

MYCOLOGY IN THE CANADIAN ARCTIC*

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Introduction and history

STUDENTS of arctic fungi have traditionally relied largely on the practice of gleaning inconspicuous saprophytes from the old stems and leaves of vascular plant specimens brought back by botanists or others. Except for a few conspicuous fleshy fungi, which were often unidentifiable because of inappropriate handling, most of these specimens have been collected unintentionally. This was the way in which Canadian arctic mycology started. First Rostrup (1906) scrutinized Simmons's collections from Ellesmere Island made during the second voyage of the *Fram*. Later Lind (1910) published an account of fungi gleaned from the plants of the *Gjøa* expedition, collected at King Point on the Yukon coast and King William Island; and Dearness (1923) similarly treated the fungi taken on the Canadian Arctic Expedition at various points along the arctic coast.

Lind (1934) added a number of further Canadian records, arctic and sub-arctic, in his discussion of circumpolar microfungi. Linder (1947) made the next substantial contribution to our knowledge of Canadian arctic fungi, but his treatment, although part of Polunin's "Flora of the Canadian Eastern Arctic" was actually limited to those fungi collected by Polunin and did not bring together the available records.

A conspicuous feature of almost all the early records from the Canadian Arctic is the extreme paucity of parasitic fungi. Dearness was impressed by the lack of such fungi and wrote "the smuts, like the rusts, seem to be rare in the Canadian arctic regions". He recorded only one smut and three rusts from the collections of the Canadian Arctic Expedition. Actually these fungi are substantially commoner than the early records suggest. Botanical collectors who have not been coached to look for rusts and smuts tend to avoid them in trying to secure the best-looking plants. It is significant that the only rust secured by Lind from the *Gjøa* collections was *Puccinia oxyriae*. Although this fungus produces conspicuous sori in mountainous regions farther south, in the Arctic the sori are often so small that they may be barely recognizable to the unaided eye; and I have found it only rarely despite diligent searching. Lind's record certainly stems from an accidental collection.

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Methods

With a little briefing on what to look for, a competent botanical collector can bring back excellent material for the mycologist; and we have received effective co-operation at this institution. Briefly, the collector should take ample material of all foliage parasites along with phanerogamic specimens of the plants; include old leaves and flower stalks with plant specimens, since they often bear various microscopic saprophytes; and prepare fleshy fungi by drying them in gentle heat after taking notes on the fresh appearance. For mushrooms he should note the fresh colour of the different parts, and any conspicuous taste, smell or exudation of clear or milky juice. It is also desirable for many groups, and essential for a few, that a spore print be secured. We have developed a simple technique for this process. The stalks of one or more mushrooms are pushed through holes in white paper; the sides of the paper are folded back over the cap and the ends turned down at right angles to form a support that keeps the fruit body vertical; the enclosed mushrooms are then set upright in a paper bag and kept for a few hours in a cool, moist place, after which they are set to dry, still wrapped and in the bags, which provide protection later for shipment.

As in all biological field studies, it is essential that the arctic mycologist should do a substantial amount of his own field work. With complete reliance on other people's collecting he can do little more than record most of the species to be found in his region, with no real understanding of their natural history. Moreover, it has become plain from my own field work that only an experienced mycological collector can expect to secure approximately complete collections. For example, a number of inconspicuous systemic parasites prevent the infected plant from flowering, so that the general collector leaves it behind. Even the mycologist may at first overlook these fungi, but when he once "gets them in his eye" he picks them up repeatedly. The substantial cost of arctic field work requires that the field biologist makes the fullest possible use of his time. As it is generally impossible to keep fully occupied collecting fungi in the Arctic, the mycologist must be prepared to undertake other biological work.

Recent progress

It is curious in view of the several extensive papers that had been written on Canadian arctic fungi that no mycologist visited the Canadian Arctic before 1950 when I spent the summer at Chesterfield Inlet. In fact no other mycologist entered this huge region until 1959.

Shortly after World War II increased activity in the North resulted in numerous botanical collections from the Arctic and Subarctic. Many fungi were secured intentionally or accidentally in these activities. In the course of the Northern Insect Survey, undertaken by the Canada Department of Agriculture and the Defence Research Board of Canada, extensive plant collections were secured from many northern stations. I scrutinized all these collections for parasitic fungi as soon as the plants were identified; but, with

10,000 or more sheets being processed each year for 4 years, the mere removal of and making labels for the parasites took about 6 weeks each year. With the pressure of other work it was quite impossible to find and remove the much more numerous saprophytes; and only a few of the more conspicuous ones were taken. However, I have since returned to a few of these collections and so filled in a few gaps.

Although I spent the summer of 1950 at Chesterfield Inlet with the Northern Insect Survey, my field work for the next few years was in the south and there seemed no prospect of producing a definitive treatment of the arctic fungi. Recently the situation has improved markedly. Dr. Margaret Barr (1959) has published an important paper on the Pyrenomycetes of the Eastern Arctic and Subarctic, based on specimens gleaned from several phanerogamic collections. This paper is important not only for the many records it brings together, but because it provides a taxonomic framework for these diversified organisms that form nearly half the arctic fungus flora. This paper greatly simplifies identification of these fungi by anyone who is not a specialist in this group. A very recent publication of importance to the arctic mycologist is the monograph of Wehmeyer (1961) of *Pleospora* and allied genera. This large and difficult complex is second only to *Mycosphaerella* in arctic species and has caused much trouble both in identification of specimens and in interpretation of early published records.

Prospects

When renewed opportunities for arctic field work arose in and after 1958 it began to appear that a definitive fungus flora might be feasible and we are now committed to such an undertaking.

If we define the Arctic to embrace all the region beyond the northernmost trees, which seems to be the most practical definition for our purpose, the Canadian Arctic comprises more than 900,000 square miles. Tree line in Canada, represented by the limit of spruce, is fortunately a reasonably clear climatic and biological boundary. The mountains of the northern Yukon Territory present a complication, which probably must be avoided by including only the lowland coastal strip. By ignoring outliers of spruce one simplifies the treatment by excluding all the fungi exclusively associated with conifers. One minor drawback of such a treatment is that we cannot expect complete correspondence with the Greenland flora. In coastal southern Greenland, where tall deciduous thickets occur, spruce could certainly grow if the seed had been able to clear the sea barrier from Labrador. Thus southern Greenland, although technically unforested, must harbour numerous fungi that are lacking from the Canadian Arctic as here defined.

Obviously a really detailed geographic coverage of an area of this extent cannot be expected for such inconspicuous organisms as are most fungi. However, by thorough collecting at selected sites and continued scrutiny of plant specimens from various regions, we believe that we can secure records

of almost all species and an accurate distribution pattern of the commoner ones. There will inevitably be rare and inconspicuous species, represented by one or two specimens, whose true distribution will be unknown.

Our coverage has improved encouragingly in the last 4 years. In 1958, accompanying Prof. J. Brian Bird, I studied six sites on Somerset Island and also collected at Spence Bay and Cambridge Bay. In 1959 Mr. J. A. Calder, Dr. Ilkka Kukkonen, and I were able to join the arctic field trip of the IXth International Botanical Congress and did selective collecting at Frobisher Bay, Cambridge Bay, Resolute, and Coral Harbour (from all these points we had already some specimens), as well as at three subarctic stations. In 1960 I was able to work out of Isachsen with the Polar Continental Shelf Project and in 1961 Dr. J. A. Parmelee worked at the Jacobsen-McGill camp in western Axel Heiberg Island. In 1962 I was a member of a group from the Department of Agriculture studying insect ecology at Lake Hazen under the auspices of the Defence Research Board. This is a critical area because its benign summer climate guarantees it to be a northern outpost for many fungi, as it is for many higher plants. It is tentatively planned that in 1963 Dr. Parmelee and I shall work in the southeastern and southwestern Arctic respectively, completing our personal collecting for this project.

Because arctic mycology is still in a pioneer phase, we must emphasize taxonomy and floristics, which are the ultimate prerequisite for all other studies. We are gradually learning something of the limitations and adaptations of some species, but it is idle to suppose that we are close to a satisfactory understanding of arctic fungi in general. After working at more than fifteen arctic sites and still shedding illusions at each new one, I am painfully aware of how far we still have to travel. It is hoped that in future years, either at northern laboratories or with simulated arctic conditions in the south, more elaborate mycological studies will be undertaken.

Characteristics of arctic fungi

As we might expect from our knowledge of the flowering plants, the arctic fungus flora is largely a mosaic of alpine and temperate elements, both palaeartic and nearctic. Although some species are almost confined to the Arctic, I know of no genus except the monotypic *Arcticomyces* (which extends south to Great Whale River and also occurs in Iceland) with such a distribution. Thus, the twenty or so species of *Pleospora* recorded in the Canadian Arctic represent most of the sections of that vast genus and many of the closely related smaller genera are also represented.

We are gradually learning some of the adaptations of fungi to the arctic environment. Most of the limitations and adaptations of the rust fungi have been clear for some time (Savile 1953). The long-cycled heteroecious rusts, so abundant in the temperate zone and exemplified by *Puccinia graminis* with aecia on barberry and with uredinia and telia on cereals and other grasses, are left behind at about tree line. Even just inside tree line they generally occur only if the alternate hosts are contiguous, for the short

season prevents enough build-up of spores to allow distant plants to be infected with any certainty. Only if it has some device to allow it to persist on a single host, as has *Melampsora epitea*, which occurs in various races on *Saxifraga* and several willows, can a heteroecious species persist in the Arctic. As we progress north and northwest toward the severer parts of the Arctic we find that the rusts that are left have only a single spore state, there being barely time for a single spore generation in the year, so that long-cycled rusts would lack time to produce the overwintering telial state. Finally, in the severest sections with a very short and cold summer, we find that most of the few rusts and other obligate parasites have a systemic mycelium that persists in the crown of the host plant. Here we have a close analogy with the perennial flowering plants. Annual plants are lacking in the High Arctic because they are subject to elimination in disastrous summers when they could not set seed, but perennial species are not seriously affected. Similarly the parasites with localized mycelium may be eliminated in poor summers unless the host produces at least a few evergreen leaves on which the overwintering mycelium may fruit in the next year (e.g., *Puccinia heucherae* var. *saxifragae* on *Saxifraga nivalis*); whereas survival is guaranteed in a species with a perennial mycelium.

Among the saprophytes and hemiparasites (those that invade living tissue but mature on dead tissue) we find a tendency to simplify the life-cycle similar to that seen in the rusts. Thus, Pyrenomycetes with associated conidial states are much rarer than in temperate regions. The reduced value of accessory spore states is obvious, but the mechanism is not yet understood. Is the suppression purely physiological or are these northern forms of such fungi genetically distinct from their more southern counterparts? There is reason to believe that some of these fungi may have split up into races that are either wholly ascigerous or wholly conidial.

The dominance of the Pyrenomycetes among the saprophytic fungi seems to be due in part to an ability to halt development at any stage with the onset of winter and resume it in the spring. Thus at and near Isachsen, despite very cold summers and an exceptionally depauperate flora (49 species of vascular plants), 38 species of Pyrenomycetes were reported out of a total of approximately 85 species of fungi (the total is uncertain because of a few unresolved taxonomic problems). This substantial total is evidently owing to these fungi being able to take 2 to 3 years to mature their ascocarps. The extremely slow bacterial decay of plant parts keeps the tissues available to the fungi until their spasmodic development is completed. We have here an analogy with a behaviour pattern of some arctic insects, which take 2 to several years to complete their larval development (references in Downes 1962), or with some mosses whose indeterminate growth allows them to persist in areas covered with snow regularly for most of the summer and occasionally for all of it.

Our understanding of the dispersal of fungi in the Arctic is developing more from inference than from direct observation and experiment. There is no problem in visualizing the dispersal of a species such as *Cladosporium*

herbarum that produces great quantities of air-borne spores and can grow on dead parts of almost any flowering plant. With strictly host-limited parasites and hemiparasites the chances of spores landing on the host plant become progressively less as the plants become more widely separated toward the edge of their range. Yet sometimes such fungi are found where their hosts are extremely scarce. At Isachsen only single small colonies were found of *Arctagrostis latifolia*, *Polygonum viviparum*, and *Taraxacum lacerum*. Even if future collecting shows these plants to be rather more widespread in the northwestern Arctic than they are now known to be, yet they will still present infinitesimally small targets for fungus spores whose abundance is limited by restriction to a scarce host. *Wettsteinina macrotheca* or some closely related fungus (poorly developed spores make its identification doubtful), which has not been found in the High Arctic on any other host, occurred on *Arctagrostis*. *Wettsteinina eucarpa*, a distinctive fungus confined to *Polygonum viviparum*, occurred sparingly in the Isachsen colony. *Mycosphaerella taraxaci*, which occurs mainly on *Taraxacum* but occasionally on other Compositae (none of them collected within hundreds of miles of Isachsen), occurred on two plants at Isachsen. *Mycosphaerella taraxaci* does have a conidial state with air-borne spores, but for the spores to blow from distant colonies in such numbers as to land on a few small plants growing alone in many square miles would require a staggering spore production. The other two fungi have no conidial state but produce only ascospores, which are forcibly discharged from the ascus and travel only a few millimetres unless caught in an air current. It is inconceivable that great numbers of such spores should be carried aurally. Ascospores generally stick to whatever they strike when discharged; and large pigmented spores, such as those of *Pleospora* and *Clathrospora*, may be seen in numbers under the dissecting microscope attached to the leaves and stems of the plants on which they were produced. It is believed that the spores of these fungi are spread largely by sticking to the seeds or other disseminules of their host plants; and that they either are carried as attached spores or germinate and grow into the tissues so that they may even survive ingestion of seeds by birds.

Among other microfungi recent collecting has demonstrated some remarkable extensions of known range. *Acrospermum compressum*, widely known in temperate Europe and North America, has been found since 1958 at Great Whale River, Coral Harbour, Aston Bay, eastern Banks Island, and Isachsen. *Isariopsis albo-rosella*, which causes a leaf-spot of *Cerastium* in temperate regions, is now known (growing diffusely on old leaves) from Coral Harbour, Victoria Island, Somerset Island, and Isachsen. *Niesslia pusilla*, known from temperate Europe and North America and as far north as McLellan Strait in northeastern Quebec, was collected twice at Isachsen. *Coremiella ulmariae*, a very inconspicuous hyphomycete known only from temperate Europe, has been found at Isachsen. It seemed worth scrutinizing the Isachsen collections particularly thoroughly, both because the small flora made it practicable to do so and because of the realization that a fungus that can grow at Isachsen can grow near sea-level in any ice-free part of the

archipelago. Obviously the records of such inconspicuous fungi must be treated with caution. If the scrutiny of the more southerly plant collections had been delayed, these records from Isachsen might have been used by the incautious as evidence of a refugium in the northwestern islands. What these records do show is how much hard work lies ahead in filling out the distribution patterns of arctic fungi. For low-arctic stations, with many more vascular plants to be scrutinized and with a much larger fungus flora, the task of securing complete collections of fungi becomes extremely time consuming.

Through working substantially with specimens from some of the severer parts of the Arctic, from Meighen, Ellef Ringnes, and Borden islands, down to Cornwallis and Somerset islands, I have become increasingly aware of saprophytic fungi occurring occasionally on the "wrong" hosts. Thus *Diplodina papaveris*, which occurs abundantly on various dicotyledons, has been found once on *Festuca brachyphylla*. *Hendersonia arundinacea* and *Pleospora longispora*, typically on grasses, and *Leptosphaeria caricinella*, *L. eustoma*, and *L. insignis*, which occur on grasses, rushes and sedges, have been found occasionally on several dicotyledons. This phenomenon is perhaps due indirectly to the meagre bacterial breakdown of dead plant parts. Old stems and leaves generally persist for at least 3 years. During this time they may become substantially leached of phenolic compounds and other selective inhibitors, so that little but a carbohydrate substrate remains. Thus, spores discharged from a normal host on to dead parts of an adjacent anomalous host may have a good chance of establishing the fungus.

Arctic botanists are familiar with a phenomenon whereby the species of some genera, notably *Potentilla* and *Draba*, mature their fruits while the plants are morphologically immature, which greatly complicates identification. Rather similar situations are found among some arctic fungi. Unfavourable conditions cause most puffballs and mushrooms to be small in the High Arctic and progressively larger in the Low Arctic and Subarctic. This effect seldom causes much confusion, but in extreme cases some mushrooms produce their spores while the fruit-bodies are so immature in morphology that it may be impossible to distinguish closely related species.

A comparable situation exists also in some microfungi. Thus, the ascocarps of many Pyrenomycetes tend to be smaller in the Arctic than in the south. A substantial reduction in the size of the ascocarp may cause a reduction not only in the number but sometimes in the maximum length of the asci. Since the spore size is generally relatively constant, a reduction in ascus length means that the spores tend to be crowded in the ascus, and the ascus width may therefore be increased. I have found that for several species the ascus widths in the Arctic are substantially greater than in the south. Then we often must rely almost entirely on spore characters to separate related species.

Fortunately the effect seems to be rare, but we have recently seen evidence that unfavourable conditions in the Arctic may affect ascospore morphology, a situation that would greatly complicate taxonomy if it occurred frequently. It has been found that *Pleospora scrophulariae*, and especially

its variety *spinosella*, both of which occur sparingly in the Arctic, may show very variable spore morphology. A strain of the variety *spinosella* occurs, evidently as a hemiparasite, on *Tofieldia*. Many of the ascospores are very small, with only three transverse septa, although the structure and pigmentation of the walls show them to be fully mature. Dr. Barr assigned these specimens, with some misgivings, to *Pleospora kansensis*, an essentially temperate species. However, further examination has shown that in some ascocarps the spore morphology, although constant within each ascus, varies markedly from one ascus to another. In some asci we find only small 3-septate spores, in others 5- to 6-septate spores typical of *spinosella*, and in still others a number of intermediate or curiously aberrant forms. Whether this can be directly a climatic effect seems doubtful. Since the fungus is evidently at least partly parasitic, it seems probable that the effect is nutritional, and that under severe climatic conditions nutrition becomes inadequate before the fungus has passed a critical stage of development. A less extreme modification may be seen in the spores of *Pleospora longispora*, which, if poorly developed, simulate those of *P. heleocharidis* var. *arctica*.

Arctic mycology in relation to other sciences

In its relatively undeveloped state arctic mycology does not yet impinge very conspicuously on other scientific disciplines. There are a few indications that its role may eventually be significant, indications that at least justify a serious attempt to remedy past neglect.

The importance of fungi in breaking down plant remains in the Arctic, where bacterial action seems to be ineffective, is certainly great, for they eventually occur in profusion on almost every plant tissue. A better knowledge of their activities is clearly essential to studies in soil formation and fertility and in general ecology. In this connection much remains to be learned of the interrelationships of saprophytic fungi and mites and Collembola in the late stages of decomposition.

We are reaching the point where information on plant distribution can provide a detailed picture of summer climatic patterns in the Arctic. This information may eventually allow us to deduce much more detailed July isotherms than the network of meteorological stations permits. When fungus distribution patterns are better known some of them will supplement this information. One example is seen in the smuts (*Cintractia* spp.) that attack the florets of *Carex* and *Kobresia*. These smuts are common in the Low Arctic and occur sparingly at Cambridge Bay, Spence Bay, and in the deep valleys of the Eastern Arctic as far north as Lake Hazen. They are not to be found, however, on Somerset Island where several potential hosts occur, or, as far as is known, in the large area to the northwest where so many plants are excluded by the cold summer weather (Savile 1961). One might expect these smuts, with air-borne spores, to spread quickly to the limits of their hosts, but they have failed to do so. The pattern of development of most of

the sedges on Somerset Island suggested the explanation for the absence of their parasites. Although some sedges, notably *Carex misandra* and *C. physocarpa*, were abundant in marshy ground, they generally threw up only 2 to 10 fruiting stalks in 100 square metres. In the succeeding year the fruiting stalks are often not produced close to those of the preceding year. Unless the old and new stalks are produced within a metre or so of each other, the chance of a sporidium from the old culm landing on and infecting a floret on the new culm is very small and thus the parasite cannot maintain itself.

Another minor but interesting role of arctic mycology has recently come to light. In identifying plants recovered by Mr. Keith Arnold from under the retreating edge of the ice cap on Meighen Island it was found that some were completely overrun by saprophytic fungi, which indicates that they were dead before being covered; whereas others were in much the state of living plants, with the new growth uninvaded but the old leaves and stems attacked, which indicates that they were alive until covered. It is just possible that such clues may be of some help eventually in elucidating the past behaviour of these shallow and essentially stationary ice caps.

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