæochroma</i> v. <i>muscorum</i>	—
— <i>assimilata</i>	—
<i>Lepraria</i>	—

To these must probably be added almost all the other species which have been found, some by me on the ground in other plant-

associations, and some by others on Icelandic soil without closer notification of the association. There is hardly a single Icelandic earth-lichen which avoids the heath; they certainly all occur there occasionally, although those enumerated in the above list doubtless form the nucleus of the lichen-vegetation of the heath.

As may be seen, there have been found 9 fruticose podetia-wanderers, 6 fruticose hypothallus-wanderers, 3 erect and 8 procumbent foliaceous lichens, and 19 crustaceous lichens.

But, as already mentioned, to these must probably be added all the other earth-lichens, viz. 12 fruticose, 16 foliaceous and 48 crustaceous species.

It is much to be desired that we could compare the lichen-vegetation of the Icelandic heaths with that in other countries, for instance in Denmark. Our knowledge of the lichens from heaths in other parts of the globe, is practically *nil*. As we know, lichen-ecological observations have, up to the present date, played a very subordinate part in scientific work.

Some of the most conspicuous points which there could be reason to compare are the agreements or disagreements as regards (1) systematic species, (2) growth-forms, (3) frequency-degree and (4) mass-occurrence.

With regard to systematic species there is a very conspicuous difference between the Danish and the Icelandic heaths. Whilst the Danish heaths — as far as they contain lichens at all — are entirely dominated by *Cladonia rangiferina*, the Icelandic heaths are not dominated by any single species. It is true, reindeer moss occurs, but only in small quantities. Of far more frequent occurrence are *Alectoria ochroleuca*, *Thamnolia vermicularis*, *Cetraria islandica* and *Lecanora tartarea*. Thus the Icelandic heaths cannot be characterized by any single species. We shall not, however, go further into details as regards the systematic species, it will suffice to refer to the list of the Danish Heath-lichens in "Danske Licheners Økologi" (p. 305) and, as regards the Icelandic lichens, to the list of species given above.

The growth-forms are not exactly the same on the heaths of Iceland and Denmark. Whilst Denmark has 21 fruticose lichens (57 % of the heath-lichens), 3 foliaceous lichens (8 %) and 13 crustaceous lichens (35 %), in Iceland the proportions of growth-forms are distributed as follows: — 15 are fruticose lichens (33 %), 11 are foliaceous lichens (24.5 %), and 19 are crustaceous lichens (42 %).

The Growth-forms of the Heath-lichens.

	Fruticose	Foliaceous	Crustaceous	Number of species
Danish heaths .....	57 %	8 %	35 %	37
Icelandic heaths.....	33 %	24.5 %	42 %	45

Of these numbers the Danish will scarcely be altered to any extent, whilst the Icelandic, through more numerous and more detailed investigations, will probably undergo a very radical alteration in favour of the crustaceous lichens. On riding across the heaths in Iceland it strikes one that the crustaceous lichens are more dominant there than in Denmark. This agrees closely with the fact that the chamæphytes are, as a rule, obviously poorer and less well-developed there than on Danish heaths, and are consequently more hospitable towards lichens, than are the taller, well-grown species.

With respect to the frequency-number of the lichens, none are to hand from Denmark. Those from Iceland are given above. Judging from what I remember, and compared with what I wrote on the subject in "Danske Licheners Økologi" (p. 301 et seq.), I am, however, inclined to believe that in Denmark all possible frequency-numbers occur, from 0 to 100, as in Iceland, in that we have in Denmark *Calluna*-heaths, which are sometimes very rich in lichens and sometimes almost devoid of them. In this respect there is scarcely any difference worth mentioning between the Danish and the Icelandic heaths.

It is as difficult or, properly speaking, still more difficult to state anything about the mass-occurrence of the lichens in Denmark compared with Iceland. I must, however, enter somewhat more closely into this question, as it is, in addition, of more far-reaching ecological importance.

If we are briefly to compare Iceland and Denmark as regards their lichen-vegetation on heaths, as far as this can be done on the basis of the investigations hitherto made, which in a high degree require to be more detailed as regards both countries, especially with reference to the mass-occurrence of the species, it may be stated that: —



The heaths of Iceland and Denmark, regarded from the point of view of a landscape, resemble each other as regards their whole physiognomical feature, besides which there is a great similiarity as regards the frequency-degree of the lichens (as far as this can be decided by a rough estimate). The difference as regards mass-occurrence (stated in weight) is not known (but at a rough estimate it would not seem to be great; the mass-occurrence is greatest perhaps on the Danish heaths). With respect to growth-forms the similiarity also appears to be rather great, but it will probably, on a closer investigation, be lessened by the fact that more crustaceous lichens will be found on the heaths of Iceland, than on those of Denmark. The systematic species of the two countries differ by no means slightly from each other.

It may therefore be said generally, that the conception "heath," as we know it from Denmark, does not undergo any great fundamental change through a closer investigation of the Icelandic heaths.

After having thus dwelt upon the appearance of the lichen-vegetation, it now remains for us briefly to point out the conditions which the lichens find on the heath and which have a determining influence as regards whether they thrive or do not.

The following are the most essential: —

(1) Nowhere on the heaths did I observe, that the chemical composition of the soil had a detrimental influence on the lichen-vegetation — but in other localities, for instance near Solfataras, etc., the conditions were very unfavourable to them.

(2) Thermal conditions and water contents are so closely connected with each other, that it is usually difficult to separate them. Damp, cold soil is generally unfavourable to many lichens (compare Bogs), whilst desiccation is not detrimental to them in a climate where the precipitation is as great as it is in Iceland. The greatest degree of moisture which permits the growth of heath-vegetation (i. e.  $F \frac{1}{100}$  chamaephytes) is however also favourable to lichens (mountain-heaths at higher altitudes).

(3) Loose, drifting soil frequently bears heath-vegetation, when the soil does not drift very greatly. But such heaths are devoid of lichens.

(4) Leaf-fall, which covers the lichens, does not hamper them greatly on the heaths: luxuriant dwarf-birch growths and in some degree a few other larger species may, however, by this means prevent the appearance of lichens.

(5) The snow-covering in some localities has a not unfavourable influence provided it disappears for a few weeks every summer without leaving too great masses of water behind it (in which case mosses and algæ gain the upper hand). The heaths of mountain heights are sometimes rather rich in lichens.

(6) Conditions concerning the *niveau* of the ground, appear to be of fairly great importance, inasmuch as knolly ground, in most cases, bears lichens on the sides of the knolls, whilst the horizontal surfaces of the knolls are covered with lichens in damp heaths only. The depressions between the knolls frequently bear mosses and no lichens at all or only a minute quantity. Here, it is most probably, the conditions of moisture that make themselves felt.

(7) The plant-covering (the competitors) plays essentially the part of contending against the lichens by covering them with decaying leaves (see above) or by overshadowing them. Both these drawbacks occur on Icelandic as well as on Danish heaths, where the higher plant-growth is more luxuriant. But experience shows that the growth and luxuriance of the chamæphytes themselves is not great enough on all heaths to exclude lichens.

#### f. Coppices.

These, the only phanerophytic birch-vegetation of Iceland, are, as elsewhere mentioned in this work (see vol. I, p. 312 et seq.), widely distributed over the whole of the island, — but may, however, possibly be absent from a narrow strip of North Iceland. They do not extend upwards on the mountains beyond a height of about 550 metres, and the majority of them are situated at lower levels. Everywhere the coppices consist, to a certain extent, of rather poorly developed individuals, the height of which ranges from that of a low-growing shrub to a height of several metres (8—9). (The most frequent height is 1—2 metres). The density of the tree-trunks varies considerably, which consequently results in a fairly varying ground-vegetation.

The soil is often knolly clay, and rests on gravel or also on rock, but sometimes there is a stony bottom, and sometimes the bottom is boggy soil (Thoroddsen, p. 342). According to H. Jónsson the most common ground-vegetations are: heather-moor (of *Empetrum nigrum*, *Arctostaphylos uva ursi* and *Vaccinium uliginosum*), grassland (of *Agrostis vulgaris*, *Aira flexuosa*, *Anthoxanthum*, *Festuca rubra*), herb-flat (of *Angelica silvestris*, *Spiræa Ulmaria*, etc.) and

moss-vegetation (of *Hylocomium proliferum*, *H. triquetrum*, *H. squarrosum*, *H. parietinum* and *Climacium dendroides*).

In Hálsskogur I noted a vegetation consisting of various grasses, of *Arctostaphylos*, dwarf birches, *Vaccinium uliginosum*, *Equisetum*, *Rubus saxatilis*, *Empetrum* and a few other plants. The ground was in part covered with decaying birch-leaves, forming a layer of about 2–6 cm. in depth, and the trunks had an average height of about 3 metres. The ground there was quite devoid of lichens as were also the trunks.

The information contained in the literature on the subject, as regards the ground-vegetation of coppices, is not very exhaustive, and does not give much information with regard to how far lichens occur or not. One must, however, expect that coppices, the floor of which is occupied by heath-vegetation, can also harbour lichens, but nothing concerning this is mentioned in the literature on the subject, and I myself have not seen any coppices with an actual ground-vegetation of heath. Nor is there any information to hand as to how far grassland, mat-herbage or moss-carpets, when occurring as ground-vegetation, shelter lichens.

It is, however, certain that earth-lichens may occur here and there, but even in the most favourable cases, they are but few in number and physiognomically little dominant.

H. Jónsson mentions for instance “*Cladonia*-species” (which?) as occurring near Breiðibólstaðir (South Iceland) and says that they occur there “abundantly, but are far from playing so important a part and from being so widely distributed, as in South Greenland.”

I myself only once found a small tuft of *Cladonia pilyrea*.

I do not doubt that, on the whole, the floor of the coppices may be regarded as poor in, or devoid of, lichens and the reason for this is undoubtedly to be found as usual, in the want of light and in the leaf-fall.

Nor does the ground-vegetation of willow-coppices appear to include lichens.

The epiphytic flora will be mentioned elsewhere, so I shall not enter into the subject more fully here, where only the earth-lichens of the plant-associations are being discussed.

### 3. ROCK-LICHEN ASSOCIATION.

By far the greater part of the rocky substratum of Iceland consists of basalt, but recent lava and liparite occur also, the latter, however, in a small quantity only. All these three kinds of rocks are fine-grained volcanic rocks. Considered from a chemical point of view, liparite differs distinctly from the other two, in that it is of the same mineralogical composition as granite, and is consequently rich in silica.

How the lichens penetrate into these substrata with their hyphæ has not been investigated even in the case of a single species.

The same applies also to the Icelandic tuff — cemented volcanic ashes of a similar chemical composition as lava, but of quite different physical qualities.

We shall now consider more fully the individual substrata and their vegetation.

#### a. Basalt.

On this kind of rock there occur, as on many others, lichen-vegetations which vary greatly. They may be classified according to different principles exactly as is the case with vegetations on loose soil. I consider it best — as in the case of earth-vegetations — to take the plants themselves as a guide in the classification, and shall therefore treat the associations in three main groups, viz. associations of crustaceous, foliaceous and fruticose lichens respectively; under the last group there are two essentially different sections, viz. erect and pendulous lichens.

With regard to these associations it may be said in general that: —

Crustaceous-lichen-associations grow on rocks of all possible angles of declivity — on horizontal surfaces, on vertical or sloping rock-faces, and on roofs of caves.

Foliaceous lichens grow in a similar manner to crustaceous lichens on horizontal surfaces, on vertical or sloping rock-faces, and in caves.

Erect fruticose lichens are found only on horizontal and on gently inclined surfaces, because they are as a rule very slightly attached to the substratum, in fact, they are generally attached to other plants which in their turn are anchored to the substratum, they are not themselves immediately attached to the rock-substratum. They are absent from vertical rock-faces and from the roofs of caves

Pendulous fruticose lichens can be found on rocks of all degrees of inclination: horizontal surfaces, vertical and sloping rock-faces, etc.

The associations may be — as in the case of the phanerogams — divided into formations, facies or whatever we may choose to call them, and they may be named after the one or more species which dominate the community.

In addition to the chemical and physical qualities of the rock and the degree of inclination of the substratum, there are other conditions which play a part as regards the physiognomy of the vegetation, primarily conditions pertaining to moisture, and the competitive relations between the species themselves.

Thus the same vegetations are not found on rocks wetted with spray, on submerged rocks and on dry emergent rocks. The quality of the water also — salt, fresh or distilled (rain) water — plays an essential rôle here. Moreover, it is of no slight importance, whether the rocks are frequently manured by birds or whether this does not take place.

We can, as already mentioned, divide the associations, which are produced by the action of each of these complexes of life-conditions, in very different ways: we may speak of “nitrophilous associations” (Sernander), of halophilous associations, associations of hollows, associations of horizontal surfaces, etc., according to our knowledge of the factors which determine the association. But this mode of naming them appears to me to be extremely unpractical, because we may very often be at a loss with regard to the group to which we are to refer the association in question. It is in reality not at all possible to draw a decided line between a nitrophilous and a non-nitrophilous association: all lichens are in fact nitrophilous to some degree.

It is the same difficulty with which the ecologists have had to contend as regards the soil-associations, but in this department order is appearing owing to the fact that the association is not named after factors — as a rule imperfectly known — which condition its well-being (“sand-vegetation,” “rock-vegetation,” “xerophilous cop-pice,” etc.), but after the plants themselves (phanerophyte-vegetation, chamaphyte-vegetation, etc.).

Whether one choose the one or the other mode of procedure is by no means a matter of indifference. The associations living in nature are naturally the same, whether we give them the one or



the other name, but for the sake of synonymy it is necessary to have simple and easily definable conceptions, and this is best done by naming the association after the dominant plant-growth-form.

With regard to lichens we will therefore employ as the principle of main division the grouping indicated above, viz. that of crustaceous, foliaceous and fruticose lichens, and, as far as possible, follow them on each rock-substratum.

The Crustaceous-lichen-association is widely distributed on all kinds of basalt. Several types (formations) may be distinguished, e. g. mixed crustaceous-lichen-formations, *Staurothele*-formations, *Caloplaca*-formations and *Verrucaria*-formations.

Mixed crustaceous-lichen-formations are widely distributed especially on the almost vertical faces of basalt rocks along the fjords.

The plant-density is often rather slight, in that the individuals are not in contact with each other, i. e. they leave the rock-surface visible between them. In such places, therefore, there is no actual competition between the species, and the community is consequently analogous to the desert-vegetation of loose soil.

In other places the plants may be closely in contact with each other, and struggle for space. In this case competition arises, where sometimes the one and sometimes the other plant predominates, but all the circumstances concerning this interesting struggle have not been investigated and are not known.

Many interesting observations could undoubtedly be made as regards the frequency-number and mass-occurrence of the single species under different conditions, but all this requires both a long sojourn and also patient investigations on the spot. I presume, that among other things, we should thereby acquire a closer knowledge of the life-necessities of each species, and that we should be able to sub-divide the "mixed crustaceous-lichen-associations" into perhaps as many formations as the number of the systematic species. But this the future must decide.

To this association almost all the crustaceous lichens of Iceland must undoubtedly be referred, i. e. somewhat above 100 species. There are, however, some which occur repeatedly and which ought to be enumerated as characteristic of the association, viz.

<i>Lecanora cinerea.</i>	<i>Lecanora intricata.</i>
— <i>pallescens.</i>	— <i>frustulosa.</i>
— <i>atra.</i>	— <i>sordida</i> v. <i>glaucoma.</i>

*Lecidea pantherina*.  
 — *cyanea*.  
 — *erratica*.  
 — *speirea*.  
 — *lapicida*.  
 — *elæochroma*.

*Lecidea elata*.  
*Rhizocarpon geographicum*.  
 — *geminatum*.  
*Caloplaca vitellina*.  
*Physcia aipolia*.

Occasionally there also occur mixed with the above: *Racodium rupestre*, *Polyblastia hyperborea*, *Acarospora Heppii*, *A. fuscata*, *Catillaria athallina* and a few foliaceous lichens (*Parmelia lanata*, *Gyrophora cylindrica* and *G. erosa*).

This association grows from the coast — where it begins a short distance above the *Verrucaria*-belt — to far up the mountains, where it stops at the snow-line. As regards its luxuriance at various heights above sea-level, very little is known, but it appears to be least developed at great altitudes. I myself had a distinct impression of this for instance from my observations on the mountain Súlur near Eyjafjörður and the mountains near Húsavík (on the north coast), and H. Jónsson states the same as regards the conditions on Snæfellsnæs; he writes: "The same is the case with the crustaceous lichens as with the phanerogams; they occurred extremely sparsely on the stones in the upper part of the rocky flat." The association is quite absent from the pebbles on the shore; it cannot endure inundation by salt water.

The *Staurothele*-association occurs almost exclusively by waterfalls, where it forms black crusts on the rocks in all places where the spray from the falling water reaches. It is extremely characteristic of all such localities. Mixed among the slender, black thalli of *Staurothele* occur crust-like thalli of various *Cyanophyceæ*, so that it is often difficult to decide which of them is the more abundant. I have never found any other species of lichen directly connected with this association, which therefore contains only the one species *Staurothele clopima*.

The *Caloplaca*-association (*Placodium stramineum*, *P. alphoplacum* and *Caloplaca murorum*), which on Bornholm (Denmark) is so common on the shore above the *Verrucaria*-belt, is very little developed in Iceland. I found only slight indications of it in Seyðisfjörður. Helgi Jónsson records it from West Iceland.

The *Verrucaria*-association, formed by *V. maura* and an inconsiderable quantity of *Lichina confinis*, which is well-known from Bornholm and from all the other rocky coasts of the North, is also found in Iceland, where it borders the sea-shore from high-

water level as far upwards as the spray of the waves reaches. I have seen it developed very distinctly for instance on the sides of Seyðisfjörður, Reyðarfjörður, Eyjafjörður and in several other places. Its natural history is in all respects a repetition of what we know from Denmark, Finland, etc. Therefore, there is no special reason to dwell upon it more fully here.

Foliaceous-lichen-associations are found here and there, fairly well-developed, especially in the low land, where they frequently consist of *Parmelia saxatilis*, *P. lanata*, *P. stygia* or of species of *Gyrophora* (*G. cylindrica*, *arctica*, *erosa*). Sometimes the one, sometimes the other species predominates, whereby several formations may be distinguished ("Parmelia-formation," "Gyrophora-formation," etc.). As far as my observations go these communities are most luxuriantly developed in places where it is light and damp. For instance, they are found well-developed by the waterfalls at the head of Seyðisfjörður and by Dettifoss (North Iceland).

The density of the plants is as a rule high and consequently the competition is keen, but regarding this point no detailed investigations have been made. The crustaceous lichens are however mercilessly exterminated when *Parmelia saxatilis* puts in its appearance; in many places this process of extermination may be observed in various stages.

It is more rare for the *Gyrophora* spp. to dominate so decidedly; I did not see them as pure growths, as they may be found in Arctic countries.

The Fruticose-lichen-association. Helgi Jónsson records that *Ramalina cuspidata* often occurs abundantly on the rocks of South-west Iceland. He does not, however, state more explicitly whether it actually forms carpets. I myself never saw it occur in such abundance as to make it justifiable to speak of *Ramalina*-carpets, like those found on the shores of Bornholm. Nor did I come across such a feature on the coastal rocks of Iceland.

*Usnea melaxantha* may sometimes be found in tolerable abundance near the snow-line on mountain heights, but I did not see this species either actually form carpets.

Therefore it appears that Iceland has no continuous carpets of pendulous fruticose lichens which are attached to the rock-substratum itself like those we have in Denmark.

Erect fruticose lichens (*Alectoria*, *Stereocaulon*, *Cladonia*, *Cetraria aculeata*, etc.) are frequently found covering the rock-substratum at

almost all altitudes. But it must be remembered that all the lichens belonging to this group, are more or less dependent upon the presence of other plants, for — as I have fully explained in my “Danske Licheneres Økologi” — they always follow an initial vegetation of other lichens (crustaceous or foliaceous lichens) or of mosses and live so actually on the soil formed by them that they are not even attached to the rock-substratum, but on the contrary, in some cases die away at the base. This circumstance has also been considered more fully in the present treatise under the heading “Earth-lichens” and will not be discussed further here.

An exception to this rule is formed, it appears, by *Stereocaulon denudatum*, which at least appears to be able to live upon the rock itself. I have not found it, however, upon basalt, but in great abundance upon recent lava, and shall treat of it under the heading “Lava.”

#### b. Lava.

The post-glacial lava is black, with many small cavities and vesicles, and sometimes of an appearance similar to cokes. When it gradually becomes covered with vegetation, this usually consists of *Grimmia*-carpets, which again can develop into heaths, etc. But those areas which do not immediately become moss-covered, frequently become first lichen-covered. The lichens may occur on the rock-substratum itself, at first crustaceous lichens, then foliaceous and fruticose lichens. The latter are, however, probably most frequent in places where moss had first been growing.

I have not had the opportunity of seeing lava at all altitudes, and therefore I am not prepared to say how far it supports *Verrucaria*- and *Caloplaca*-associations near the sea-shore, which it is evidently able to do. My observations are made from lava-streams in rather low-lying land, up to a height of about 300 metres above sea-level, and there I found the following associations: —

Crustaceous-lichen association. By way of example I quote such associations from a lava-field near Havnefjord. I found growing here, on sloping surfaces, a vegetation which consisted mainly of crustaceous lichens; in 90 % of the sample-areas were found a few foliaceous lichens (1 %), fruticose lichens (40 %) and moss (90 %). The latter did not cover the rock to such an extent, as might be expected, judging by the high frequency-number. On the whole, the substratum was visible everywhere between the lichens. The following species were found: —

<i>Lecanora atra</i> ,	crustaceous lichen.
— <i>badia</i> ,	—
— <i>varia</i> ,	—
— <i>tartarea</i> ,	—
— <i>pallescens</i> ,	—
<i>Caloplaca vitellina</i> ,	—
— <i>ferruginea</i> v. <i>obscura</i> ,	—
<i>Acarospora Heppii</i> ,	—
— <i>fuscata</i> ,	—
<i>Hæmatomma coccineum</i> ,	—
<i>Lecidea elæochroma</i> ,	—
— <i>auriculata</i> ,	—
— <i>convexa</i> ,	—
— <i>panæola</i> ,	—
— <i>pantherina</i> ,	—
— <i>cinereoatra</i> ,	—
<i>Buellia myriocarpa</i> ,	—
<i>Rhizocarpon geographicum</i> ,	—
Sterile crustaceous lichens,	—
<i>Lepraria</i> ,	—
<i>Parmelia saxatilis</i> ,	foliaceous lichen.
<i>Ramalina subfarinacea</i> ,	pendulous fruticose lichen.
<i>Stereocaulon denudatum</i> ,	erect fruticose lichen.

In a locality, close to the one described above, there occurred on a vertical lava-face a crustaceous-lichen growth, poor in individuals; fruticose and foliaceous lichens were quite absent from it; and all the sample-areas showed bare rocky substratum, whilst not even all of them contained crustaceous lichens, which were found only in 76 % of the samples. All other plants were absent.

A Foliaceous-lichen-association was observed by me, for instance near the farm Reykjahlíð, near Mývatn (North Iceland). The dominant species were: —

<i>Parmelia saxatilis</i> ,	foliaceous lichen.
<i>Physcia stellaris</i> ,	—
<i>Xanthoria lychnæa</i> ,	—
<i>Stereocaulon denudatum</i> ,	fruticose lichen.
<i>Lecanora saxatilis</i> ,	crustaceous lichen.
<i>Caloplaca elegans</i> ,	—
— <i>vitellina</i> ,	—
<i>Lecidea confluens</i> ,	—
— <i>assimilata</i> ,	—
— <i>paupercula</i> ,	—
— <i>pantherina</i> ,	—
<i>Rhizocarpon geographicum</i> ,	—
— <i>geminatum</i> ,	—



I had not time to determine the frequency-numbers of the crustaceous, foliaceous and fruticose lichens, but even on a superficial view, it was evident that foliaceous lichens were in the majority, and that the vegetation was fairly dense, so that competition existed amongst the individuals.

Fruticose-lichen-association, very vigorously developed, was observed by me on lava in another locality near Mývatn. Here I traversed a large tract of country, which was entirely covered by a thick, well-developed carpet, consisting almost exclusively of *Stereocaulon deudatum*, which formed a very dense, pure and fine growth, without any intermixture of other species worth mentioning. This species of *Stereocaulon*, as long as it is young, is able to grow on bare (but of course weathered) rock. Afterwards its podetia die away at the base, and form a peaty layer; as a consequence it gradually becomes an earth-lichen. But, at any rate to begin with, it can occur as a rock-lichen, i. e. it does not require a preceding growth of mosses to which to attach itself. But from this it does not follow that, when occurring as a carpet, it has always been the first species to arrive. In fact, I have observed it growing upon moss.

Consequently, we have here to do with a form intermediate between an earth-lichen-association, and a rock-lichen-association.

Another fruticose-lichen-association on lava is formed by *Ramalina subfarinacea*, which lives immediately attached to the rock-substratum, and never develops into an earth-lichen. I found this species near Havnefjord, where it grew on the top of a mass of lava, mixed with some crustaceous lichens (F % 100), which, although they occurred in all the sample-areas, were evidently on the point of becoming overgrown, and killed by the *Ramalina*.

How many species in all are found on lava, is not known, but a list is given above of those which occur most frequently on it. I am, however, inclined to believe that, practically, all the rock-lichens found in Iceland can grow both on lava and on basalt; partly because the two kinds of rock are in the main of the same chemical composition, and partly because it appears that lichens are very partial to lava as a substratum. From a superficial point of view, the vegetation of the lava appears to be considerably richer in quantity, than that of the basalt; for instance, I never saw such immense quantities of *Stereocaulon* on the latter, as on lava. But it is desirable that the conditions concerning masses, by the method

of weight, and the number of the species, may be investigated more thoroughly.

### c. Tuff.

On the tuff-deposits of Iceland, lichens occur very sparsely. The tuff consists of rather loosely-connected ash-particles, and is naturally stratified like other æolian sedimentary deposits. Its chemical composition comes very near to that of the basalt and the lava, but its physical conditions, as a plant-substratum, differ very essentially, since, in the first place, its porosity causes all the water which falls upon it, to be absorbed and retained, as in a piece of blotting-paper, so that the lichens are deprived of this water; and in the second place it has, in all probability, quite different thermal qualities, inasmuch as it no doubt gets heated far more slowly than the two other kinds of rock.

Taken as a whole, it may be said that tuff is a very unfavourable lichen-substratum. But then I must acknowledge that I saw it only in a few places, partly as a shore-rock, where it was quite devoid of lichens, since both *Verrucaria*- and *Caloplaca*-vegetation were totally absent; and partly in the interior of the country, where, in a few places, I saw old crater-cones (extinct) consisting of tuff, where the vegetation was so scanty that everything but lichens was wanting, consequently both mosses and phanerogams, whilst the lichen-vegetation was restricted to a few specimens, which, if the frequency-number had been determined, would hardly have amounted to one individual per 1000 sample-areas (à 2 dm.<sup>2</sup>).

Not far from the farm Ljósavatn, between Háls and Einarstaðir (North Iceland) I found specimens — perhaps 50 in all — of a sterile, undeterminable, crustaceous lichen. On tuff in Reyðarfjörður (East Iceland) I found a few specimens of

Lecanora Hageni,  
— calcarea,  
Arthonia ruderalis.

Such paucity of lichens as this on porous rock, is known almost nowhere else but in Denmark in the case of the chalk. It is possible that the cause of this is the same in both cases, viz., the unfavourable conditions with regard to moisture. I can express no opinion as to whether the tuff occurs anywhere on the island, under conditions which permit it to bear lichens, but, in the litera-

ture on the subject, I have not found any allusion made to anything of the kind.

#### d. Liparite.

This rock is not widely distributed in Iceland, and therefore plays a very inferior part in the physiognomy of the country. In chemical respects it is of the same composition as granite, since it is the corresponding volcanic rock.

I have only had an opportunity of investigating its vegetation in very few localities, viz., in Hlíðarfjall, near the farm Reykjahlíð, close to Mývatn, and near Geysir. I am therefore not prepared to state anything about the vegetation it supports, when it stands in salt water, nor what the conditions on it may possibly be, when we find it as a lofty mountain.

Near Geysir, on the mountain situated close to the spring itself, I found a very scanty vegetation consisting of crustaceous lichens (F % 100), a few foliaceous lichens (F % 36) and a little moss (F % 16). The mountain was far from being covered, consequently, the vegetation was desert-like, and all the specimens were small, and only slightly developed. The following species were found: —

<i>Lecanora pallescens</i> ,	crustaceous lichen.
— <i>varia</i>	—
<i>Lecidea auriculata</i> ,	—
Sterile, undeterminable,	—
<i>Rhizocarpon geographicum</i> ,	—
<i>Gyrophora erosa</i> , foliaceous lichen.	
— <i>cylindrica</i> ,	—

On Hlíðarfjall near Mývatn, at the base of a solitary mountain-summit, which rises above the surrounding country, there is a mighty talus of large fallen blocks, and of débris. Upon the blocks, and upon the mountain itself, there occurred a scanty vegetation — open and desert-like — of various foliaceous and crustaceous lichens. The following species were found: —

<i>Lecanora polytropa</i> ,	crustaceous lichen.
— ( <i>Aspicilia</i> ) <i>alpina</i> ,	—
— <i>impavida</i> ,	—
<i>Rhizocarpon geographicum</i> ,	—
<i>Parmelia lanata</i> , foliaceous lichen.	
<i>Gyrophora erosa</i> ,	—
— <i>cylindrica</i> .	—

*Gyrophora arctica*, foliaceous lichen.

— *hyperborea*, —

*Stereocaulon denudatum* v. *pulvinatum*, fruticose lichen.

Taken as a whole, the liparite impresses one as being a very poor substratum for lichens. This fact is curious, considering that granite, which has the same chemical composition as liparite, is so rich in lichens. It must therefore be presumed, that the difference is due to physical conditions.

---

## V. THE VERTICAL DISTRIBUTION OF THE LICHENS.

---

Thoroddsen, in vol. I of this work, has given an account of the little which is, as yet, known as regards the vertical distribution of the phanerogams. It must unfortunately be admitted, that our knowledge of the lichens is, in this respect, still more scanty. The object which it was desirable to attain, viz., a thorough knowledge of the occurrence of each single species, from sea-level upwards on the mountains, is still unattained, but something is known on the subject.

It is not known with certainty, as regards any single species, how far it has any other upper limit on the mountains, than the snow-line, with the sole exception of the decidedly maritime species *Verrucaria maura* and *Lichina confinis*, which are connected only with localities washed by the spray of the waves.

Nor is it known with any certainty as regards a single species, how far it has any other lower limit than the sea-level; several species are, however, known, regarding which it is, at any rate, probable that they are associated with cold mountain heights, and avoid the milder climate of the low land. This is the case, for instance, with *Usnea melaxantha* and *Solorina crocea*, which hardly ever descend anywhere into the lowlands, without its being possible to give a tolerably definite lower limit.

In order, however, to give a small contribution to our knowledge regarding this point, I shall proceed to enumerate the lichens found in a few localities situated on high ground: —

On Hliðarfjall, which is mentioned under the rock-lichen-associations, under “Liparite,” there grows a scanty vegetation consisting of the following species: —

<i>Rhizocarpon geographicum.</i>	<i>Gyrophora cylindrica.</i>
<i>Lecanora polytropa.</i>	— <i>arctica.</i>
— <i>alpina.</i>	— <i>hyperborea.</i>
<i>Gyrophora erosa.</i>	<i>Parmelia lanata.</i>



The mountain is 790 metres high. The species found there were not, however, collected on the summit itself — which is almost inaccessible — but yet not far below it.

On Sulur, near Eyjafjörður (height about 1400 metres), I found the steep mountain summit free from snow on July 5th, 1913. The summit itself was almost devoid of lichens; there occurred only a few specimens of: —

Lecanora polytropa.	Lecidea fuscoatra.
— varia.	— Siebenhaariana.
— (Aspicilia) gibbosa.	Rhizocarpon geminatum.
Caloplaca vitellina.	— geographicum.
— elegans.	Parmelia lanata.
— pyracea.	Gyrophora erosa.
— cerina.	— arctica.
Lecidea auriculata.	Usnea melaxantha.

On detached blocks of rock and on smaller rock-fragments immediately below the summit, there occurred: —

Lecidea lapicida.	Caloplaca vitellina.
— confluens.	Pertusaria oculata.
— subconfluens.	Parmelia lanata.
— panæola.	— saxatilis.
Lecanora gibbosa.	Cetraria Fahlunensis.
— varia.	Gyrophora cylindrica.
— polytropa.	— erosa.
— badia.	— hyperborea.
Rhizocarpon geographicum.	

On loose soil there occurred a scattered desert (rocky-flat-) vegetation, consisting of a few plants of *Dryas*, *Silene acaulis* and some other species (*Ranunculus glacialis*, *Saxifraga oppositifolia*) and a little moss; intermixed with this vegetation occurred some lichens, which grew exclusively on the mosses, and were quite absent from the purely inorganic soil. The following species were found: —

Lecanora tartarea.	Peltigera aphtosa.
— castanea.	Solorina crocea.
Pertusaria oculata.	Cetraria Fahlunensis.
Caloplaca Jungermanniae.	— aculeata.
Psoroma Hypnorum.	— islandica.
Lecidea assimilata.	Alectoria nigricans.
Bacidia flavovirescens.	Cladonia turgida.
Buellia parasema (v. papillata and triphragmia).	— pyxidata.
Rinodina mniaræa v. cinnamomea.	— rangiferina.
Pannaria microphylla.	— coccifera.
Dermatocarpon hepaticum.	Thamnolia vermicularis.
	Stereocaulon spp.

The species here enumerated, which occur on rock and on earth, consequently represent what may be called the nival lichen-flora of Iceland: they are the most hardy species, and ascend far above the coppices, heaths and grass-carpets, right up to the snow-line. With regard to the majority of them it may be asserted — as already mentioned — that they also descend far into the low land; only *Solorina crocea* and *Usnea melaxantha* can with certainty be regarded as exclusively mountain-height plants.

But in addition to the species mentioned here, various others will no doubt be found in the future, when more mountain summits and the interior plateau of Iceland have been better investigated.

In the above, when discussing the earth-lichens, those species have been mentioned, which are found in the common earth-plant-associations, as far as these, taken as a whole, bear lichens. The lists of species given there, are consequently also illustrative of the vertical distribution of the lichens, inasmuch as the heath with its lichens ascends to about 300 metres up the mountains, the birch coppices to about 550 (more frequently less), the willow-coppices (which do not appear to be very widely distributed and are almost unknown as regards their lichens) to about 800 metres, the grass-vegetation, with the upper limit of which I am not acquainted, and the desert-vegetation up to 1000—1400 metres; then comes the ice-region.

If we now go through the lists, which are given above for each individual association — grass, heath, moss, coppice, etc. — we shall find that they do not include all the earth-lichens of Iceland, inasmuch as they do not contain all the numerous species, which have in part been found by other collectors without their having stated more closely in which association they were collected. Consequently, here is a large field left for future investigations, i. e. an elucidation with regard to the particular association in which each single species lives and — together with this association — at what sea-level.

With regard to the mass-occurrence of the earth-lichens at various altitudes, very much is likewise wanting to our possession of reliable data as regards the heights, which are most favourable to them. This much can only be said as a general fact, that (1) close to the sea no lichens live on the earth, if the ground-water reaches to the surface of the earth; and (2) from these low altitudes, and upwards, the mass-occurrence of the lichens appears to be

essentially dependent on local conditions, i. e. conditions pertaining to soil, competition with other plants, etc., as has been more fully mentioned under the individual association.

The main question — whether the differences in the climate, which prevail at various altitudes, have any other importance than that which they have by indirectly exposing the lichens to the competition of sometimes the one and sometimes the other plant-species (in heaths, coppices, grass, etc.) — is best answered by investigating the vegetation at higher levels. Or to put the question more simply: Can any connection be shown to exist between the character of the climate and the mass-occurrence of the lichens? To this we must reply with a fairly certain “Yes.” It is to be expected that, when all competition with other plants is absent, and the soil is of suitable composition, the lichens must be abundantly present in great masses, in other words: mountain heights must necessarily be very rich in lichens. Now there is no doubt at all that the lichens, at higher altitudes, are more conspicuous in the landscape, than at lower levels, but on the other hand, neither can it be doubted that the lichens are far, very far, from covering all the soil on mountain-heights, which is bare of all other competitors. There can, on the whole, be no doubt at all that, both as regards number of species and mass-occurrence, the mountain-height manifests a poverty, which cannot be due to soil and competition, but must largely be a result of the more severe climate.

With regard to the rock-lichens, the list of the hardy mountain-height-species is given above. With respect to mass-occurrence it can likewise be said that the mass is evidently smaller on that ground, which lies highest even though, as in the case of the earth-lichens, more reliable determinations concerning mass-occurrence are still wanting. It is, however, evident even from a superficial survey, that both as regards number of species and mass-occurrence the highest mountains are poorer than the lower.

With the Epiphytic lichens the matter is quite simple: they are solely connected with coppices and cease at the alpine limits of the latter, i. e. they are entirely absent from mountain-heights.

## VI. THE ABUNDANCE OF LICHENS IN ICELAND.

---

In my work "Forberedende Undersøgelser til en almindelig Lichen-Økologi" (1813) I have made a preliminary attempt towards characterizing the various zones of the globe, as regards their abundance of lichens. I shall now mention in short the problems pertaining to this department, which require to be solved more particularly as regards Iceland.

The abundance of lichens in a country may be characterized in various ways, but those that, as a rule, will interest us most, are (1) the abundance of species and (2) the abundance of individuals (mass-occurrence) in a country.

Let us firstly regard the abundance of species of the various climate-belts and the method by which to determine this numerically.

This task is very comprehensive and cannot in reality be worked out with the aid of the floristical works, which we have at our disposal at present, and this for various reasons. The principal of these are the following two: — (1) The floras comprise, as a rule, politically — not with regard to climatology — limited areas, and (2) as a rule they give no information as regards the distribution of the species in a vertical direction above sea-level in the "Region."

But let us suppose these wants supplied at some future time by laborious and protracted investigations in the field. We shall then by that time be able to give the abundance of species of the various climate-belts in absolute figures — so many in the whole of the Arctic, respectively temperate, sub-tropical and tropical belts.

I have reason to assume — as I have more fully shown in my "Forberedende Undersøgelser til en almindelig Lichen-Økologi" — that the abundance of the various climate-belts given in such absolute figures will show that the Arctic-belt is poorest in the northern

hemisphere. The mutual relationship of the other belts, in this respect, is somewhat doubtful.

But let us now also suppose, that at some future time we shall succeed in deciding the absolute number of species for each climate-belt; there will nevertheless be highly important and interesting details to investigate as regards these numbers; first and foremost the mean number of species of the climate-belts, that is the number of species per unit of area.

For in itself it is very probable that a relatively small territory as, for instance, the Antarctic region has a very small number of species, whilst, for instance, the Tropical region, the superficial measure of which is many times larger than that of the Antarctic, has a great number of species. If we compare the area of the climate-belts with their number of species, dividing the number of the species by the superficial measure (for instance, in geographical square miles), we get fractions which give us a clear idea of the abundance of species in proportion to the area of the climate-belt. For if we imagine a climate-belt investigated, square mile after square mile, and new species are constantly found, over and over again, in every such small area, the sum total for the entire belt would become very great. On the other hand, if we find in another belt, a certain number of species in the square mile first investigated, and thereafter the same species over and over again in the areas subsequently investigated, the sum total for the whole climate-belt would become rather small. It is exactly this circumstance which will be recorded in the fraction, which results from the division of the number of the species of a climate-belt by its area (e. g. in geographical square miles or kilometres). This fraction expresses the greater or lesser monotony of the area as regards the occurrence of the species.

A third valuable means, wherewith to compare the abundance of species of various climate-belts, is to take equally large (preferably very large) areas characteristic of the belts (that is to say areas which contain all the plant-associations contained in each single belt) and add up the number of their species, which then directly indicates the comparison of them with regard to abundance of species. This method is the most elucidatory of all three and has therefore been made the subject of a fuller discussion in my "Forberedende Undersøgelse" (1913). In itself it is immediately evident, that no other means of comparison is equal to this as regards reli-



ability; this, which is simply a special lichenological employment of a geographical principle commonly employed in almost all other possible circumstances.

If we want to compare the abundance of species of a certain limited area, for instance, that of Iceland with that of other areas within the same climate-belt or in others we must naturally first and foremost employ just this last method, that is, we must take for comparison areas equal in size to Iceland.

It is in the nature of the matter, that such investigations involve considerable difficulties and, in fact, they have not yet been made at all. But before they may happen to be made, we must help ourselves with less valuable and easier methods, which can give us hints with regard to the questions which we wish to have solved, and which will presently be more fully discussed.

If we wish to compare the abundance of species of the various plant-associations with one another, several methods can naturally be employed, but already here the absolute figure for the species is very elucidatory. Thus, for instance, it is very interesting to ascertain the difference between the number of species in a grass-field and in a heath in Iceland (see above). But here also it is naturally still more valuable to determine the number of species of a certain unit of area in one association, and compare it with an equally large area of another association, for instance the number of species, let us say in one square mile of heath, compared with one square mile of forest, etc.

But in the main, these statistical investigations are as yet tasks for the future, — much still remains to be done in this respect, but what we already know for certain as regards Iceland will be recorded here.

Iceland has, according to the list given here, about 285 species; a few more may probably be added to this number by latter investigations, but judging from what is known — only few.

Now does this figure represent many or few species in proportion to the area of the island?

Let us first compare it with some countries from the Arctic regions: Greenland has 287 and Spitzbergen 207 species. In proportion to its area, Spitzbergen — the smallest of the three countries — has consequently the greatest number of species; then comes Iceland and — as the one poorest in species — that immense Greenland, which has, within its domain, an almost equally great absolute

number of species as Iceland, which is about 22 times smaller. These figures are in themselves striking enough, but they give no information concerning the equality of the distribution of the species in the areas of these three countries occupied by the lichens. We know, it is true, from other sources, that all three countries have a larger or smaller area covered with inland-ice, which however, in proportion to the entire area of the country, is most strongly developed in Greenland. Even this alone naturally brings about a heterogenous lichen-colonization in these countries. But even if we do not take this into consideration, but only regard the areas which are free from ice, the figures do not state anything about the equality of the distribution of the lichens: whether we can meet with all the species of Greenland, of Iceland or of Spitzbergen within every lesser area or whether the distribution is quite otherwise. We have in this respect a small hint from Greenland, where at least the north-eastern area, which has been investigated by the "Danmark Expedition," gives only about 100 species, which with tolerable certainty can be taken as an indication of the fact, that the difference between South and North in this country of great length is of importance. But a reliable comparison of the distribution within the three countries in question, cannot be obtained until equally large areas from each of them have been compared with one another, which has not yet been done.

On comparing the number of species from Iceland with those from Denmark — to take a well-investigated area from another climate-belt — we find that Denmark, on her 38 000 square km., has 397 species against Iceland's 285 species on 104 000 square km., or 0.0021 species per square km. in Iceland and 0.0104 species per square km. in Denmark. Nor do these figures give any insight into how the species are distributed within each country. In this case also it will be necessary to compare equally large areas of the two countries (taking their characteristic plant-associations into consideration).

But until such a comparison has been made, it must suffice to substantiate the fact, that the abundance of species in the whole of Iceland is less than in the whole of Denmark, in spite of Iceland being  $2\frac{1}{2}$  times the size of Denmark. In the same way it may be said that Greenland is far poorer in species than is Denmark, although it is many times the size of Denmark, whilst, for instance, Germany, France and Great Britain, with their greater stretch of

country, have also many more lichens than has Denmark, viz. 1100—1400 species.

On the whole it holds good, as a general rule, as has been stated and more fully proved in my "Forberedende Undersøgelser," that the Arctic countries and Iceland are poorer in species, even considerably poorer, than are the temperate or the subtropical countries. The cause of this fact may be disputed, but the fact itself cannot be denied.

And yet it has been denied! For instance when discussing verbally with men of science in my own department, I have heard the assertion advanced, that exactly the Arctic regions, in contradiction to what I maintained, were comparatively rich in species! In this respect they have referred to the results arrived at by Nylander in his "Synopsis methodica lichenum." Nylander there shows that the Arctic regions are comparatively rich in species! But it should be noted that he arrives at this conclusion by comparing the number of phanerogams (!) with the number of lichen-species.

I have previously (Forberedende Undersøgelser, 1913) mentioned the figures given by Nylander and his comments on them. They are I presume correct — both the figures and the comments — only they do not at all affect the circumstance which I am endeavouring to elucidate, viz., the abundance of species in relation to area: and therefore they cannot at all be used as a corrective of my results. And yet, in verbal discussions, I have more than once come across this entirely erroneous view.

I have shown that the Arctic regions — as also Iceland — is poor in lichen-species in proportion to their area, far poorer than the temperate regions.

But there are many details in this connection which require to be more fully discussed, and for that reason we will regard the separate biological groups of lichens more closely: Bark, Epiphyllous, Earth and Rock-lichens, in order, if possible, to arrive at some explanation with regard to the cause of the phenomenon.

Bark-lichens. We must *a priori* expect the bark-lichens to be greatest in number in places where there is the greatest abundance of substratum for them, i. e. many species of trees, and in great number of individuals. Iceland is badly off in this respect, having on the whole, only one species of tree, which bears lichens somewhat abundantly, viz. the birch.

If we regard the bark-lichens in the various belts, it is seen that there are many in the Tropics, that for instance tropical Africa has almost 500 bark-lichens, already known, which form 65 % of all its lichens, Italy 508 (about 32 %), Denmark 165 (about 39 %) and Iceland 59 (about 15 %, inasmuch as Iceland's 285 systematic species constitute 337 biological forms, as several of the species occur sometimes as earth- and sometimes as rock-lichens, etc.). Now the areas which have here been compared with one another, are far from being all equally large and therefore do not give any figures, which are useful for purposes of direct comparison. But, at any rate, they give an indication of the fact that bark-lichens are comparatively more numerous in countries rich in trees than in Iceland; and they give the very important-information that Iceland, although it is much larger than Denmark, has only 59 species, whilst Denmark has 165! Whether this circumstance is solely due to want of necessary tree-substratum is not easy to decide. For instance, whether the bark-lichens of Denmark would be able to thrive in Iceland, if, by way of experiment, we removed them thither, together with the stems upon which they occurred, or whether the climate alone would kill them, we do not know. But that the paucity of species is due to the climate — directly or indirectly — is evident enough.

Epiphyllous lichens. These occur, as is well-known, on ever-green leaves only. 24 species are known to occur in tropical Africa and 3 in Italy. From the climate-belts north of Italy they are practically absent, and in Iceland, with its deciduous birches and willows, they are totally wanting. The same consideration which applies to the bark-lichens may be extended to the epiphyllous lichens, viz., that the climate is, directly or indirectly, a hindrance to their growth in Iceland.

Earth-lichens. We must expect *a priori*, that regions with a luxuriant vegetation of phanerogams and other good-sized plants are not favourable to earth-lichens. From the whole of that immense, tropical Africa (outside its alpine regions) only some 50 lichens are known! (about 5—6 %), from Italy 275 (about 17 %), from Denmark 86 (about 20 %) and from Iceland 121 (about 36 %). As may be seen, the percentage of the earth-lichens becomes greater and greater, the farther we proceed northwards to the cold regions. This is without doubt correlated with the fact, that the number of the competitors of the lichens decreases towards the north, the ground becoming more destitute of other plant-growth.

But the absolute number itself is greater for Iceland than for Denmark! Does this imply that the climate up there in the north is more favourable to lichens than down here in Denmark? Does not this contradict our general assumption, that lichens are more abundant in temperate countries than in Iceland? Anything of this kind cannot be deduced from the aforesaid fact. Considering the particularly favourable conditions which Iceland can offer the earth-lichens as regards competition, the number 121 in proportion to the 104000 square km. of country is very modest compared with Denmark's 86 on 38000 square km.

Still more interesting conditions become apparent when we regard the sub-divisions of the earth-lichens: the crustaceous, foliaceous and fruticose lichens. It is then seen that Denmark and Iceland have the following earth-lichens: —

	Crustaceous	Foliaceous	Fruticose
Denmark .....	34	21	31
Iceland .....	67	27	27

These figures are most peculiar, inasmuch as they show that Iceland's predominance as regards the number of earth-lichens, is due to a greater number of crustaceous lichens, inasmuch as both countries have about the same number of foliaceous and fruticose lichens, taken collectively, whilst Iceland has very nearly twice as many crustaceous lichens as Denmark. Remembering, that this growth-form in particular, in order to be able to live at all, demands either a very moderate competition, or none whatever, on the part of other plants, it is easily to be understood, that an Arctic country in particular, with a slightly developed phanerogamic vegetation, offers the crustaceous lichens the most favourable conditions possible, as regards competition. In reality there is so much unoccupied ground, free from other plants, that we might expect a much greater number, offering an analogy with the fact, that much tree-vegetation (for instance in the Tropics, in Italy, etc.) serves greatly to increase the number of species of tree-lichens. When in spite of the very slight competition, the number of earth-lichens is so limited, this can only be regarded as a direct result of the climate.



Rock-lichens. With regard to these it can be stated that tropical Africa has 182 species (24 %), Italy 729 (46 %), Denmark 169 (39—40 %) and Iceland 157 (47 %). The figures indicate that the sub-tropics are rich, and the purely tropical regions poor, in species; whilst the temperate and Arctic regions are less rich in species than are the sub-tropics.

On comparing more particularly Denmark with Iceland, we find that the number of species is greatest in Denmark, although Iceland is much larger in area. Remembering, moreover, that Iceland has bare rock-substrata, the superficial extent of which is so great that in Denmark we can form no conception of it, whilst our Danish species are limited to the very modest granite-surfaces on Bornholm, and to the loose stones found scattered about in fields and in fences, the small number connected with Iceland appears extremely elucidatory. It is impossible to explain this as anything else than a direct result of the climate, because Iceland has so many kinds of rock-substrata, that there would be plenty for the lichens to choose among, if the climate had otherwise been favourable to them.

We can consequently briefly sum up the above in the following few sentences: —

(1) Iceland (as also the Arctic countries) has on the whole a lichen-vegetation poor in species in proportion to its area, poorer than have the temperate and sub-tropical countries.

(2) The Bark-lichens meet with the most favourable conditions in the tropics — that is to say, they are rich in species there — in the Sub-tropics and in the Temperate regions they are poorer, whilst in the Arctic countries and in Iceland they are poorest of all: this should probably be correlated with the abundance of substrata present.

(3) The Epiphyllous lichens find the most favourable conditions in the Tropics, less favourable in the Sub-tropics, and least favourable of all in the Temperate regions; in the Arctic countries and in Iceland they are entirely wanting.

(4) The Earth-lichens meet with very unfavourable conditions in the Tropics, better in the Sub-tropics, better still (probably) in the Temperate regions, and best of all in the Arctic regions — as regards conditions concerning competition. The climate, on the other hand, appears to be directly unfavourable to them in the Arctic regions and in Iceland.

(5) The Rock-lichens meet with very unfavourable conditions

in the Tropics, better in the Sub-tropics, better still in the Temperate countries, and best of all in the Arctic countries and in Iceland — as regards conditions concerning competition. The climate, on the other hand, appears to be directly unfavourable to them in the Arctic regions and in Iceland.

This is best shown in a Table: —

	Bark-lichens	Epiphyllous lichens	Earth-lichens	Rock-lichens
Tropical Africa.....	498 (65 %)	24 (3.2 %)	45 (5.8 %)	182 (24 %)
Italy .....	508 (32 %)	3 (0.2 %)	275 (17 %)	729 (46 %)
Denmark .....	165 (39 %)	—	86 (20 %)	169 (39 %)
Iceland .....	59 (15 %)	—	121 (36 %)	157 (47 %)

These figures have been commented upon more fully in the above, both the actual figures and the percentages.

But the other side of the matter still remains to be discussed, viz., the valuation of the wealth of the various regions as regards the mass-development, as far as this is manifested by frequency numbers and masses (given in weight per unit of area). Hitherto we have been exclusively dependent upon a superficial valuation of this, and we are as yet hardly beyond the very rudiments as regards this point, but it need not continue to be so in the future. I shall record here the little that is known and may be discerned, but, firstly I shall dwell a little on the precautionary measures which must necessarily be taken in order to be able to judge somewhat correctly.

The cause which chiefly leads us to judge erroneously, is the fact, that we are involuntarily deceived by the size of the phanerogams compared with the lichens. Thus, we may very easily be struck by the abundance of lichens on mountain heights, in places where phanerogams are either totally or almost wanting, and on the other hand, underrate the abundance of lichens where the larger phanerogams are more numerous. This is in itself so common and significant a source of delusion when forming an estimate of the abundance of lichens, that as a rule we must be very cautious about relying on the results which the botanist in question puts forward, if we do not know beforehand his conception of this circumstance. But even if the botanist happens to judge quite correctly, yet he

has no other descriptive means with which to express his judgment than the terms "abundant," "less abundant," etc., merely relative expressions, which have no relation to any fixed and invariable unit.

It must therefore be absolutely recommended, in future, to determine the abundance of lichens in a country, a plant-association, a zone, etc., by still two other means, viz., frequency-number and mass-occurrence (in weight per unit of area) — in addition to its number of species.

In the present treatise I have as regards some of the Icelandic associations — as far as travelling-conditions permitted — given some frequency-numbers, which may be obtained, for instance by demarcating small sample-areas (1 or 2 square decimetres each) with equally large, intermediate spaces between them — in some places it is practicable to employ the smaller unit, whilst in other places the larger unit is preferable — and by noting whether they contain lichens. This method, as already mentioned, is Raunkjær's for phanerogams, and is also very good for lichenological purposes. In that way it is possible to determine almost all possible frequency-numbers in detail, to investigate for instance the frequency-number for crustaceous-lichens only, foliaceous-lichens only, etc., or the frequency-number for lichens taken collectively. If it be a question of wishing to know, for instance, how frequently lichens, as compared with phanerogams, occur in the sample-areas one can just take, say 100—200 or 1000 sample-areas, according to what may be considered necessary in order to obtain a reliable impression of the conditions, and note down in which areas lichens occur and in which phanerogams (mosses, algæ, etc.). If lichens occur in all the samples, then the frequency-number of the lichens is  $F\% 100$  ( $F\%$  stands for the frequency-percentage); if they occur only in 50 out of 100 sample-areas, then the frequency-number is  $F\% 50$ , etc. — All this has been treated of above to some extent, but here it is explained more fully. — In the case of phanerogams, mosses, etc. exactly the same method is employed.

If one should wish to determine how frequently crustaceous, foliaceous and fruticose lichens occur among themselves, one must note down, with regard to each of these little sample-areas, which of these growth-forms occur in it. For instance, in a series of samples, crustaceous lichens may be found in 50, fruticose lichens in 100, and foliaceous lichens in 20 sample-areas. The frequency-

number is then F % 50, F % 100 and F % 20 respectively, all of which has already been known and employed for several years in ecology, with regard to phanerogams.

This frequency-number serves to indicate how equally the lichens are distributed in an association or similar limited area. This has the great advantage, that even non-specialists, who have a general botanical training, can note down various facts with regard to the distribution of special groups of plants (lichens, earth-algæ, mosses, etc.) in the associations, without knowing the name of a single species found.

A specialist, when he has time at his disposal, will be able to go more into details, and even determine the distribution of a single species within a certain area.

The determination of the mass-occurrence of lichens has never yet been undertaken; it has been mentioned under the treatment of the heath-lichens. For this determination it is necessary to reap everything that grows on each sample-area, and weigh it. By this means one obtains figures, which are directly useful for purposes of comparison, as regards the relative extent of mass-occurrence of the plant-association in question. This method is useless as regards the crustaceous lichens, but in their case it is possible to state, with some certainty, the size of the area covered by them.

If we are to compare the abundance of the lichens of the various countries, according to the methods which have been briefly treated here, and, by means of these methods, try for instance to answer the general question: "Where are the lichens to be found in greatest abundance, in Iceland or in Denmark?" This question must be further detailed, in order to be answered, and cannot, upon the whole, be answered as yet. The Icelandic heaths can be compared with the Danish, the Icelandic grasslands with those of Denmark, etc., as has been done above, by way of experiment, in the special sections, with regard to frequency-number and mass-occurrence (in weight per unit of area). But a thorough comparison cannot yet be made, as it requires many more investigations in the field, than have hitherto been undertaken.

It is, however, my impression, as it has been the impression of other botanists, already in former times, that as regards frequency number and abundance the Arctic regions and Iceland appear to be richer than other regions, no doubt chiefly on account of the

slight competition to which the lichens are subjected. It must, however, be remembered that the cold mountain heights in Iceland appear to be less rich in lichens, than are the more low-lying parts, and are remarkably poor when the fact is considered that the competition on the part of other plants is only slight, or altogether wanting; so that one is led to the conclusion that the climate, as such, is not favourable.

---



## BIBLIOGRAPHY.

- Babington, C. C., 1871: A Revision of the Flora of Iceland (The Journal of the Linnean Society, vol. XI, London).
- Deichmann Branth, 1903: Lichenes Islandiæ (Botan. Tidsskrift, Bd. 25, Kjøbenhavn).
- Ferdinandsen, C., 1918: Undersøgelser over danske Ukrudsformationer. (Diss. Kjøbenhavn).
- Galløe, O., 1908: Danske Likeners Økologi (Botan. Tidsskr., Bd. 28, Kjøbenhavn).
- , 1913: Forberedende Undersøgelser til en almindelig Likenøkologi (Dansk Botan. Arkiv, Bd. I, No. 3, Kjøbenhavn).
- Gelert og Ostenfeld, 1898: Nogle Bidrag til Islands Flora (Botan. Tidssk., Bd. XVI, Kjøbenhavn).
- Grønlund, Chr., 1870—71: Bidrag til Oplysning om Islands Flora (Botan. Tidsskr., Bd. 4).
- , 1873: Bidrag til Oplysning om Islands Flora (Botan. Tidsskr., Bd. 7).
- , 1877: Islandske Naturforhold med særligt Hensyn til Mosvæxtens Betydning for Landskabet (Tidsskr. for populære Fremstillinger af Naturvidenskaben, 5. Række IV, Kjøbenhavn).
- , 1881: Islands Flora (Kjøbenhavn).
- , 1884: Karakteristik af Plantevæxten paa Island sammenlignet med Floraen i flere andre Lande (Den Naturhist. For. Festskrift, No. 1, Kjøbenhavn).
- , 1885: Afsluttende Bidrag til Oplysning om Islands Flora (Musci, Hepaticæ, Lichenes). — (Botan. Tidsskr., XIV, Kjøbenhavn).
- , 1895: Tillæg til Islands Kryptogamer (Botan. Tidsskr., Bd. XX, Kjøbenhavn).
- Hayrén, E., 1914: Ueber die Landvegetation u. Flora der Meeresfelsen von Tvärminne. (Acta Soc. pro Flor. et Fauna, Fenn.).
- Hesselbo, Aug., 1918: The Bryophyta of Iceland (The Botany of Iceland, Part II. Copenhagen and London).
- Jónsson, Helgi, 1895: Studier over Ost-Islands Vegetation (Botan. Tidsskr., Bd. XX).
- , 1899: Floraen paa Snæfellsnæs og Omegn (Botan. Tidsskr., XXII).
- , 1900: Vegetationen paa Snæfellsnæs (Videnskab. Meddelelser fra den Naturhist. Forening, i Kjøbenhavn).
- , 1905: Vegetationen i Sydland (Botan. Tidsskr., XXVII).
- Lauder Lindsay, 1861: Flora of Iceland (New Philosophical Journal, New series, Edinburgh).
- Mentz, A., 1913: Studier over danske Mosers recente Vegetation (Kjøbenhavn og Christiania. Bot. Tidsskr. XXXI).
- Ostenfeld, C. H., 1899: Skildringer af Vegetationen paa Island (Botan. Tidsskr., Bd. XXII).
- Petersen, H. E., 1917: Maglemose i Grib Skov. (Botan. Tidsskr., Bd. 36).

- Raunkiær, C., 1909: Formationsundersøgelse og Formationsstatistik (Botan. Tidsskr., Bd. 30).
- , 1912: Measuring Apparatus for Statistical Investigations of Plant Formations (Botan. Tidsskr., Bd. 33).
- , 1916: Om Valensmetoden (Botan. Tidsskr., Bd. 34).
- , 1917: Recherches statistiques sur les formations végétales (Det Kgl. Danske Vid. Selsk. Biolog., Meddelelser I).
- Rostrup, E., 1888: Bidrag til Islands Flora (Botan. Tidsskr., XVI).
- Stefánsson, St., 1890: Fra Islands Væxtrige, I—III (Vid. Medd. fra Nat. For. i Kjøbenhavn).
- , 1896: Bemærkninger til Chr. Grønlunds Tillæg til Islands Kryptogamflora, etc. (Botan. Tidsskr., Bd. XX).
- , 1901: Flora Islands. (København).
- Strömfelt, H. F. G., 1884: Islands kärlväxter (Öfversigt af Kgl. Vetensk. Akad. Förhandlingar, Stockholm).
- Thoroddsen, Th., 1914: An Account of the Physical Geography of Iceland, etc. (The Botany of Iceland, Part I, 2, Copenhagen and London).
- Warming, E., 1895: Plantesamfund (Kjøbenhavn).
- , 1909: Oecology of Plants (Oxford).
-

# CONTENTS.

	Page
Introduction.....	103
I The Lichen Flora of Iceland.....	106
II The Means of Propagation and Dispersal of the Iceland Lichens.....	130
III The Biology of the Lichens of Iceland .....	137
1. Bark Lichens.....	137
2. Epiphyllous Lichens .....	142
3. Earth Lichens .....	142
4. Rock Lichens.....	156
5. Synopsis of the chief Biological Conditions of the Lichens of Iceland	164
IV The Classification of the Lichens into Associations .....	172
1. Bark-Lichen Association .....	172
2. The Earth-lichen Associations .....	174
a. The Deserts .....	182
b. Lichen-heaths .....	187
c. Moss-vegetations .....	187
d. The Grass Vegetation.....	191
e. Heaths.....	197
f. Coppices .....	217
3. Rock-lichen Association .....	219
a. Basalt.....	219
b. Lava.....	224
c. Tuff.....	227
d. Liparite.....	228
V The Vertical Distribution of the Lichens .....	230
VI The Abundance of Lichens in Iceland.....	234
Bibliography .....	246