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## RESPIRATION IN SOME ARCTIC AND TROPICAL LICHENS IN RELATION TO TEMPERATURE<sup>1</sup>

P. F. Scholander,<sup>2</sup> Walter Flagg,<sup>3</sup> Vladimir Walters,<sup>4</sup> and Laurence Irving<sup>5</sup>

LICHENS FORM an important part of the vegetation of the arctic and they penetrate also into the tropics. They constitute a staple food of the caribou, which in the winter scratch through the snow to get at the well-known "reindeer-moss," i.e., *Cladonia rangiferina* and related species. Several species of lichens are accessible at or near Point Barrow throughout the winter, and a survey of their respiration in relation to temperature was undertaken. A similar investigation was made on tropical forms from Cuba and Panama.<sup>6</sup>

It has been demonstrated in a series of arctic and tropical cold-blooded animals that the arctic *aquatic* forms show a marked respiratory adaptation to cold, i.e., they can maintain a relatively high metabolic rate in spite of the cold. They are also able to maintain locomotion at temperatures which would

put tropical forms into cold coma. In contrast the *terrestrial* forms (insects) exhibit little metabolic adaptation, and many of the arctic insects, just like all the tropical forms, are rendered practically motionless at 0°C. (Scholander et al., 1952). Favorable microclimatic conditions are essential for activity and survival of these arctic terrestrial animals. Arctic aquatic forms cannot usually avoid cold by the selection of warm microclimates, and it seems only natural that they should have evolved a greater degree of cold adaptation.

The arctic flowering plants complete their active life cycle within the short span of the arctic summer. The development of many arctic or alpine snow-patch plants appears almost explosive. When they are suddenly uncovered from under the melting snow they rush through their active cycle in what is left of the short summer, often with their roots in ice water. Sørensen (1941), from his experience in northeast Greenland, characterizes the rapidity of these events as unparalleled among the phanerogamic vegetation on the globe. We might anticipate that such an accelerated development would require a metabolic adaptation to cold, probably the more pronounced the more aquatic the plant.

Stocker (1935) compared the respiration of leaves from three species of tropical trees in the Buitenzorg Botanical Garden, Java, with respiratory data on leaves from two arctic shrubs, *Betula nana* and *Salix glauca*, obtained by Müller (1928) at Disco, West Greenland. The comparison revealed that the arctic leaves at 10°C. respired at as high a rate as the tropical leaves at 30°C. By a large compilation of data from tropical greenhouse and temperate climate plants, he verified his general conclusion that there is an adaptive increase in oxygen consumption which is greater the colder the climate. These comparisons were made on the basis of unit leaf area. Wager (1941), during a year's stay at the Kangerdlugssuag Fjord in East Greenland (68° 30' latitude), measured the respiration at graded temperatures in twigs, shoots, and leaves of some 16 species of arctic flowering plants. He compared the respiration per unit fresh weight in these plants with a series of data compiled from temperate species. His results showed a considerable overlap between arctic and temperate forms, but many of the arctic records were higher.

Terrestrial lichens have habitually a highly variable metabolic rate, depending upon their moisture content. When they are saturated with water, or nearly so, the metabolic rate attains a maximum, but when they are dry the rate may reach extremely low values (Jumelle, 1892; Henrici, 1921; Stocker,

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<sup>6</sup> We wish to express our gratitude to the staff of the Point Barrow camp for facilitating our work in the North. At Coco Solo Naval Air Station, Captain H. W. Taylor, USN, provided exceptionally good working conditions and arranged airplane transportation to obtain our tropical lichens. To Dr. James Zetek, of the U. S. Department of Agriculture in Balboa, and to Dr. Ignacio C. Molino, Jr., Minister of Foreign Relations, Republic of Panama, we are indebted for making the arrangements to secure material outside the Canal Zone. Mr. John R. Andrews and Mr. Otto K. Hebel provided excellent technical assistance on instrumentation. Our Eskimo helpers, Mr. Joseph Ahgeak and Mr. Clay Kaigelak, gave us invaluable aid at Barrow, and Mr. Carlos E. Hooker helped us as guide and collector in Panama.

We were privileged in having our tropical lichens determined by Dr. Carroll W. Dodge of the Missouri Botanical Garden, and Dr. George A. Llano of the Arctic, Desert, Tropic Information Center, Maxwell Air Force Base, has kindly checked our arctic determinations. In preparing the data for publication we very much appreciate the advice of Professor M. G. Stålfelt of the Institute of Physiological Botany, University of Stockholm. We wish to thank the officers of the Marine Biological Laboratory for their cooperation, and we gratefully acknowledge the interest and help of Mr. C. Lloyd Claff, Captain F. Randolph Philbrook, Mr. Homer P. Smith, and Mrs. Deborah L. Harlow.

1927; Fraymouth, 1928; Smyth, 1934; Cuthbert, 1934; Neubauer, 1938; Ellée, 1939). Lichens of all climates are hence normally subjected to periods of very low metabolic activity without harmful effect. They reproduce by spores or by various kinds of thallus fragmentation, and this reproduction is not limited, as in the flowering plants, to a hectic summer season, but may take place at any time of the year. It seems, therefore, that lichens might represent a group which could get along well in the arctic without much need for metabolic adaptation.

Thus far no work has appeared which deals with possible climatic differences in the gas exchange of lichens of different latitudes. However, Stålfelt (1938) describes seasonal adjustments in the photosynthesis of several species of lichens. In the wintertime he found a lower and more extended temperature optimum for photosynthesis than in the summer, and the efficiency was likewise higher in the subdued light of winter. The respiration curve for different temperatures did not show a consistent elevation during the winter, however. Of five species investigated, two (*Ramalina farinacea* and *R. fraxinea*) were highest in the winter, one (*Cetraria glauca*) was highest in the summer, and two were very nearly the same in spring and winter (*Cetraria islandica* and *Evernia prunastri*).

In the present investigation we have endeavored to find out whether or not arctic lichens tend to run at a higher metabolic rate at low temperatures than do tropical lichens. This aspect of climatic adaptation can be approached through simple respiratory measurements, like those performed on the series of cold-blooded animals mentioned above. We have compared arctic material taken in the winter with tropical material taken in the dry season. Hence both materials were obtained during a time of relative inactivity. To what extent materials taken at other seasons would change the results is not experimentally known. Seasonal respiratory changes were, however, not indicated by Stålfelt's investigations (1938).

**MATERIAL.**—In the late August of 1947, before the ground was covered with snow, a series of suitable plant and animal habitats were marked with numbered poles in the vicinity of the Point Barrow laboratory. These included large patches of several species of lichen. Later in the winter (October–December) these patches were dug out, while frozen brittle, from under the often scant snow cover. They were taken to the laboratory where they were kept frozen in open boxes outdoors until they were used a few days later.

The following species were used:

Arctic Lichens	Climatic Range
<i>Lobaria linita</i> (Ach.) Rabenh.	Arctic-temperate alpine.
<i>Lobaria scrobiculata</i> (Scop.) D.C. <sup>7</sup>	Arctic-temperate.
<i>Solorina crocea</i> (L.) Ach.	Arctic-temperate alpine.

<i>Peltigera aphthosa</i> (L.) Willd.	Arctic-temperate.
<i>Peltigera canina</i> (L.) Willd.	Arctic-temperate to tropical alpine.
<i>Cladonia sylvatica</i> (L.) Hoffm., s.l.	Arctic-subtropical to tropical alpine.
<i>Omphalodiscus decussatus</i> (Vill.) Schol. <sup>7</sup>	High arctic-temperate high alpine.
<i>Umbilicaria cinereorufescens</i> (Schaer.) Frey <sup>7</sup>	Arctic-temperate alpine.
<i>Umbilicaria proboscidea</i> (L.) Schrader <sup>7</sup>	Arctic-tropical high alpine.
<i>Parmelia centrifuga</i> (L.) Ach. <sup>7</sup>	Arctic-temperate alpine.
<i>Cetraria chrysantha</i> Tuck. <sup>7</sup>	Arctic.
<i>Cetraria cucullata</i> (Bell.) Ach.	Arctic-temperate alpine.
<i>Cetraria islandica</i> (L.) Ach.	Arctic-temperate.
<i>Cetraria nivalis</i> (L.) Ach.	Arctic-temperate alpine.
<i>Cetraria richardsonii</i> Hook.	Arctic.
<i>Dactylina arctica</i> (Hook.) Nyl.	Arctic.
<i>Cornicularia divergens</i> Ach.	Arctic-temperate alpine.
<i>Alectoria nigricans</i> (Ach.) Nyl.	Arctic-temperate alpine.
<i>Thamnolia vermicularis</i> (Sw.) Ach.	Arctic-temperate alpine.

#### Tropical Lichens

#### Climatic Range

<i>Sticta laciniata</i> (Sw.) Ach.	Tropical.
<i>Sticta cf. weigelii</i> (Nyl.) Hue	Subtropical-tropical.
<i>Peltigera subamericana</i> Gyelnik	Tropical.
<i>Cladonia scholanderi</i> Des Abbayes	Tropical.
<i>Parmelia nigrociliata</i> B. de Lesd.	Subtropical-tropical.
<i>Ramalina alludens</i> Nyl.	Subtropical-tropical.
<i>Ramalina dendrescoides</i> Nyl. <sup>8</sup>	Subtropical-tropical.
<i>Ramalina leptosperma</i> Nyl. <sup>8</sup>	Subtropical-tropical.
<i>Ramalina usnea</i> (L.) Howe <sup>8</sup>	Subtropical-tropical.
<i>Teloschistes flavicans</i> (Swartz) Norm. <sup>8</sup>	Temperate-tropical.

**CLIMATOLOGICAL DATA.**—The lichens at Point Barrow were taken in the arctic winter, from October to December. During this period the ground was hard frozen and covered with snow. Air temperatures are given in table 1. The ground level temperature was measured in several places around the camp and was found to be about  $-20^{\circ}\text{C}.$  under some 6 in. of snow. The microclimatic summer temperatures may vary from just above freezing to probably some  $20^{\circ}\text{C}.$  at Point Barrow. Some of the lichens were brought to the laboratory in November from exposed snow-free ledges at Chandler Lake in the Brooks Range, 200 mi. south of Point Barrow, where temperatures occasionally hit  $-50^{\circ}\text{C}.$  In the summertime the microclimates in this place would easily exceed  $+20^{\circ}\text{C}.$  *Solorina crocea*,

<sup>7</sup> Obtained in November at Chandler Lake, Brooks Range.

<sup>8</sup> Obtained from Guantanamo, southeastern Cuba.

TABLE 1. *Air temperature at Barrow, Alaska (lat. 71°) in °C.*<sup>a</sup>

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Average	—28	—24	—27	—17	—10	— 1	5	2	— 4	—12	—21	—29
Minimum	—38	—42	—43	—32	—26	—10	— 2	— 5	—15	—26	—40	—43
Maximum	— 5	— 4	—13	1	0	4	22	14	5	— 2	— 2	— 8

<sup>a</sup> From Climatological Data, Alaska, 1948.

typical for naked soil wet by ice water, *Peltigera canina*, *P. aphthosa*, and *Lobaria linita* all form a more or less shield-like cover directly on the ground, and presumably get relatively little heated. Of the arctic species, *Omphalodiscus*, the umbilicarias, *Parmelia centrifuga*, *Cetraria chrysantha*, and *Lobaria scrobiculata* are species always, or usually, growing on rocks. All the others are more or less erect, fruticose species. Both these and the rock species can presumably be quite well warmed by the sun.

Three species of *Ramalina* and one of *Teloschistes* were taken on dry bushes in hot (22°–30°C.) and arid country around Guantanamo Naval Base, Cuba, January, 1948. They were placed, naturally dry, in a box and taken as personal baggage by air back to Point Barrow, where they were used approximately 2 weeks after they were taken from their natural habitat. They were at no time subjected to freezing or cold temperature. The other tropical species are from Panama. *Ramalina alludens* was the only lowland species found. It grew on trees by the Caribbean shore subjected to temperatures of some 25°–35°C. The others were taken in a jungle below the Chiriqui Volcano at an elevation of about 1400 m. The temperature at this place, according to information kindly supplied by Dr. R. K. Enders of Swarthmore College, is usually about 25° C. in the daytime and 11°–13°C. at night. However, around February, night frosts do occur occasionally. Microclimatic temperatures both here and in Cuba can be considerably higher than the shaded air temperatures given. The Panama lichens were used within a few days after collection at the Coco Solo Naval Air Station, Canal Zone.

**EXPERIMENTAL.**—Immediately before the experiment the lichen was cleaned in cold water, and all dead parts were trimmed off, so that only fresh living parts of the entire lichen were used. The material was divided into even bunches, put into 20–25 ml. respirometer vials, and a few drops of water were added. These vials had been covered with light-tight masking tape, and the Lucite attachment button to the respirometer was blackened. All experiments were made, therefore, in darkness, with completely moist plants in a water-vapor-saturated atmosphere. As CO<sub>2</sub> absorber, ascarite or KOH was used. Two sizes of respirometer were used: a regular plastic syringe respirometer and a more sensitive modification for low temperatures (Scholander, 1950). With five water baths, kept at 0°, 10°, 20°, 30°, and 40°C., and 40 respirometers, one species could be tested in a day, provided enough material was available. In a few cases (see legend for fig. 1) we were forced to use the same material at all temperatures; the runs at low temperatures were then always made first. Checks made on other material did not show significantly lower results in such repeated determinations. The experiments at each temperature lasted regularly 4–5 hr. with readings taken every hour.

The curves obtained were usually quite linear, but occasionally showed a tendency towards a decrease of the respiratory rate with time. When this happened the average rate over the whole period was used. In a few species it will be seen (fig. 1, 2) that the rate at 20°C. appears abnormally low. We have no explanation for this irregularity (cf. *Sticta laciniata* in fig. 5).

The tropical lichens were run up to 40°C. In most cases the material turned brown and emitted an abnormal odor at this temperature, and the oxidative rate accelerated greatly, as the heat damage progressed (fig. 5). In nature the tropical lichens may well be subjected to 40°C. and more in the sunshine, but they are then practically always dry and much less susceptible to heat damage.

After the run, the lichens were taken out of the vials and each bunch was dried at 100°–110°C. and weighed. All data are given relative to dry weight. Live weight cannot very well be used, since there is no standard wetness of a lichen.

As in the previous paper on the cold-blooded animals, we have plotted the temperature in C. on a semi-log graph against the metabolic rate, which in this case is given as mm.<sup>3</sup> oxygen consumption, reduced to dry gas, 760 mm., 0°C./g. dry weight/hr. Each point represents a single determination performed on several thalli. Each temperature was usually covered by eight separate oxygen consumption determinations. Representative examples of the detailed data are given in fig. 4 and 5. In fig. 1 and 2 the averages of these determinations are plotted.

We express the change of respiratory rate in relation to changing temperature as Q<sub>10</sub>. This presentation gives, for practical purposes, curves identical with those obtained by the Arrhenius plot, but they are more easily readable. The Q<sub>10</sub> for each temperature has been calculated according to the procedure previously described (Scholander et al., 1952).



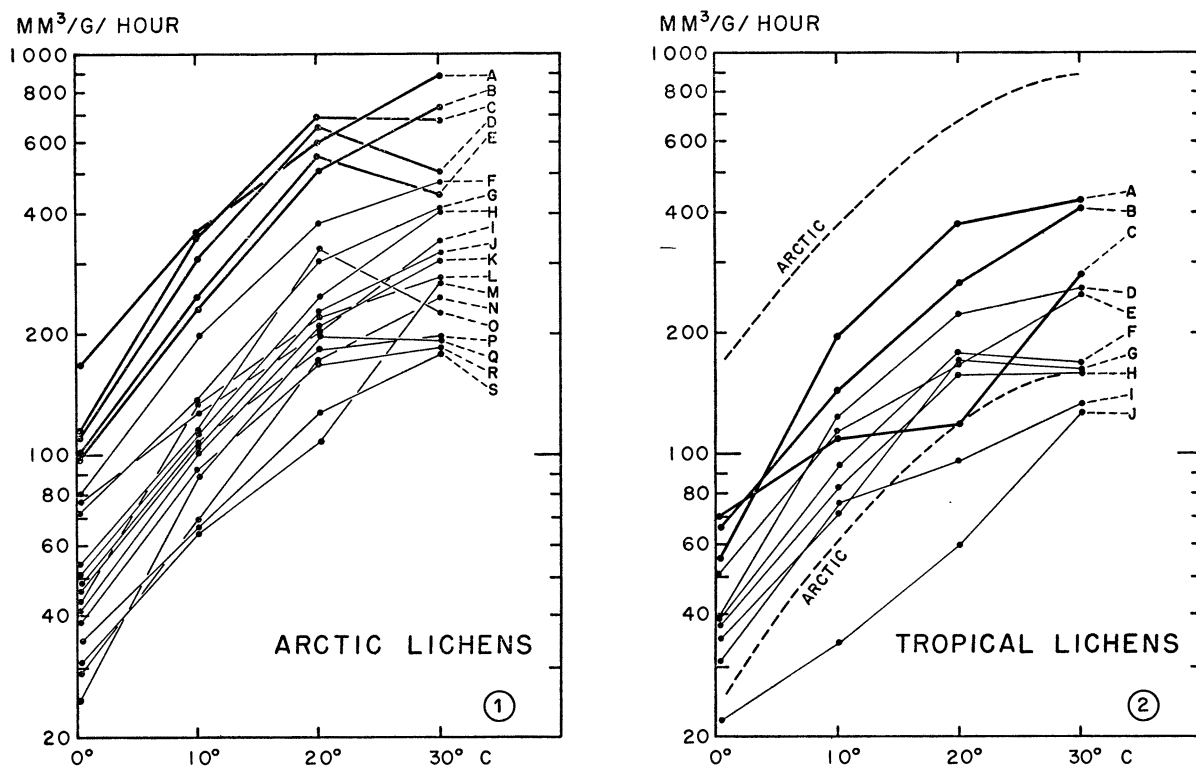


Fig. 1-2.—Fig. 1. Oxygen consumption in arctic lichens in relation to temperature. Each point represents the average of usually 8 separate determinations. The determinations were made on wet lichens in darkness, and are given in  $\text{mm}^3$  oxygen consumed/g. dry weight/hr. Members of the families Stictaceae (genus *Lobaria*) and Peltigeraceae (genera *Peltigera* and *Solorina*) are drawn in heavy lines. A, *Peltigera aphthosa*; B, *Lobaria linita*; C, *Peltigera canina*; D, *Lobaria scrobiculata*; E, *Solorina crocea*; F, *Cetraria islandica*; G, *Dactylina arctica*; H, *Cornicularia divergens*; I, *Alectoria nigricans*; J, *Cetraria nivalis*; K, *Umbilicaria cinereorufescens*; L, *Thamnolia vermicularis*\*; M, *Omphalodiscus decussatus*\*; N, *Cladonia sylvatica*; O, *Cetraria richardsonii*\*\*; P, *Cetraria cucullata*; Q, *Parmelia centrifuga*; R, *Cetraria chrysantha*; S, *Umbilicaria proboscidea*\*. \* Same material used for all temperatures; \*\* single determination at each temperature using the same plant.—Fig. 2. Oxygen consumption in tropical lichens in relation to temperature. Each point represents the average of 4-8 separate determinations. All experiments were made on wet lichens in darkness and are given in  $\text{mm}^3$  oxygen consumed/g. dry weight/hr. Members of the families Stictaceae and Peltigeraceae are drawn in heavy lines. The dotted lines indicate the range of the arctic forms. A, *Peltigera subamericana*; B, *Sticta weigeli*; C, *Sticta laciniata*; D, *Parmelia nigrociliata*; E, *Teloschistes flavicans*; F, *Ramalina dendrescoides*; G, *Ramalina usneae*; H, *Ramalina leptosperma*; I, *Cladonia scholanderi*; J, *Ramalina alludens*.

**RESULTS.**—It will be seen from fig. 4 and 5 that the variability within the species is often as high as 100 per cent. The spread in these data is not much less than in our insect or crustacean material, although motility is not a disturbing factor in plants. The reason for this variability may be the varying amount of old and young tissue in the thallus, and the immediate circumstances before the experiment may also have an influence. Stålfelt (1936) found that the respiration had increased by 18-144 per cent in five species of lichens when measured during 30 min. directly after illumination with 16,000 Lux. Most likely the metabolic rate per weight in lichens is normally rather variable. We have tried to keep the influence of extraneous factors uniform by storing the lichens cool in outdoor open boxes and by using fresh material for each run.

*Intraspecific comparison.*—Unfortunately we found no species common to the warm lowlands of

Panama and to Point Barrow, although at least morphologically very closely related forms living under similar extremes can be found. Several authors have, however, studied the metabolism of species belonging to our arctic series which they have taken in a temperate climate, but the data on respiration are most frequently given in terms of fresh weight or surface area, which renders a comparison with our material impossible (Henrici, 1921; Stocker, 1927; Boysen-Jensen and Müller, 1929; Smyth, 1934). Schütt (1932) and Stålfelt (1936, 1938) have given comparable data, however, on *Cladonia sylvatica* and *Cetraria islandica*. The arctic and temperate cladonias are not significantly different. The arctic *Cetraria islandica* is higher than the temperate material. The material is not sufficient to give any evidence upon climatic adaptation.

*Interspecific comparison.*—There is a considera-

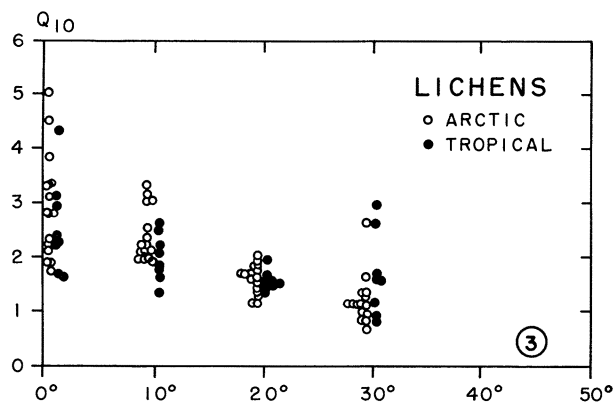


Fig. 3.  $Q_{10}$  of the dark-respiration in arctic and tropical lichens. At each temperature given, every dot stands for a different species.

ble difference in the rate of oxygen consumption from one species to another, both in the arctic and the tropical material. This, of course, renders the conclusiveness of a general comparison between the arctic and tropical species somewhat uncertain. If we regard the sum total of all the arctic curves and all the tropical curves (fig. 1, 2), it will be seen that the bulk of the tropical curves can be superimposed upon the bulk of the arctic curves. Four of the arctic species belonging in the families Stictaceae and Peltigeraceae show a higher metabolic rate at all temperatures. The tropical species of *Sticta* and *Peltigera* seem also high amongst the tropical material, but much below their arctic relatives (fig. 1, 2, heavy lines). Within these families the arctic forms at 10° C. run as high as the tropical forms at 20° C., and in this respect appear to be cold-adapted. For the rest of the material we may say that there is no evidence of difference.

The tropical material is somewhat weighted by ramalinas. One of these, *R. alludens*, has a very low  $Q_{O_2}$  and was also exceptionally heavy and wiry. Stålfelt (1936, 1938) found the temperate *R. fraxinea* and *R. farinacea* to have a  $Q_{O_2}$  essentially within the range of species from other genera, as was also indicated by our Cuban ramalinas.

In a truly arctic habitat the temperature may only occasionally on sunny summer days rise above an average of +5°–+7° C. against a tropical steady temperature of about 20°–30° C. It follows that the bulk of the arctic species will metabolize some four to five times less than the tropical species at their normal habitat temperatures. The arctic summer at Point Barrow lasts for little more than 2 months. During the rest of the year the arctic species are frozen, and remain for several months at

temperatures of –10°––20° C., or even lower, with corresponding metabolic rates on the order of 40–1000, or more, times less than at +5° C. (Scholander et al., data to be published). If we disregard drought, an arctic lichen during one year can metabolize only one-twentieth to one-thirtieth as much as a tropical lichen. It is hardly likely that a respiratory increase by assimilation would materially change this ratio.

Many lichens, like *Cladonia sylvatica* or closely related species, grow abundantly on the Gulf Coast of Mexico and in Florida, where most of the year is very hot and humid. The yearly metabolic turnover in these plants must be ten to twenty times higher than in the same species living in an extreme arctic locality. It seems hence to be a relatively unimportant factor in the physiology of a lichen whether its machinery runs at a fast or slow rate.

In fig. 3 the  $Q_{10}$  for the oxygen consumption in the dark has been plotted for the arctic and tropical lichens. There is on the whole no visible difference between them. One might have thought a priori that lichens living under the most variable temperature conditions might have adapted to them by having a low  $Q_{10}$ . This does not seem to be so. The metabolic rate of the arctic species is retarded just as much by low temperatures as is the rate of the tropical species.

Most of the arctic species discussed are restricted to cool climates and the tropical species to warm climates. It seems from the present investigation that the overall respiratory rate is, in general, but little concerned with the considerable physiological differences which must be responsible in the last analysis for the different climatic requirements exhibited by these lichens.

#### SUMMARY

Oxygen consumption at graded temperatures has been determined in a series of 19 arctic and 10 tropical species of lichen. The arctic members within the families Peltigeraceae and Stictaceae respire faster at all temperatures than other species within the same families in the tropics, and may be metabolically adapted to cold. In the main bulk of arctic and tropical lichens, the oxygen consumption data overlap at all temperatures, and hence show no clear metabolic adaptation to different climates. It seems that, in general, the metabolic rate of a lichen is highly variable, depending largely upon its moisture content and temperature, and that this group has not developed any demonstrable homeostatic mechanism or adaptation to counteract climatic influences on the respiratory metabolic rate.

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POINT BARROW, ALASKA

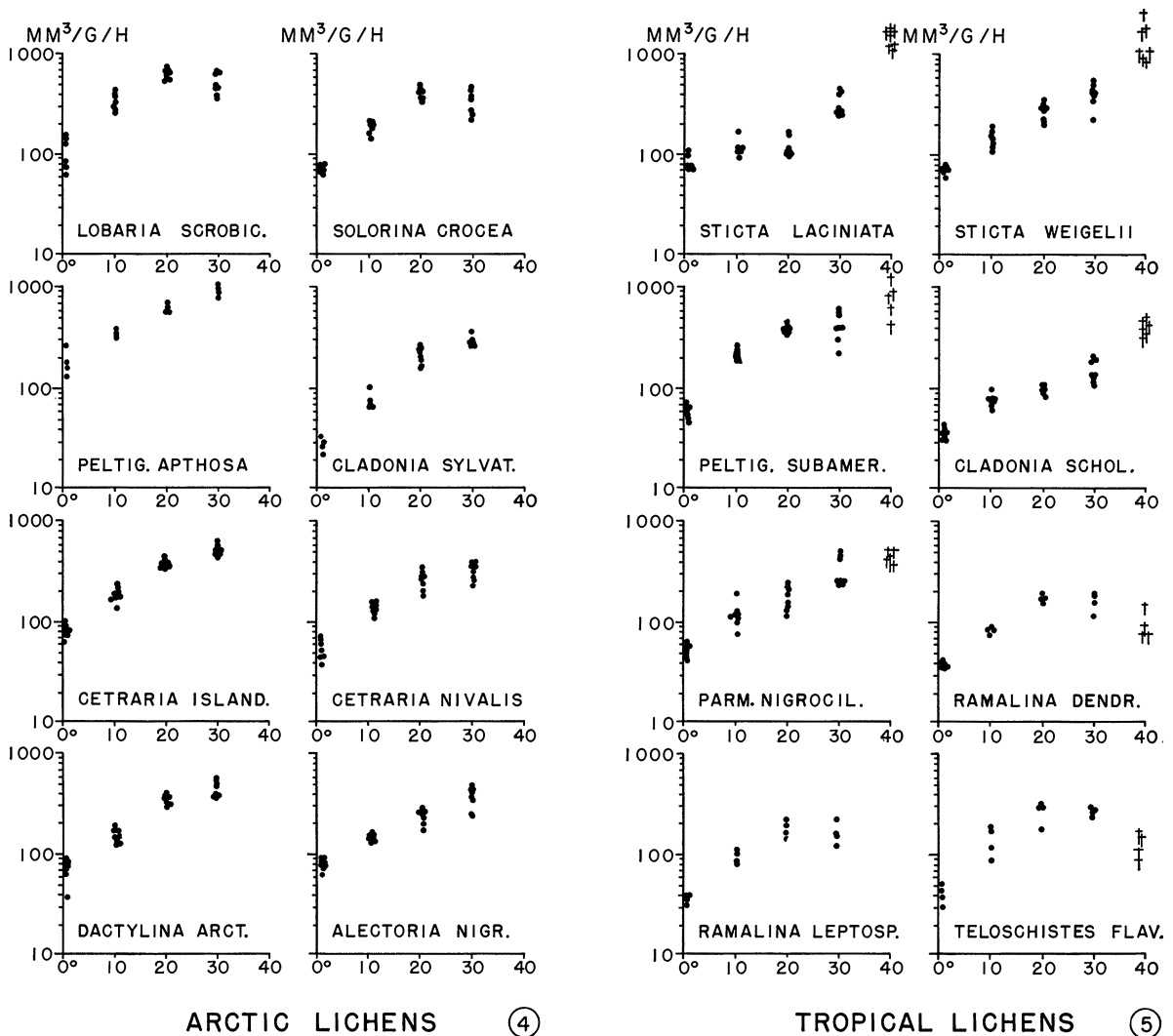


Fig. 4-5.—Fig. 4. Oxygen consumption in arctic lichens at graded temperatures. Determinations were made on wet plants in the dark. Oxygen consumption is expressed on the basis of dry weight. Each point represents a single determination.—Fig. 5. Oxygen consumption in tropical lichens at graded temperatures. Determinations were made on wet plants in the dark. Oxygen consumption is expressed on the basis of dry weight. Each point represents a single determination. Where the lichen was heat damaged crosses have been substituted for points.

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## CYTOTAXONOMIC STUDIES OF GEUM<sup>1</sup>

Louise A. Raynor

CYTOLOGICAL AND GENETICAL evidence has been compiled to supplement taxonomic data bearing on the problem of the natural relationships of *Geum* L. The cytological aspects are emphasized in this paper, with chromosome number, polyploidy, chromosome morphology, meiotic behavior in species and hybrids treated in turn. The taxonomic aspects will receive further treatment in a subsequent paper.

*Geum*, a genus of the Rosaceae, has a world-wide distribution, largely in temperate and cold temperate regions, yet it consists of a relatively small number of species. The most recent, extensive taxonomic work on *Geum* and closely related genera is that of Bolle (1933), who lists thirty-six species within *Geum* proper.

In this investigation ten species, three of which were represented by two varieties each, were studied, as well as six hybrids and two collections for which complete identification is still lacking.

**MATERIALS AND METHODS.**—Sources of the material, which was secured through the help of Dr. Robert T. Clausen and others, or collected by the author, are listed in table 1. The plants were grown both in the greenhouse, to facilitate root tip study, and in the experimental plot where the comparative morphological observations and microsporocyte collections could be made. Herbarium specimens have been deposited in the herbarium of Cornell University. Root tips were killed and fixed in CRAF and stained with crystal violet; the buds were fixed in Carnoy's and the anther contents smeared into acetocarmine. The camera lucida drawings prepared from representative mitotic and meiotic figures are re-

produced at a magnification of 3350 $\times$  and 1675 $\times$  respectively.

**CHROMOSOME NUMBER.**—All the species of *Geum* examined had 42 zygotic and 21 gametic chromosomes, with the single exception of *G. magellanicum* which had 84 and 42. An examination of the literature (Winge, 1925; Heitz, 1926; Prywer, 1932; Yamazaki, 1936; Gajewski, 1945, 1946) indicates that the 42 and 21 condition is by far the most common for the genus. In table 1 the counts made during this investigation, together with those from other sources, are listed. Representative figures of mitotic and meiotic chromosomes are presented in fig. 1-20. The author's count of  $2n=84$  for *G. magellanicum* does not agree with the more recent one of Gajewski, who reported  $2n=70$  (personal communication to L. W. Sharp, 1948). There appears, moreover, to be some disagreement concerning the numbers for *G. coccineum* and *G. quellyon*.

In reference to *G. coccineum*, Heitz (1926) reported a zygotic number of 70 but figured 72, whereas Yamazaki (1936) reported a gametic count of 21. Confusion in the taxonomic treatment and in the nomenclature may well be the explanation for this variance. *G. coccineum* has been used to designate two species, one Greek, one Chilean; the latter was separated by Lindley (1830) as *G. chilense* for which *G. quellyon* Sweet (1829) appears to be the valid name. It is impossible to check the identification of the material studied by Heitz and Yamazaki, but it may be that one of these authors had South American plants, and the other European. The material used in the present investigation was of the Chilean type, with the typical condition of  $2n=42$ . The counts of Gajewski do not serve to clarify the problem, for he reports gametic counts of 21 for *G. coccineum* and 35 for *G. quellyon*.

**POLYPLOIDY.**—The question of polyploidy in *Geum* is best considered in relation to the condition found in the Rosaceae as a whole, and particularly in the subfamily Rosoideae, tribe Potentilleae. According to the classification of Engler and Diels

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