SOME BOTANICAL PROBLEMS OF THE ARCTIC AND SUBARCTIC REGIONS*

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THE arctic and subarctic problems dealt with in this paper are primarily botanical. However, they are of such a nature that they require delving into many other phases of natural science, particularly surface geology, meteorology, and human geography. Consequently such problems as are suggested will have repercussions in these fields as well as in the broad field of biology. Within the field of biology my personal experience has been primarily in the study of vegetation, so that the problems I suggest will, inevitably, be weighted in that direction.

The solution of many problems in boreal biogeography will yield valuable and practically useful information for many purposes, civilian and military. The significance of these problems in the extensive use of arctic and subarctic lands by human populations lies first in the evidence they can give of the major geographic patterns or natural areas in the boreal regions. It is upon these major patterns that the outlines of use must eventually be based. This is an old concept which has been used with varying degrees of intensity and precision during the opening of the Western Hemisphere to European occupation, and the idea is still a good one. Its application is no longer simple, however, and in the hands of modern, highly trained specialists it can be badly misused. In earlier times it was successfully applied by broadly trained naturalists such as Douglas, Richardson, Macoun, and many others. It depends for its successful use upon what might be called correlative thinking in the natural sciences, and this type of thinking has become rather rare in these days of extreme specialization.

A second system of application is a refinement of the first. It involves the use of the natural vegetation in its relationship to local environments to indicate the cultural capabilities of the land. A third application is of large military significance. It involves the use of vegetation as an indicator of the "kind of ground".

All of these applications of botanical science to the intelligent use of the land depend upon a knowledge of the vegetation in all its aspects. Such knowledge is still in its infancy for most of the arctic and subarctic regions.

It is possible to make a general subdivision of northern vegetational problems into two groups, though the division is not a natural one and is to be used only for convenience.

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Floristic problems

The basic floristic problem in boreal North America is the development of a comprehensive, descriptive flora, with keys and illustrations which will aid in the identification of plants. No such comprehensive flora now exists. The last one attempted was more than a century ago. At present we are dependent upon regional lists of species, and upon a great mass of miscellaneous papers embedded in periodical literature.

The Eastern Arctic is pretty well covered by Nicholas Polunin's 'Botany of the Canadian Eastern Arctic,' Parts I and II. These papers cover the region from northern Ellesmere south to the 60th parallel. They do not, however, cover the Western Arctic islands or go much beyond the western coast of Hudson Bay, and they do not include Greenland.

My own published work covers the central and southern portions of the Mackenzie drainage basin. In the western parts of boreal America the only comprehensive work is that of Eric Hultén on the flora of Alaska and Yukon. This has been published in parts, and is now complete. The final part of J. P. Anderson's 'Flora of Alaska and adjacent parts of Canada' was issued in April 1952. Of the above papers, only those of Hultén and Anderson contain keys for the identification of the plants. Erling Porsild of the National Museum of Canada has a manuscript flora of the Canadian Western Arctic, and has recently published a critical and comprehensive treatment of the vascular flora of southeastern Yukon adjacent to the Canol Road.

All of these papers are, of course, based upon such collections of plants as have been made to date. They cannot be regarded as complete in any sense, for there are vast areas in boreal America where botanical collections have never been made. Such fundamental field work is necessary in the Western Arctic islands and particularly in the interior portions of all the larger arctic islands. Our present knowledge of most of these islands is based upon collections made at relatively few points on their shores. The same is true of the interior of the Labrador-Ungava Peninsula and the interior of Keewatin. Even south of Keewatin there are large botanically unexplored areas in northern Manitoba and northern Saskatchewan. There are huge areas in western Mackenzie, northern Alberta, northern British Columbia, and Yukon that remain to be explored. The same is true, of course, in Alaska, particularly in the mountain and plateau regions away from the main routes of travel.

The development of plant ranges and patterns of distribution will remain uncertain and incomplete until this exploration is much further along than it is now. In planning and carrying out the work, it is essential that trained men should be engaged in it. The number of persons who have collected plants in boreal America during the past century and a half is legion, but it is safe to say that not more than a dozen of them have been able to do anything that would remotely resemble a comprehensive job. If the amount of money and time that has been spent in this pursuit over the years could have been concentrated in the hands of a few well trained people, the job would have been done long ago.

In order to be a good collector, a man has to know a great deal about plants and the way they differ from one another. This can only be got from training and experience. It has been a prevalent misconception, persisting for generations, that anyone given a plant press could collect the flora. Most of the money and resources that have been spent under this misconception have been wasted. We should set out systematically to cover the area, first on a regional basis. Then all the collected materials and information should be concentrated in one place, or at least in the hands of one man who would be competent to put it together in a usable form.

This project is placed first because it is necessary to produce the grist before the phytogeographic mill can be operated profitably.

The plants which occupy a given spot in boreal America are there because they were available when a place was opened to them, because they had the capacity to move into the place when it became available, because they had the capacity to adjust themselves to the physical and biotic limitations presented by the situation, and because they were able to reproduce themselves there. It is quite obvious that simple analyses of climate and soil will not explain the occurrence and behaviour of the plants that are found in a given place, and it is necessary that the identities and geographic origins of the plants be taken into consideration, as well as migrations and adjustments in time and space.

Vegetation is composed of individual species of plants, each of which has a population that varies widely in numbers from place to place, and in prominence and significance in the total plant cover. Each of these species has had a complex evolutionary history, and now contains genotypes that are the result of this history and of the various vicissitudes that the species has been going through during its history. Within its population these genotypes are commonly not evenly distributed, so that the behaviour of the species in one region will give no indication of its behaviour in another. In one area it may be predominant in numbers and in influence upon the total vegetation, and in another it may be reduced to insignificance. Herein lies a mass of problems in the nature of species—problems that are of fundamental significance to the study of vegetations and ultimately to their significance in the use of the land. Experimental studies in the genetics of boreal species, carried on in the field, are at the base of these problems.

This can be illustrated with the common white spruce, the most important timber tree in the subarctic forest. It is generally recognized as a single species ranging from Newfoundland to Alaska. It contains at least three separate entities which differ in general appearance, in local habitat selection, and probably in the quality of the wood. The most easterly form ranges westward into Saskatchewan, and probably into northern Alberta. It is a tree of moderately drained upland soils and flood plains. Another form ranges through northern British Columbia, northern Alberta, southern Mackenzie, south in the Rocky Mountains, and northwestward into Yukon and Alaska. It is the so-called "Alberta spruce", and has a much wider range of habitat selection than the eastern spruce. I have found it on high mountain slopes, on dry sand plains, and in muskegs. There is a great variety in the quality of its

wood, though, so far as I know, no one has ever made comprehensive tests of these qualities. A third phase of the white spruce grows in Yukon, western Mackenzie, and parts of Alaska. It has only recently been described, and its range and characteristics are only partially known. It appears to be quite limited in the range of its habitat selection, growing on gravelly terraces and glacio-lacustrine deposits. I have also found it on dry south-facing mountain slopes. I think I am safe in saying that nothing whatever is known about its timber qualities, or its genetic origin. Workers in western Alaska are turning up still another spruce, which may or may not be a separate strain.

These spruces are sufficiently well known to indicate a pattern of distribution, and we know that they differ superficially. Beyond this we have nearly everything to learn about them, except that we know the timber values of the eastern form and something of the values of the Alberta spruce. This kind of problem can be multiplied by the hundreds in the boreal flora. In detail it has all the aspects of a problem in pure science, but it can have immediate repercussions in the practical use of the northern lands. It will require for its solution not merely a working knowledge of taxonomy and genetics, but also of the whole gamut of geological and meteorological changes that have affected boreal North America during and since the Pleistocene. Corollaries to it are broad problems of speciation in all of the boreal parts of the world, such as the occurrences and distribution of endemism, polyploidy, apomixis, and the like. The broad outlines of some of these problems are beginning to take form, but we are only at the beginning.

It has been suggested above that the ultimately useful units in the flora may not be the units that will be recognized by the taxonomists who develop the "Flora", because of genetic variations within the species. In key situations, therefore, experimental studies in the nature of certain species should be initiated *in the field*. Some of these experiments will be comparatively long-term affairs, and will have to be established at bases that can be continued for some years. There are plenty of establishments throughout the boreal regions which could be used for such purposes, given funds for necessary adjustments or reorientations.

Men of special training in practical genetics will be necessary for this work. They should be men who are broadly trained in botanical science, rather than one-sided students of plant inheritance, for it will be necessary that they understand something of the broad significance of what they are doing. They must be content to spend long summer seasons at relatively isolated stations. It is only from such work that we will learn how the taxonomist's species have been put together during glacial and postglacial time.

The history of vegetation involves the study of plant fossils which, in the present problem, involves the study of peat. Very little is known of geologically recent peat deposits in the north. One of the reasons for this is that the peat is frozen and cannot be sampled as easily as that in temperate regions. The study of peat deposits in the north involves to a considerable extent an engineering problem. It is essential, however, that it be done if we are to understand the geographic patterns involved and to make them useful.

Problems in plant communities

A second great complex of problems relating to the plant cover is in the study of the masses of vegetation which are made up of the various species. In this field some of the main outlines of geographic distribution have been known for a long time. The boundaries between the tundra and the forest, whether on the northern interior plain of the continent or on the mountain slopes, are relatively well known. One of the great natural boundaries in the world's vegetation is between the northern forest and the tundra. At present, however, this boundary is little more than an observed fact, for we do not have a clear idea of why it occurs where it does. It is presumed to reflect a climatic boundary, but how the climate differs on either side of it, and how the difference affects the growth of trees is very little known.

A primary characteristic of vegetation in the mass is that it is extremely unstable. It undergoes changes which may be due to influences external to itself, such as alterations of climate and soil. It is also affected by the results of its own existence on a given area, because in itself it alters the soils and the microclimates. It is also subject to modification, especially in the arctic and subarctic regions, by the influx of species from other regions, and by the effects upon it of grazing and other animals. The resultant of all these changes, both internal and external, is the vegetation on the ground at any point in time. It follows that the significance of vegetation as an indicator of the kind of ground, or of the usability of the ground for agriculture or silviculture rests upon an understanding of the rate and kind of changes that are occurring. Here are some of the most important problems in the boreal biota, and here again we are only at the beginning of the necessary understanding. Here also are excellent examples of failure due to extreme specialization on the part of field workers. Far too many of the students who have undertaken to use the vegetation for its indicator values in the north have failed to take into consideration its quality of instability.

The difficulties in the use of natural vegetation in the north for its indicator values are manyfold greater than they are in temperate regions, because the very base for interpretation is a new and little understood one. In temperate regions the development of vegetation is very closely related to the development of land forms under the influence of subaerial erosion. The fundamental concept here is the "cycle of erosion" by running water. Land surfaces are uplifted by orographic movements, stream gradients are increased, water tables are lowered, erosion is stepped up, and new flood plain deposits are formed. Vegetation on the uplifted surfaces is altered or destroyed, and develops on new deposits. Other effects related to this occur on beaches subject to wave action, or on dry surfaces subject to wind action. On the aquatic side, ponds and lakes are physiographic features that are made or reduced by surface changes due to erosion. Out of these complexes we have developed what is known as the "physiographic ecology" of vegetation.

In the arctic and subarctic regions subaerial erosion is often a minor factor in the degradation of land surfaces, and the slow movement of surface materials

under the influence of frost is of primary significance. The effects of frost action on the details of surface configuration, and their significance in the moulding of larger surfaces, are just beginning to be known. Each year that geologists work in the Arctic they turn up new aspects of these processes. The development of vegetation there must be related to a developing knowledge of surface changes under the influence of frost. In short, a new brand of physiographic ecology must be written. Botanists are now making a fine beginning in this field.

It was said above that the indicator values in northern vegetation cannot be interpreted from simple observations at given points in space and time, because the vegetation is not a dead blanket, but rather it is an unstable, developing, biotic phenomenon. The whole plant cover of the boreal regions must be studied and interpreted in this light if it is to be significant for purposes other than immediate utilization. Attached to many kinds of parties engaged in field operations, whether they be in photo-interpretation, geological investigations, engineering reconnaissance, or agricultural and forestry reconnaissance, there should be men who are especially trained to interpret vegetational change. These men, again, should not be too highly specialized, for they must have a working knowledge of floristic geographic phenomena, and they must understand the relationships between vegetation and climate and soil. They must have a working knowledge of the evolution of soils and land forms, and of the occurrence and significance of microclimates and of climatic change. Of all the men in the field, these will be the most difficult to find, for our system of training students of vegetation during the past fifty years has not produced many of the kind that is necessary. On the other hand, the study of vegetational change involves many disciplines which can be applied by specialists provided there is adequate direction and correlation.

Arctic vegetation bristles with problems relating to the physiological relations between the plants and their environments. Water relations in arctic vegetation are very poorly understood, as are those involving the availability and use of mineral salts. The nitrogen cycle in arctic and subarctic regions is particularly worthy of investigation. However, I do not believe that these physiological problems should be stressed until much more basic work on the geography of the plant life has been done. A certain amount can be accomplished by men who are versed in the intricacies of such problems and who can be attached to field parties, but far too much physiological work has been done without reference to the basic facts of the identity and natural occurrence of plants. This work now stands alone and probably can never be fitted into a natural context of vegetation. Physiological research on arctic plants must somehow be carried into the field, out of the laboratory. The progress that has been made by the group working at Point Barrow is encouraging.

The use of lands for agriculture, grazing, or timber production in the American north is in its early stages. My own studies indicate that frost and the short growing season in most parts of the Arctic and Subarctic are not so significant in this connection as is the shortage of water. Whoever

attempts to develop northern land should approach the problem with a completely open mind, trying many kinds of plants, in many kinds of sites, and by many modifications of the existing growing conditions.

The following is an outline of problems derived from the above discussion:

Botanical exploration

1. Floristic exploration:
   Western Arctic islands
   Interior of arctic islands
   Interior of Labrador-Ungava Peninsula
   Interior of Keewatin
   Northern Manitoba and Saskatchewan
   Western Mackenzie
   Eastern and northern Yukon
   Northern British Columbia
   Mountains and plateaus in interior Alaska.
2. Description and analysis of plant communities:
   Needs to be done in most of the boreal regions.

Flora of boreal America

3. Preparation of a comprehensive "Flora", with keys and descriptions, preferably illustrated.

Origin and distribution of the flora

4. Preparation of range maps of species.
5. Investigation of genetic variability in species as related to their geographic behaviour in Pleistocene and post-Pleistocene time.
6. Relation of species distribution to development of landscapes.

Origin and distribution of plant communities

7. Relation of development of plant communities to development of arctic and subarctic land forms, particularly with respect to cryoplanation.
8. Reconstruction of post-Pleistocene landscapes, both as to morphology and biota.
9. Investigation of the concepts of "succession" and "climax" as applied to boreal vegetation.
10. Relation of climates, both local and general, to the nature and distribution of vegetation.
11. Effects of man and other animals upon the vegetation.
12. Effects of fire upon native vegetation.
13. Studies of peat deposits and other fossil remains.

Problems in applied botany

14. Sustained yield utilization of native forests and grasslands.
15. Investigation of agricultural expansion.
16. Interpretation of vegetation as an indication of "kind of ground".
17. Interpretation of air photographs for the mapping of natural resources and "kind of ground".