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THE VEGETATION OF WEST GREENLAND

By R. E. HOLTUM.

(*With Plates III—V.*)

(1) INTRODUCTORY.

The first description of the vegetation of west Greenland is that contained in Hans Egede's *Perlustration* (4), illustrated by figures of plants collected by his son Poul Egede, whose herbarium is the earliest existing collection of arctic plants. Some of the missionary successors of Egede made further collections, and Rottböll in 1770 published an account of the flora based on their material. The geologist Giesecke made extensive explorations of the west coast during the years 1806–13, and published a list of plants. J. Vahl visited the whole coast from south to north during the period 1828–36 and made large collections of the flora. Some of his work in connection with these has never been published, but his material was used by Lange in the preparation of the *Conspectus Florae Groenlandicae* (12), which appeared in 1880, and with its supplements is the most complete list of Greenland plants. Surgeons on board whaling vessels and on the various expeditions in search of Franklin collected plants on the coasts they visited, and lists of these were published by Hooker and others¹, but the first general descriptions of the vegetation were made by Robert Brown (2), who visited various parts of the west coast with Whymper in 1867, by Berggren (1) (Disko Bay, 1871) and by Hart (5), who accompanied the *Discovery* in 1875–6. In 1888 appeared Warming's paper (27), the first ecological study and still the most complete account of the vegetation of the country as a whole. This was supplemented as regards the southern districts by Rosenvinge (25) in 1898, and as regards the Disko neighbourhood by Porsild (18) in 1902 and in the later papers issued from the Danish Arctic Station at Godhavn after its foundation by him in 1906. Other papers of ecological interest during this period are by Hartz (accounts of voyages during 1889 to parts of the coast south of Holsteinsborg, and during 1890 to Disko Bay and the Waigat), Kruuse (Egedesminde district, 1897) and Vanhöffen (Drygalski Expedition of 1891–3, Umanak fjord). Ostenfeld has written a short account of the plant life of the extreme north, based on the diary of Wulff, the Swedish botanist who died on Rasmussen's second Thule expedition, 1916. There are also annotated lists of plants collected on various expeditions, but these are not primarily of ecological interest². A series of papers entitled "The structure and biology of arctic flowering plants" has appeared in the *Meddelelser om Grønland*, the earliest being Warming's account of the morphology and biology of the Ericaceae; other groups dealt with are Saxifragaceae, fresh water

¹ For complete list of botanical literature up to 1880 see Lauridsen (14).

² References to a number of these will be found in the various papers by Porsild cited in the bibliography at the end of this paper.

aquatics, Ranunculaceae, Pinguicula, Rosaceae, Cornaceae, Caprifoliaceae, Primulaceae, Caryophyllaceae and Liliaceae. A complete list will be found in the latest of the series (22). Porsild has in course of publication a list of the plants growing on and near Disko, with notes on their distribution, habitat, seed production and hibernation. He has also numerous important observations on the occurrence of seedlings.

The questions of distribution of species and of the origin of the present flora have been dealt with by several writers. The first important contribution was by Hooker in 1860. In 1881 Lange criticised Hooker's statistics and conclusions, and during the course of the next decade appeared several papers by Nathorst and Warming (15, 16, 27). Further facts, both floristic and geological, have since come to light, and Porsild (23) has summarised the present knowledge of distribution of species, and the probable conclusions to be drawn as to the origin of the flora. Geological evidence shows that probably the whole of Greenland was covered with ice during the glacial period, and that accordingly the flora must have been completely destroyed; the present vegetation is therefore due to post-glacial invasion. The nearest land from which such vegetation could have come is to the north-west, across Smith Sound, and it is suggested that all western and circumpolar arctic species came this way. This accounts for about 36 per cent. of the total number of species, but a difficulty arises with regard to the 60 per cent. of southern types. Nathorst supposed that a land bridge existed in post-glacial times connecting Europe by way of the Faeröes and Iceland with east Greenland, but from a geological standpoint this appears doubtful, and the number of species occurring commonly in Iceland which are absent in east Greenland is evidence against it. Some of the southern plants were undoubtedly introduced by the Icelandic colonists of the tenth century, but most of them must have been carried over the sea by natural means. The total number of species and varieties of vascular plants in the whole of Greenland is 416. This is much smaller than that of other arctic lands of similar extent, no doubt on account of the absence of land connection to the south.

The following account attempts to summarise the present knowledge of the vegetation of west Greenland from an ecological standpoint; the writer's own observations of particular pieces of vegetation have been included in some cases. He had the privilege of visiting the Danish Arctic Station at Godhavn on Disko Island in company with Prof. A. C. Seward during the summer of 1921. The primary object of the expedition was to collect fossil plants from the well-known localities on Disko and parts of the coast north of it. Calls made at various places during motor-boat voyages of over 700 miles furnished opportunities for making notes on the vegetation as well as for collecting herbarium material. The writer is very greatly indebted to the Director of the Arctic Station, Mr Morten P. Porsild, for much help, both

in identifying plants collected and in placing his wide knowledge of local conditions at his visitors' disposal, and also for his very kind hospitality during two pleasant months. The assistance of A. Erling Porsild on the motor-boat voyages was also invaluable, both as guide and interpreter and on account of his thorough knowledge of the flora. The writer wishes also to express his very cordial thanks to Prof. Seward for the opportunity of accompanying him on the expedition.

(2) TOPOGRAPHY.

With the exception of a strip of land of varying width round the coast, the whole of Greenland is covered with a continuous ice-field. The exposed coastal region consists mainly of irregular mountainous land, intersected by numerous fjords, at the heads of many of which large iceberg-forming glaciers reach the sea. Most of this country consists of gneissic rock, and the lower parts of it, near the shore, are typically formed of low ice-worn hummocks, with vegetation only continuous in the hollows or on old moraines.

Between the latitudes of 69° and 71° N. there is a change in the character of the country. Here there are considerable layers of Cretaceous and Tertiary sedimentary rocks (sandstones and shales, with thin coal seams, containing the celebrated fossil flora of this part of Greenland) and above them thick layers of tuff and basalt, bringing the general height of the land up to 3000–5000 ft. above the sea. These newer rocks weather quite rapidly, and the appearance of the country is quite different from that to the north and south of it. Typically a fairly gentle and even slope rises from the shore, covered with vegetation at least to the height of the basalt, which then rises in steep terraces, above a talus of boulders. This shore slope is broken up by steep narrow valleys, cut in it by streams formed by melting of snows above, or from small glaciers which do not reach the coast. These streams are particularly violent in spring, and bring down much sediment which is deposited in fan-shaped deltas, some of considerable size. The whole of the smaller deltas, and the central regions of the larger ones, are almost entirely flooded in the spring, but during the summer their boulder-strewn surface is baked dry, except where it is intersected by the stream courses. There is a sandy beach on the shore almost everywhere in this region, sometimes with low dunes, and behind the dune banks small lagoons and salt marshes may occur.

The soil on the gneiss rocks, except where there are old moraines, consists very largely of raw humus formed of remains of the previous vegetation which has formed a mat on the surface of the rock itself. On the more recent rocks there is usually a fairly considerable depth of loose soil, but the soil from weathered tuff is heavy and retentive. None of the rocks represented contains any quantity of calcium carbonate; nitrogen is also deficient, so that there must be some organic agent operative in the fixation of atmospheric nitrogen. Doubtless nitrogen-fixing bacteria are present in the soil, but this matter has not been investigated.

(3) CLIMATE.

The mean annual air temperature varies from about 1° C. in the extreme south of Greenland to about - 8° C. at Upernivik (73° N.), the northernmost Danish colony. The mean temperatures for July at the same localities are about 10° and 5° respectively. The total rainfall at Ivigtut, in the extreme south, is about 130 cm., and at Jakobshavn in Disko Bay only 22 cm. During the summer there is frequently low sea fog round the more outlying parts of the coast, and this has a great influence on the climate of, for instance, the small islands of the Egedesminde district (11) in the south of Disko Bay. At Cape Dalton (on the east coast) Hartz and Kruuse (7, p. 343) record that frequent low sea fog greatly retards the growth of plants near the shore as compared with those higher up; a marked difference of temperature was noted, 2° C. at sea level as against 10° at an altitude of a few hundred feet. The difference between coast and inland localities as regards climate is illustrated by the statistics for Godthaab (on coast) and Kornok (inland), both about lat. 64° N. (25, pp. 94-5). The annual rainfall at the former is 71.4 cm. and at the latter 36.5 cm., while the numbers of days of fog in the year are respectively 57 and 12. Where clear sunny weather prevails during the summer the surface of dry soil and rocks is raised to 40° C. or more. A black bulb thermometer in the sun at noon on July 26, 1897, on the south of Disko Bay registered 40.5°, the air temperature at the same time being 14.5° (11, p. 367). Porsild records 48° with black bulb on a "black streak" of Cyanophyceae on gneiss in Diskofjord (18, p. 210).

During the winter snow covers most of the ground, but near the coast the strong winds leave only a small covering on the exposed shore slopes; in the valleys it collects and may persist till late in the summer if not exposed to the direct heat of the sun. The cold dry winds prevent any plants growing up above the level of the snow surface. In places well sheltered from the wind and with a southern exposure, where thick snow collects early, melts early and is never packed hard, there is a greater protection for the vegetation in the winter and at the same time the best summer conditions. Here a thick willow scrub can develop, or a vegetation of herbaceous plants which cannot stand the more severe conditions of exposed situations. Further inland, especially on the coasts of some of the fjords, there is greater protection from wind, and a thick even layer of snow can accumulate over larger areas. In such situations the greatest development of willow scrub occurs.

(4) CLASSIFICATION OF VEGETATION TYPES.

Warming classified the vegetation of Greenland under the following headings:

- (i) The birch scrub of south Greenland.
- (ii) Willow scrub (Pilekrat) and associated herbaceous vegetation (Urte-mark).

- (iii) Heath (Lynghede).
- (iv) "Fjaeldmark"¹; permanent open vegetation.
- (v) Vegetation of fresh water marshes and pools.
- (vi) Shore vegetation.
- (vii) Nitrophilous vegetation round settlements.

This classification has been adopted, with some additions, by Porsild. It appears to the present writer, regarding the vegetation from the successional standpoint, that heath represents the climatic climax over the greater part of the country, with the probable exception of the birch region in the south, and of the extreme north where closed vegetation is infrequent. According to this view the willow scrub must be regarded as a post-climax due to favourable local edaphic and topographic conditions, and the "Fjaeldmark" as a stabilised pre-climax due to unfavourable conditions. A doubtful case is that of moss bog, which appears to be persistent for a considerable period at least under certain circumstances; it is not clear whether this will necessarily pass over into heath, and it will therefore be described separately. The same remark applies to the aquatic vegetation of ponds. Salt marsh may possibly in some cases pass over by silting up into heath, directly or through the stage of fresh water marsh, but it is not certain that this is the general rule. The highly nitrogenous soil round settlements bears a characteristic vegetation, chiefly of grasses, which does not lead to heath. With these exceptions, all the vegetation may be regarded as representing stages in the heath succession. Succession is naturally very slow, especially in very dry or exposed situations, and in many cases it is not possible to say whether the heath stage will be reached.

The following scheme embodies the above suggestions:

A. North of 62° N. Lat. (limit of *Betula odorata*).

(a) *Climax*: Heath, arising as a result of successions on

1. bare gneiss rock: (i) xerosere,
(ii) hydrosere;
2. talus slopes of recent rocks;
3. areas of silt brought down by streams. Here the first stage may be either open vegetation on dry ground or fresh water marsh vegetation;
4. raised beaches;
5. dunes on sandy shores;
6. moraines.

(b) *Stabilised pre-climaxes*: Fjaeldmark and (?) Moss bog.

(c) *Post-climax*: Willow scrub, with associated herbaceous vegetation as a stage of development.

(d) *Special edaphic types*: Nitrophilous vegetation round settlements and Halophilous vegetation of salt marsh.

¹ The term "fell-field" used by the translators of **Warming's** *Ecology of Plants* (1909) is not a very suitable English term.

B. South of 62° N. Lat. (region of *Betula odorata*).*Climax*: Birch-willow scrub.*Stabilised pre-climaxes*: Heath and Grassland.A. NORTH OF THE REGION OF *BETULA ODORATA*.

(a) *Heath and phases of the heath succession.* Heath is the typical vegetation over the greater part of the country, varying little in character even in the extreme south. On Disko it extends to an altitude of over 2000 ft. It consists essentially of low woody plants, mainly ericaceous, of which the most important are *Empetrum nigrum* and *Cassiope tetragona*, each being locally dominant and of about the same range of distribution, except that *Cassiope* occurs at higher altitudes than *Empetrum*. Both occur on all types of soil. Perhaps the most universally present plant, occasionally also dominant, is *Vaccinium uliginosum* v. *microphyllum* Lange; *Salix glauca* also occurs almost everywhere, but is never dominant in the heath. *Betula nana* is frequently present, and in the drier parts may be the dominant phanerogam, the rest of the vegetation consisting of a carpet of lichens (species of *Cladonia*, *Cetraria*, *Alectoria*, etc.), but it is rather local in its occurrence without apparent connection with changes in the soil or other conditions. South of 63° N. Lat. *Betula glandulosa* replaces *B. nana* in the heath. Associated ericaceous plants which are more or less abundant are *Phyllodoce caerulea*, *Ledum palustre* v. *decumbens* Ait., *Rhododendron lapponicum* and *Loiseleuria procumbens*. The last two plants are rarely met with on the sandstone, though both are common on the gneiss. In many places the vegetation is very mixed, and it is not possible to name any one plant as the dominant. This is certainly the case in early stages of the succession, when the ground is not completely covered, but it is not clear whether any one plant has sufficient advantage over the others finally to become dominant in all cases. Certainly one does find almost pure patches of *Cassiope*, sometimes in thick tufts, or of trailing matted stems of *Empetrum*, but these are usually in rather favourable situations. In the south Rosenvinge (25, p. 193) records *Empetrum* as dominant in the heath near the coast where the climate is moist. Farther inland, where it is drier, *Betula* and *Vaccinium* are dominant; this is no doubt connected with their deciduous habit. The associated herbaceous plants differ also, and mosses tend to disappear. Except on the sandstone, mosses are constantly present in large numbers and variety of species among the heath plants near the coast.

On the gneiss the heath occurs as an irregular carpet covering the rock surface, except in the steepest and most uneven places, where the rock is exposed; here it is covered almost entirely by species of *Gyrophora* and crustaceous lichens, typically black and giving a characteristic appearance to the whole landscape. On the more recent rocks of Disko and the Nugsuak peninsula heath covers the greater part of the permanent shore slopes, though

(b) Succession on gneiss, Godhavn; *Gyrophora* sp. on bare rock, and spreading mat of lichens with *Salix herbacea*; below, *Cladonia gracilis* and *Carex rigida* (right).

(a) Luxuriant herbaceous vegetation on slope, Englishman's harbour, including *Polygonum viviparum*, *Habenaria albida*, *Taraxacum* sp., *Dryopteris linneana*, *Alchemilla glomerulans*, *Sibbaldia procumbens* (under-growth) and *Salix glauca* (right).

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often it is not quite closed, especially at higher altitudes. At Patoot on Aug. 8, 1921, between the heights of 2200 and 2500 feet, A. E. Porsild and the present writer observed 67 species of vascular plants, practically all the normal heath species being represented, though the normal heath dominants were very restricted, especially *Empetrum*. The vegetation was very open, *Dryas integrifolia* being among the most abundant species, and forming large mats which faced steeply towards the sun. All the plants contained a greater amount of anthocyan pigment than was normally present at that date in plants at lower altitudes. Where a small stream flowed down the slope there was a much more luxuriant vegetation, with a good deal of moss, and it seems probable that dryness of soil and strong insolation were the factors limiting plant growth, rather than cold. On the northern shore of the Nugsuak peninsula, at Ekorgfat and elsewhere, the snow melts more slowly and insolation is less intense, and the heath vegetation on the sandstone was more luxuriant, *Dryas*, for example, having much broader leaves than usual, and a greater vegetative development.

1. *Succession on gneiss rock: Xerosere.* As above mentioned, the surface of the rock is usually covered with crustaceous lichens which quite obscure its natural colour, except close to the sea where the ice-foot forms in winter. The most typical of these lichens are species of *Xanthoria* and *Gyrophora*. Starting in small crevices fruticose lichens and xerophytic mosses begin to form cushions which spread over the surface. Very numerous species may be present at this stage. One may find tangled mats of *Cetraria islandica*, *Cladonia sylvatica*, *Alectoria jubata*, and other lichens of similar habit, or close *Racomitrium* cushions fringed by the above lichens, or crusts of *Lecanora tartarea*, while *Cladonia gracilis* is often found climbing up quite steep rock faces. When these mats are well-established, higher plants appear in them, *Lycopodium selago*, *Pyrola grandiflora* Rad., *Vaccinium uliginosum* often being among the first. In shaded places where snow lies late *Salix herbacea* is very frequent but may also occur in more exposed situations; it is often accompanied by *Cassiope hypnoides*. In some places small Carices are numerous, among the commonest being *C. rigida*, *C. alpina* and *C. scirpioidea*. In rather moist hollows, not wet enough for bog mosses, thick mats of *Aulacomnium turgidum*, almost pure or with other mosses, are found. In rock crevices cushion plants often appear before any other phanerogams are present. The most typical are *Silene acaulis* and *Diapensia lapponica*, but many other plants characteristic of open vegetation are met with, such as *Saxifraga tricuspidata*, *S. aizoon*, *S. oppositifolia*, *S. groenlandica*, *Campanula rotundifolia*, *Viscaria alpina*, *Potentilla* spp., *Poa glauca*, *Cystopteris fragilis* and *Woodsia ilvensis*. Many of these plants are found growing in vertical crevices, especially the ferns.

Hydrosere. In hollows of the rock surface there occur frequently moss bogs, or ponds of varying size, with or without aquatic flowering plants. In the Egedesminde district Kruuse (11, pp. 384–92) describes the invasion of such

ponds by vegetation, implying that they may finally pass over into heath by accumulation of humus. It seems probable that this may happen, though slowly, in the case of the smaller ponds, but in the case of larger lakes such as those described by Porsild in Diskofjord (18, pp. 205–6) there is little evidence of it. The present writer did not give any special attention to this matter, but perhaps this is the most suitable place to insert a brief description of the vegetation of the ponds and hollows in question. The species of aquatic flowering plants are all characteristic of temperate regions, and occur in all ponds which are large enough to be permanent and shallow enough to be appreciably warmed during the short summer. None of them produce ripe fruit, and many of them rarely flower, especially in the north. The commonest is *Hippuris*, *Menyanthes trifoliata* also being very common in the south; species of *Callitriche*, *Potamogeton*, *Sparganium*, *Myriophyllum* and *Ranunculus* also occur. This co-existence of temperate aquatics with arctic terrestrial vegetation is paralleled in plant remains from the glacial period in temperate regions. Rikli (24, Taf. 47) describes the zonation round a small pool at Godhavn. The outermost zone consists of a mat of small Carices, the most frequent being *C. alpina*, *C. rariflora* and *C. rigida*; here also occur *Juncus castaneus*, *J. biglumis*, *Salix groenlandica*, *Tofieldia palustris*, *Saxifraga stellaris* v. *comosa* (bearing usually a few flowers at the apex of the inflorescence, the rest of which is covered with bulbils) and other plants. Next is a zone of larger Carices often growing in water, *C. rotundata* being most frequent, with *C. misandra* on small tussocks above the water level. Following this the *Eriophorum* zone (*E. polystachium* and *E. scheuchzeri*) extends into water 50 cm. deep. With the *Eriophorum* grow sterile shoots of *Chamaenerium latifolium*. Finally comes *Hippuris*, with submerged mosses. In rock hollows which have not ponds in them in which *Hippuris* can grow, *Eriophorum* (either species or both together) almost invariably occurs in shallow water or among wet bog mosses; or *Eriophorum* may be absent in less wet places, and *Juncus castaneus* the most conspicuous angiosperm, in association with Carices. Kruuse describes ponds as invaded from the west or south-west (direction of prevailing winds), the zonation being as follows: (1) *Empetrum*; (2) *Polypodium*; (3) *Sphagnum*, with *Eriophorum*; (4) *Hypnum* (*H. scirpioides* and *H. fluitans* occurring throughout on the bottom to a depth of at least three metres). *Hippuris vulgaris* and *Ranunculus hyperboreus* occur in shallow water, and *R. paucistamineus* Tausch. to a depth of three metres.

2. *Talus slopes of recent rocks.* These are frequently too steep and not sufficiently stable to allow of the development of a closed vegetation. This is particularly the case on the sides of the narrow valleys cut into the sedimentary rocks; here occur at most only scattered plants of *Papaver radicum*, *Oxyria digyna*, *Cerastium alpinum*, etc. Where the slope is more gentle, heath can develop, the early stages consisting of open vegetation of a great variety of herbaceous plants, *Dryas integrifolia* among the most important, and also low

(a) Edge of delta, Ata. Dune bank with *Elymus* and marsh with *Eriophorum scheuchzeri*; in foreground *Eriophorum*, *Juncus arcticus*, and *Salix glauca* (on bare silt).

(b) Silted-up stream bed on delta, Ata, close to (a). Low spreading plants of *Salix glauca*, fringed with *Equisetum variegatum*, on either side.

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straggling *Salix glauca*. Mosses and lichens are not found in any quantity on the sandstone. Boulder-strewn slopes below steep terraces of basalt have a similar first phase of vegetation to that of the raised beach described below, i.e. lichens and mosses are typically the first plants to appear.

3. *Areas of silt brought down by streams.* The deltas at the mouths of streams in the sandstone districts are the only important areas of this kind. Their vegetation no doubt often originates from plants washed down from the sides of streams higher up during the spring floods (18, p. 135). Seeds and bulbils (e.g. of *Polygonum viviparum*) might well be transported in the same way. The surface of such deltas consists of sand strewn with boulders of all sizes, and bears usually an open herbaceous vegetation. On the delta at Patoot the following plants were noted: *Chamaenerium latifolium*, sometimes in large clumps covered with very fine purple flowers; *Artemisia borealis*, *Oxyria digyna*, *Cerastium alpinum*, *Silene acaulis*, *Campanula rotundifolia*, *Papaver radiculatum*, *Statice maritima* v. *sibirica*, *Salix glauca*, *Trisetum spicatum*, *Poa glauca*, *Calamagrostis purpurascens*, *Juncus arcticus* (locally) and *Equisetum arvense*. On the deltas at Kook and other places on the north coast of the Nugsuak peninsula *Melandrium triflorum*, *M. apetalum*, *Lesquerella arctica*, *Cochlearia officinalis*, *Hierochloa alpina*, *Arctagrostis latifolia* and *Luzula confusa* were conspicuous and often comparatively large plants were present.

The large delta at Ata was the only one visited by the writer which showed all stages of succession from the open stony ground subject to violent erosion of the central area to a true closed heath vegetation. The level of the principal stream bed at the head of the delta is nearly 200 feet above sea, and the total width of the delta, which is formed by streams from two adjacent valleys, is somewhere about three miles. Between the two streams occurs the highest part, with a vegetation of *Cassiope* heath. Near the western margin is a flat area of silt which appears to be on either side of an old water course, which itself is filled with sand. Here the ground is almost covered with prostrate *Salices* (*S. glauca* or hybrids). The branches of these, which are sometimes over a metre long, are quite horizontal and in contact with the soil surface. Only very short shoots bearing leaves and inflorescences grow upwards; such willows can probably stand fresh deposits of silt, and grow up through it. Violent breaking up of this vegetation is always possible by the formation of new stream beds which cut right through it, uprooting willows and washing them away. The situation is very exposed, and the ground may even be free of snow in the winter. With *Salix* are various other plants, especially *Polygonum viviparum*, *Pedicularis lanata*, *Equisetum arvense*, with tufts of *Poa*, *Trisetum* and *Luzula confusa*. The soil is moist almost to the surface everywhere, but the surface itself is hot and dry and in some places baked into a hard crust. The latter condition prevails especially in parts more remote from any stream bed; here in the crevices of the uneven surface appear small

dried mosses, but mosses are never abundant on the sandstone, except in marshes and well-established heath. *Dryas* is perhaps the most characteristic plant of the drier parts which have a fairly permanent soil. *Alectoria jubata* is of occasional occurrence, forming black patches; other flowering plants are *Saxifraga tricuspidata*, *S. oppositifolia*, *Carex rupestris* and other Cyperaceae.

On the western edge of the delta there is a small lagoon behind the low dune bank. Round the lagoon is a salt marsh, which gradually changes into a fresh water marsh on its landward side. When visited by the writer, perhaps the most typical plant association here was dominated by *Carex stans* of medium height (less than 30 cm.) with much *Equisetum variegatum*, less frequent *E. arvense*, both quite short, and always some almost prostrate *Salix glauca*, with a good deal of moss between the higher plants. Locally *Equisetum variegatum* was dominant over a considerable area, with very fresh green shoots, the associated plants being as before. On adjacent ground, where the surface is raised somewhat and drier, *E. variegatum* was still dominant but brown and less upright, and *Carex stans* almost entirely absent; *Polygonum viviparum* and *Pedicularis lanata* had established themselves. In other parts of the marshy area were almost pure growths of *Eriophorum*, patches of each species alone being easily recognisable from a distance by the different habit of the inflorescence. Invading what appeared to be a silted up-stream course were very fine plants of *Carex stans*, with leaves and flowers almost 50 cm. high, and very long rhizomes. With this were also very vigorous vegetative shoots of *Eriophorum*, much larger than those occurring elsewhere. *Juncus arcticus* was also pushing its way into the unoccupied ground, its lines of growth being indicated by the close rows of upright shoots. More raised patches of silt had prostrate willows growing on them, and it is probable that by progressive silting the marsh will in time be replaced by heath, through a phase like that on the drier silted areas described above. Porsild (18, pp. 167-70) describes similar vegetation near Skansen. Here stream beds in summer are usually strips of bare sand with no water showing, but the vegetation on either side, principally of *Carex stans*, *Eriophorum* and *Equisetum arvense* (often pure patches of each of these species), shows the ground to be very moist below. If in spring the stream makes a new course for itself, as often happens, the large *Carex* and *Eriophorum* disappear and the area is invaded by heath plants; traces of former *Carex* vegetation can sometimes be found in the heath.

4. *Raised beaches.* Porsild (18, pp. 172-9) describes the development of heath vegetation as indicated by a series of raised beaches near Sinigfik (south Disko). The beaches consisted of rolled shingle of varying size. Species of *Gyrophora* are characteristic of the first phase, with later *Sphaerophoron fragile* and *Stereocaulon denudatum*. Xerophytic mosses soon appear, *Racomitrium hypnoides* being dominant, growing first in the crevices between the stones. The mixed mosses finally form cushions as much as one metre long, resting on bare stones; at the edges of the *Racomitrium* cushions occur fruticose

lichens. The next invaders are xerophilous *Polytricha* and angiosperms, at first poorly developed and not flowering. Finally the vegetation becomes closed by other mosses, particularly species of *Dicranum* and *Oncophorum*, and fruticose lichens, especially species of *Cladonia*, which fill up the spaces between the other plants. The phanerogams then gain the upper hand and *Racomitrium* and lichens occupy less and less of the available surface. In this case an accumulation of raw humus and the covering of the ground by mosses, which absorb water and prevent rapid desiccation of the soil, are necessary before the higher plants can form a sufficiently vigorous growth to become dominant.

5. *Sand dunes*. These are rarely well developed, but almost everywhere in the sandstone districts, and also where basalt is present, the shore is fringed by small dunes with characteristic vegetation. On the landward side there is a more or less gradual transition to heath in many cases. *Elymus arenarius* v. *villosus* and *Honkenya peploides* are the only two plants which always occur on the sand, the latter forming slightly convex circular patches a metre across; *Mertensia maritima* also is often present, but never very abundant. At Godhavn, on a stretch of basaltic sand, other grasses make their appearance among the *Elymus* a little distance back from the sea, *Festuca arenaria* being the first of these. Farther from the shore *Festuca ovina*, *Poa alpina*, *Poa glauca*, *Poa pratensis*, *Trisetum spicatum* and others are found, sometimes almost covering the ground, while *Salix glauca* soon appears and clothes the bases of the sand hillocks, which are still crowned with *Elymus*. Probably this vegetation would finally develop into heath; at Holsteinsborg *Empetrum* was seen to be spreading over some glacial sand by the shore, on which *Elymus* also occurred.

6. *Moraines*. The succession on old moraines will vary according to the nature of the rock from which they are formed, and with local topographic and edaphic conditions. If nearly horizontal and of heavy retentive soil they will be covered with moss bog, but if they are of lighter soil and better drained heath will probably develop if climatic conditions allow.

(b) *Stabilised pre-climaxes*: (1) "*Fjaeldmark*." True "*Fjaeldmark*" is an open vegetation of isolated stunted flowering plants, accompanied by mosses and lichens, which occurs where the climate is not sufficiently favourable to permit the development of a closed vegetation of any kind. On Disko it only occurs at high altitudes, but it is the characteristic vegetation of the extreme north. Porsild (18, p. 164) describes a high plateau on Disko, where the ground was mainly covered with snow; on uncovered patches were *Usnea melaxantha* and species of *Gyrophora*, also *Andreaea petrophila*. Of phanerogams the most frequent was *Potentilla emarginata*, with *Draba alpina*, *D. fladnizensis*, *Papaver radicum*, *Saxifraga* spp. and others. This is also the type of vegetation occurring on nunataks, isolated mountain peaks not covered by the inland ice.

As Warming remarks (28, p. 257), the term "Fjældmark" covers a very wide field, which probably should be subdivided, if sufficient knowledge were available, into a number of different vegetation types, corresponding with differences of habitat and climatic conditions. It is obvious that in such open vegetation only those plants occur which can stand the conditions and whose seeds have been carried there at a time when germination was possible. Growth of individuals is exceedingly slow, and its early stages very critical. Though it is possible that in the course of a long time a stable condition might be reached, in which the vegetation had attained its maximum possible development, probably in practice one cannot decide whether this has occurred. The number of plants which could exist under the extreme conditions is probably large, and their actual arrival and establishment very much a matter of chance. As an example, one may take Warming's (27, pp. 84-6) lists of plants found on three nunataks in south Greenland, all 4000-5000 feet above sea. One species only is common to all three of these. In general, one may say that almost any species may occur which is found in the first stages of the succession under similar edaphic conditions at lower altitudes.

(2) *Moss bogs*. Porsild (18, p. 226) describes these as occurring on Disko

(i) in gneissic soil in hollows of uneven basalt surfaces;

(ii) on horizontal undrained terraces of the trap rocks: here the bog occurs at even higher altitudes than the heath;

(iii) on broad foreshores of the trap rocks as the last phase of vegetation after the heath: for this there must be a layer of humus thick enough to stop the water, or a subsoil of gneiss or tuff. Here bog attains its most vigorous development;

(iv) on horizontal moraine soil.

They are developed on the gneiss in hollows and on undrained moraine surfaces, but probably never to such an extent as in case (iii) above. The most extensive example of bog on Disko is at the Mudderbugt on the extreme eastern point of the island. Here many valleys have their outlet to the sea and a large flat area of land with a broad sandy shore has been formed. In places this is bordered with salt marsh and dunes, but most of it is covered with bog, which has the characteristic form of isolated hummocks or ridges covered with heath plants, separated from each other by water or wet moss. The hummocks may be two or even three feet high, they appear to consist of an accumulation of plant remains and are largely covered with mosses near the water level. They are presumably kept separated by the flowing off of drainage water in the spring; as the summer advances the water between the hummocks evaporates or slowly drains away, and incidentally forms a breeding place for swarms of mosquitoes which are very trying to the traveller on a hot day in July. At Skansen the writer noticed a case where the water between such hummocks drained away almost entirely, and the intervening space was covered with a close crust of liverworts (*Gymnomitrium* etc.), or was becoming

overgrown with phanerogams. At Godhavn in such a crust of small liverworts a number of seedlings of heath plants were noticed, and also developing bulbils of *Lycopodium selago*. Whether the vegetation at Skansen had its origin as a continuous moss bog is difficult to say; it seemed to be in process of transition to heath, probably owing to the presence of sand all round it.

Rikli (24, Taf. 46) describes these moss bogs in some detail as regards their probable development. The initial moss cushions may be composed of numerous species, though according to Porsild the mosses of moist localities are less mixed than those in drier situations. Species of *Sphagnum* occur, but never dominate in arctic Greenland; in the south thick *Sphagnum* carpets are sometimes found. The first phanerogam to appear is often *Salix groenlandica* (And.) Lundstr., its horizontal stems half buried in the moss, bearing the conspicuous deep red-purple upright inflorescences. Various Carices also occur, forming compact cushions (*C. alpina*, *C. rariflora* and others), small species of *Juncus*, and occasionally the two common species of *Eriophorum* (*E. polystachium* and *E. scheuchzeri*). *Ranunculus nivalis*, *R. lapponicus* and several species of *Pedicularis* are frequent. These various plants begin to form, with the mosses, compact cushions; their dead remains from previous seasons accumulate, decay being exceedingly slow. On the raised parts of the bog so formed plants requiring less moist conditions can develop. The first of these is almost invariably *Salix glauca*, or a hybrid between this and *S. groenlandica*, and this plant remains at the top of the hummock. Later the ordinary heath plants can gain a footing, and at the Mudderbugt nearly all are commonly represented. The raised parts of the soil consist essentially of masses of raw humus penetrated by the roots and stems of living plants.

The essential characteristic of the habitat in these cases seems to be wet undrained soil; the fact that it is undrained is due to underlying impermeable soil or rock, or to an accumulated mass of wet peat which is frozen at no great depth. If there is any considerable depth of soil it is frozen at a depth of about 60 cm. on Disko; in any case the soil is cold as compared with that of the heath, or with well-drained slopes in sheltered situations where herbaceous plants of a less resistant type predominate. Porsild (18, p. 106) suggests that the origin of the raised parts of the bog vegetation on the Blaesedal moraine was due to the daily deposition of seeds which would accumulate on windy days on the wet edge of the melting snow as it retreated up the slope. This might account for the observed development of the raised parts of the vegetation more or less in parallel lines at right angles to the line of greatest slope of the surface. (This is the case only on gently sloping surfaces.)

(c) *Willow scrub (post-climax)*. As previously mentioned, this vegetation occurs only in specially favourable situations, the most important factor being adequate snow cover in winter, affording protection from cold dry winds which kill off shoots projecting above the snow surface. The best development

of scrub is along the sides of streams, where there is the necessary protection, and more rarely on the borders of lakes. Sometimes also it occurs on well-established slopes below steep faces of the trap rocks, or in sheltered spots on the gneiss as at Englishman's harbour, Godhavn. In the latter case the willows often assume an espalier form if the protection is not good, growing spread out flat against the rock surface. On Disko this type of vegetation occurs very little except in Diskofjord and at various localities along the south coast. On the Nugsuak coasts the present writer saw bushy willows only in very few localities; the largest were by the bed of a stream near Ata where the highest shoots were about one metre from the ground, but in no place did such bushes cover any considerable area.

In the vigorous willow scrub in Diskofjord there is little undergrowth, the soil consisting of black damp humus completely shaded in the summer. This condition is modified in the northernmost recorded area of willow scrub in west Greenland, namely that described by Porsild (20, pp. 356–60) at Orpik in Lakse Fjord (about 72° 30' N. Lat.) where an undergrowth was universally present consisting of grasses such as *Poa pratensis*, *Trisetum* and *Hierochloe*, also *Pyrola grandiflora*, *Stellaria longipes*, *Saxifraga* spp., *Campanula rotundifolia*, *C. uniflora* and other herbaceous plants, with mosses in the more shady places. "All the herbs are higher and more slender than those occurring on the heaths, but there is light enough to permit the development of flowers and fruit; for instance *Pyrola* is, if possible, larger flowered in the copse than on the heath. In open places pure growths are met with, usually of high, slender plants of *Equisetum arvense*, richly branching and as green as the woodland forms of Europe; or there are small meadows of *Poa pratensis*, and along the river there are enormous meadows of *Chamaenerium latifolium*, or where a small stream branches off from a bigger, pale green patches of *Mniobryum albicans* together with *Marchantia polymorpha*." Here in the interior of a fjord, a thick even covering of snow is possible over large areas, as the winds are never as fierce as on the coast. Even the dwarf birch grows obliquely upwards, with leaves evenly arranged on all sides of its branches. In the heath "*Cassiope* sends straight upwards whole bunches of shoots, closely set with white flowers; *Ledum* has larger leaves and richer inflorescences. And above all these *Hierochloe* and *Arctagrostis* protrude, the latter attaining a height of 80 cm....There are far fewer mosses at the bottom between the heath plants than in the basalt regions; but in the small damp depressions there occur, in strong contradistinction to what is the case on the basalt substratum, quantities of *Sphagna*—white, grass-green, wine-red, and nut-brown."

In more southern parts of the coast there are various records of willow scrub reaching 2½ metres in height, but according to Rosenvinge (25, p. 121) this is exceptional even in the extreme south. Warming (27, pp. 30–33) gives a description of willows reaching this height near Holsteinsborg (67° N.).

Amongst the willows grew *Archangelica*, which obviously produced ripe seeds, as young plants were abundant. Other herbaceous plants also occurred, all taller than when growing in the open. In the soil a number of earthworms were found; these are probably always present in such situations, but in the open heath were searched for in vain.

Herbaceous vegetation (Urtemark). In localities similar to those in which scrub of *Salix glauca* occurs and often bordering on it, one encounters a more or less luxuriant growth of herbaceous plants which are not hardy enough to stand the conditions prevailing in more exposed situations. There seems no reason why scrub should not develop on the ground covered by these plants, and the herbaceous vegetation is therefore considered as a stage in the succession to scrub. There are cases, however, quoted by Warming (27, p. 38), in which this type of vegetation occurs higher up on mountain sides where there is no willow scrub; climatic or other conditions here cause the arrest of the succession.

The herbaceous vegetation is particularly remarkable in the vicinity of the "warm" springs of south Disko. These have a fairly constant temperature at their source of 12–14° C., winter and summer alike. Their course is usually marked by a luxuriant carpet of *Mniobryum albicans*, often accompanied by thick mats of *Marchantia*. Close to the springs there occur a number of plants whose normal range of distribution lies farther to the south; on Disko they are entirely confined to these localities. With them are plants which are at or near their northern limit but which can also grow away from the springs in sheltered sunny places. The most conspicuous of these plants are *Archangelica officinalis* and *Alchemilla glomerulans* Buser; the former is quite confined to the warm springs, while the latter occurs nowhere else so abundantly as here.

The most remarkable of these favoured localities from the point of view of variety and luxuriance of growth of the herbaceous plants is the strip of land bordering the small bay called Englishman's harbour, lying close to the entrance to the harbour of Godhavn. The writer visited this place on July 19th, 1921, and some description of it may be appropriate here. The bay lies at the foot of steep gneiss rocks which rise to a height of perhaps 250 metres. Above the gneiss are steep terraces of basalt, and at the junction of the two the springs appear, reaching the sea at the western end of the bay; at the east end is a second smaller spring. The beach is composed of rolled boulders and shingle among which the only vegetation consisted of a few plants of *Mertensia maritima*. The most considerable flat piece of ground is towards the east end of the bay where on a wet black peaty soil was a quite closed vegetation. *Alchemilla* was everywhere, and in some places dominant, as was also *Equisetum arvense*. There were also numerous plants of *Archangelica*, with inflorescence shoots a metre high, though only just in flower. *Luzula parviflora* also is a very characteristic plant both here and by the warm springs in the Østerdal near the Arctic Station. In other places there was a consider-

able growth of *Epilobium hornemanni* with occasionally *E. lactiflorum*, and in certain areas numerous spikes of *Habenaria albida* and *H. hyperborea*, particularly of the latter which when in full flower reaches nearly a foot high. Where the taller plants were not so abundant smaller species were more noticeable, particularly *Pinguicula vulgaris* and *Thalictrum alpinum*; a few specimens of *Listera cordata* were found. A striking feature of the vegetation was the presence of numerous ferns; *Aspidium lonchitis*, *Dryopteris linneana* and *Cystopteris fragilis* were all abundant.

On sloping banks among the rocks where vegetation had become established perhaps the most universally present plant was *Polygonum viviparum*, though sometimes nothing was to be seen but the large leaves of *Alchemilla*. *Habenaria albida* was very abundant in some places and also *Taraxacum* sp., with *Sibbaldia procumbens* as undergrowth. Among these *Dryopteris* sent up young leaves, and *Gnaphalium norvegicum* showed in places its grey hairy leaves and black unopened flower buds. Grasses never dominate, but several species occur, notably *Poa*e, and *Phleum alpinum* in the wetter parts. Large bushy willows were everywhere among the rocks, but even here the more prominent young shoots are killed in the winter, so that the bushes have somewhat the appearance of a trimmed hedge.

Porsild (21, p. 255) says that much of the ground here is never frozen. In the winter when the air temperature outside may be -30°C . the temperature of small pools of water among the vegetation under the snow may be as much as 17° . Only a few rocks project through the snow which otherwise covers everything, and "up through the snow layer in the warmest places chimney-like holes are formed, through which warm and damp air as from a greenhouse streams to meet one." Earthworms occur in the soil.

In the paper just referred to Porsild describes a second locality, Østerli, a slope beneath masses of tuff on the east side of Østerdal, behind the Arctic Station; and in the Østerdal, a little higher up, occur more warm springs, with attendant carpets of *Mniobryum albicans* and much ground covered with *Alchemilla*. On the Østerli low bushes of *Salix* in many parts cover the slope almost to the top, but in other places there is an almost purely herbaceous vegetation. Here at the end of August *Epilobium angustifolium* comes into flower, and careful search among the larger plants reveals small specimens of *Botrychium lunaria*. Almost pure patches of *Gnaphalium norvegicum* are found.

At both Østerli and Englishman's harbour Porsild has placed notices asking the natives not to pull up any of the plants or gather turf for fuel, and this request has been respected, so that these interesting patches of vegetation are being carefully preserved.

(d) *Special edaphic formations.* (1) *Salt marsh.* This is very restricted in its occurrence, and is usually confined to localities where lagoons are formed behind sand banks, as on the delta at Ata. The bottom of the Ata lagoon is formed of muddy silt held together by a continuous crust of a blue-green alga

(a) Heath on gneiss, Godhavn, with *Cassiope tetragona* (below) and *Empetrum nigrum* (on right). Climax type.

(b) Bog near Godhavn, with hummocks covered by *Salix glauca*.

HOLTTUM—THE VEGETATION OF WEST GREENLAND.

(*Microcoleus* sp.). All round the edge of the water, and even in it at low tide, was a thick mat of *Glyceria vilfoidea*, which in such situations is always quite sterile. A little farther from the lagoon the *Glyceria* mat was invaded by small Carices, *C. ursina* and *C. salina* v. *subspathacea*; in places *C. ursina* became dominant, accompanied by *Stellaria humifusa*, a little *Glyceria* and mosses. The most luxuriant vegetation occurred along the small water courses which drained the marsh. Where the plants grew more thinly, on wet mud near the dune bank, *Triglochin palustre* was exceedingly abundant. It was mostly sterile, but obvious from the dark olive green of its tiny leaves, which were only about 5 cm. high. On each plant was already formed a comparatively large underground winter bud. Not far inland from the lagoon the salt marsh proper passed gradually into the previously described fresh water marsh. *Dupontia fisheri* was dominant here, with much *Carex stans*, and with these were associated the species of *Eriophorum* and *Equisetum*, and *Salix glauca*. On a small adjoining area *Carex glareosa* was dominant, with *C. ursina*, and thick patches of *Ranunculus hyperboreus*.

The most characteristic salt marsh plants in this part of Greenland appear to be *Glyceria vilfoidea*, *Carex glareosa*, *C. ursina*, *C. salina* and *Stellaria humifusa*. *Dupontia fisheri* is a high arctic type, and has its southern limit on north Disko.

(2) *Nitrophilous vegetation round settlements*. In the neighbourhood of all settlements a good deal of nitrogenous animal refuse accumulates, and the vegetation responds to this in a remarkable way. Certain grasses, notably *Alopecurus alpinus*, develop to an enormously greater extent than under normal circumstances and form a close vegetation of thick tussocks. In most places where there are long-established settlements *Alopecurus* has entirely the upper hand and itself covers nearly all the ground, though in some places, as often under bird cliffs, *Glyceria distans* forms similar tussocks. Other plants which commonly occur are *Cochlearia officinalis* and *Cerastium alpinum*. Round the Arctic Station it was very noticeable that many other grasses responded to the same stimulus, *Phippisia algida* and *Festuca ovina* for example growing into tufts many times larger than on poorer sandy soil. The sites of old settlements, long uninhabited, are still marked by the presence of thick growths of *Alopecurus*. Hartz (6, p. 58) records a number of introduced weeds round the settlements of Christianshaab and Ritenbenk, many of them growing vigorously and flowering. Among these were *Polygonum convolvulus*, *Stellaria media*, *Galium aparine*, *Chenopodium album*, *Sinapis arvensis* and *Poa annua*.

B. SOUTH OF THE REGION OF *BETULA ODORATA*.

South of about 62° N. Lat. birch-willow scrub occupies considerable areas, and must probably be considered as the climatic climax vegetation. Heath and grassland are also very extensive, and are probably in many cases stabilised pre-climaxes due to local conditions of soil, altitude, and exposure.

The scrub, consisting of *Betula odorata* Bechst. v. *tortuosa* Rgl. with the associated bushy species *Salix glauca*, *Alnus ovata* (Schr.) v. *repens* Lange (occurring also in *Salix* scrub as far north as 68°) and *Sorbus americana*, is usually very thick, and rarely up to a man's height. On level ground especially, where there is less shelter, the upper surface of the bushy layer is very even, and no doubt determined by wind and snow-covering. In the most sheltered inland valleys only do larger tree-growths of birch occur. In Tasermiut fjord some specimens attain 6–7 metres in height, and *Sorbus* nearly 4 metres. The birches never grow straight upright with one main trunk; several branches appear about the soil level, and some of these are usually prostrate at the base. Here also, as in the willow scrub farther north, where the birches are not too thick, grasses and other plants occur as undergrowth. *Juniperus communis* v. *nana* Hartm. is common in this region, but does not usually form bushy growths; specimens as old as 400 years have been recorded. In connection with the natural vegetation of this region it is interesting to note that seeds of *Picea excelsa* were sown in Agdluitsok fjord (60° 30' N.) in 1846, and in 1886 three specimens collected had only reached one metre in height.

In this region willow scrub occurs in moister and less sunny places than birch scrub, though *Salix glauca* is usually present in the latter. Though it may attain 2½ metres, the scrub is normally not more than half that height. Often the bushes grow very thickly, and the ground vegetation is of mosses only (*Hylocomium* etc.), but where they are more open herbaceous flowering plants occur, grasses often predominating, especially *Anthoxanthum odoratum*, *Aira flexuosa*, *Phleum alpinum* and species of *Poa* and *Festuca*. Willow scrub here may be found up to 1400 feet above sea-level.

On sheltered slopes a herbaceous vegetation, mainly of grasses, is probably an early stage in the development of scrub. The number of species occurring is said to be considerable, with no definite dominant. In drier soil on less sheltered plains *Anthoxanthum odoratum* and *Aira flexuosa* are the characteristic species, with a few other plants, including *Leontodon autumnale* and *Taraxacum* sp. Such grassland may occur up to 1200 feet above sea-level, and provides pasture for the sheep and cattle which in this part of Greenland alone can be reared. In Tasermiut fjord *Nardus stricta* replaces *Anthoxanthum*.

The character of the heath and fell-field in the south is much the same as farther north, but the distribution of these types of vegetation is more restricted. Species like *Papaver radiculatum*, *Silene acaulis* and *Dryas integrifolia* are here confined to the most unfavourable situations, the competition elsewhere being too severe.

The nitrophilous vegetation round the settlements is also the same, with the addition of other species, particularly *Rumex acetosa* and *Matricaria inodora*. As in the north, a similar vegetation is found to persist on the sites of old habitations. This is especially interesting in the case of the ruins of the former Icelandic colonies, some of them dating from the tenth century,

and probably uninhabited for at least 400 years. Here still grow plants which must have been introduced by the Norsemen, such as *Polygonum aviculare*, *Stellaria media*, *Capsella bursa pastoris*, *Poa annua*, *Vicia cracca*, *Achillea millefolium*. These plants never grow beyond the limits of the old settlements. It is possible that some of the plants now common in south Greenland may have been introduced in the same way, and Rosenvinge suggests that this may be the case with *Leontodon autumnale* and *Anthoxanthum odoratum*.

(5) GENERAL CONSIDERATIONS WITH REGARD TO THE
CONDITIONS OF PLANT GROWTH.

The principal factor controlling the nature of the vegetation, especially in the south, is the oceanic climate, with its short and comparatively cool and damp summer. This causes the vegetation over a long stretch of coast to be very uniform in character, and leads to the accumulation of raw humus, giving heath as the climatic climax; this is further accentuated by the non-calcareous nature of the rocks from which the soil is formed. The July isotherm of 10° C., which is approximately coincident with the northern tree limit, just touches the south of Greenland, and here alone is anything in the nature of tree growth possible. The only important arborescent species is *Betula odorata*, which is characteristic also of the tree limit in the oceanic climates of Iceland and Scandinavia. In favourable situations, however, though no tree growth is possible, considerable vegetative development during the short summer may take place, even as far north as 73°; in more exposed situations the amount of growth in a single summer is very restricted.

In such exposed situations the xeromorphic character of most of the plants is very marked. This is particularly the case with the evergreen woody plants of the heath such as *Empetrum* and *Cassiope*. These must be protected from loss of water by transpiration when the activity of their roots is completely suspended owing to the freezing of the ground; hence the need for their narrow leaves with recurved margins and protective hairs. In summer these characters are probably of service in the drier habitats, as for example on the sandstone, but in most places the presence in the heath of larger leaved plants such as *Salix glauca*, whose transpiration must be considerable, would seem to indicate that such extreme protection against drought is not essential at this season. *Salix* and *Betula* are of course deciduous, and so avoid the possibility of severe loss of water in the winter or spring when the ground is still frozen or very cold. Rosenvinge (25, p. 193) remarks that *Empetrum* in south Greenland does not grow in situations which are exposed to the winter "foehn," which may melt the snow cover from above the heath plants while the ground is still frozen. The root development of *Salix glauca* is often very considerable, a specimen collected at Atanikerdluk possessing a main root nine metres long. The ground is always frozen at a depth of at most a metre almost everywhere, so that long roots are horizontal. Those of the

evergreen plants are not so extensive, but some of the herbaceous plants, such as *Papaver* and species of *Potentilla*, have very long roots, corresponding with their relatively greater transpiration. The extensive development of fresh green flowering shoots of *Chamaenerium latifolium* in numerous apparently arid localities shows that in many places where heath may be formed there is no need for xeromorphy during the summer.

For ability to withstand low temperature the internal organisation of the plant must be responsible. It may be that the formation of anthocyan pigments in the leaves of practically all plants, both in spring and autumn, is of value in this connection. The habit of growth of the heath plants affords protection against desiccation by winter winds rather than against low temperature alone.

Mycorrhizal fungi are present in the roots of most of the common plants. Ectotrophic mycorrhiza occurs in the case of *Betula*, *Salix*, *Polygonum* and *Dryas*; endotrophic in the Ericaceous plants and *Diapensia*. This may be connected with the fact that decomposition of humus in the soil is exceedingly slow, and available nitrogenous compounds correspondingly limited. It is characteristic of all the cushion plants, for example, that dead leaves remain attached to the short stems for many years before they are decomposed.

Little work has been done on the germination of seeds in the arctic under natural conditions, though this is a matter of very great importance in the study of the development of vegetation. Porsild has made numerous observations on the ripening of seeds and the occurrence of seedlings, but these are not yet published. Hart (5, pp. 74-5, 306, 342) observed no seedlings at Discovery Bay (81° 42' N. Lat.) and concluded that no ripe seeds are produced, and that spreading of plants was exclusively vegetative, or at most due to the chance importation of ripe seed from farther south. He grew seedlings of wheat, peas, mustard etc. under a glass shelter at a temperature of about 33° F. Some of the wheat seeds had been exposed to four successive winters at that latitude before being sown, but were quite uninjured. Apparently ripe seeds from herbarium specimens collected by Hart would not germinate, but the trial was not made till four years later.

Kjellman (10, p. 480) observes that in northern Siberia 85 out of the 150 species collected on the voyage of the *Vega* had ripe seeds, and of the others some were probably only found too early in the year for the fruits to be mature.

Cleve (3, pp. 101-3) in a paper on the alpine vegetation of Sweden includes a short section on this matter. He concludes that a large proportion of arctic and alpine plants produce ripe seeds, but that it is usually necessary for these to rest at least over one winter before they are capable of germination.

Porsild (19, p. 273) says that seeds of many of the plants of west Greenland mature under the snow, and that if gathered in the autumn they are not properly ripe. Some of the plants which are beyond the normal northern limit of their distribution produce no ripe seeds, and this is also the case for most

of the aquatic plants. The present occurrence of these types may represent patches of a once continuous distribution in a somewhat warmer climate subsequent to the glacial period.

The most important agent in the dispersal of seeds is the wind blowing over the surface of the snow and sea ice in winter. Porsild gives a list of plants not occurring on Hare Island (19, p. 268); these plants are all distributed by the wind in winter, and have not reached Hare Island because strong tidal currents prevent the formation of continuous sea ice between it and Disko. Plants which are completely covered by snow in winter cannot have their seeds dispersed in this way; they are mostly of southern type which only form seeds, if at all, quite at the end of the season, so that they have little chance of spreading more than short distances, whereas the localities in which they can flourish are often few and far between. Another important factor in seed dispersal is the water from melting snow in the spring.

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