1

Division of the Arctic into geobotanical areas

Since so much will be said about division into geobotanical areas, it is first and foremost necessary to define my concept in this respect. By division into geobotanical areas I intend to divide the vegetation cover so that the characteristics of the vegetation, that is, the totality of the plant communities distributed over a given territory, can be considered as diagnostic. Other traits should be considered as characterizing.

The first person to suggest a distinction between diagnostic characteristics, according to which groups of objects may be separated, and characterizing ones, according to which the units are further differentiated, was Tuomikoski (1942). In respect to their nature, the diagnostic characteristics are analogous to the indicator characteristics of a correlation swarm (Terent'yev, 1931, 1959). Takhtadzhyan (1966: 41–2) points to their significance for plant taxonomy and Vasilyevich (1964, 1966) as well as Nitsenko (1966) have shown their importance for the classification of vegetation. The application of diagnostic and characterizing traits is expedient also for the botanical–geographical division into areas (Aleksandrova, 1974). (Note: It is suggested that the division of an area based on any botanical characteristics be called botanical – geographical). The first group of characteristics, the diagnostic ones, defines the limits and establishes the rank and configuration of distinct areas. The second group, the characterizing traits, describes the distinguished areas, emphasizes their particularity and confirms the significance and rank of the boundaries between them.

The choice of various diagnostic traits separates the different systems for dividing vegetation cover into areas. According to this criterion, the distinction is first and foremost floristic, when the

character of the flora serves as the diagnostic characteristic, or geobotanical, when the character of the vegetation plays this role. Although the flora and vegetation form a single unit, the flora exists in the form of definite plant associations, and the taxa of the flora in a given region appear as the components of the plant communities. There is, however, a distinct difference between divisions into floristic and into geobotanical areas. In the first case, the taxa of the plant systematists are the focus of attention. If, thereby, the very varied characteristics of the plants are considered, including their role in the composition of the plant communities, all these traits can be used as characters, describing given species. In the second case, the central problem for the division of the vegetation into areas is its classification (Shennikov, 1940: 25–30; Sochava, 1948*a*, *b*, 1952: 530; Braun-Blanquet, 1964: 720–56; Schmithüsen, 1968; Karamysheva & Rachkovskaya, 1973: 171–2; etc.). It is fundamentally possible to set up specific, phytocoenological characteristics here which are outside the concepts of the floristics, such as, e.g., the structure of the plant communities.

In addition, supplementary characteristics are added to define a distinct area which, together with the diagnostic traits, plays a role in its description. If a wide variety of traits, both of the flora and of the vegetation, are used as characterizing, we obtain as a result a synthetic (Lavrenko, 1968; and others) or a complex (Yurtsev, 1966; and others) botanical–geographical division into areas. It should be noted that according to the nature of the diagnostic characteristics, this division becomes, when applied by E. M. Lavrenko, a geobotanical one, and when applied by B. A. Yurtsev, a floristic one.

In the Arctic, the principles of the classification of the vegetation and its division into areas have been differently developed within the USSR and abroad. In part, it is explained by the fact that there are different geobotanical provinces in the different parts of the circumpolar Arctic.

Classification and division into areas of the arctic vegetation outside the USSR

In the western hemisphere, the application of basic, diagnostic characteristics for the division of the Arctic into areas in respect to the degree of closedness of the vegetation is very widespread. This goes back to

the principles of classification formulated by Warming (1888) who, when describing the vegetation of Greenland, distinguished two vegetation 'formations': the 'Field-Flur' or fell-field (literally: desert-like ground) and 'Heide' or 'heath' (literally: wasteland, in a sense close to what is understood by that term in Shennikov, 1938: 487). According to Warming (1928: 299) the fell-field is the formation where 'plants grow singly often with great intervals, though here and there denser spots of vegetation occur, consisting of one or more species, and it is the substratum (loose soil, rock) which lends its generally grey or greyish black tinge to the surface'. 'Heath' differs from 'fell-field' in that here the vegetation cover is closed. By heath, Warming implied not only the kind of heath where the ericaceous dwarfshrubs form a closed cover with interlacing branchlets and the space between them is filled by mosses, lichens, and grasses (Warming, 1928: 302), but also lichen-heaths and moss-heaths. By the latter, Warming meant mainly forms of *Rhacomitrieta*. In addition, Warming distinguished copses (thickets of shrubs), as well as 'herb-field and grass-field in well-ventilated soil', 'freshwaters vegetation', 'moors and meadows' and 'shore vegetation'. The terms 'heath' and 'fell-field' introduced by Warming as well as some additional ones, e.g., the term 'barrens' for areas with a very disrupt vegetation, are widely used in foreign literature, both for the purpose of vegetation classification (cf. Beschel, 1963*b*; and others) and also as additional concepts to characterize vegetation (Böcher, 1954, 1963*b*; and others). It should be noted here that although some authors imply by the term 'heath' only associations dominated by ericaceous shrubs, this term is, as a rule, applied solely for the purpose of emphasizing the predominance of a closed cover, some small part of which also may be bare ground. Thus, Porsild (1951: 12) calls the dwarfshrub tundra 'dwarfshrub heath' and the lichens and moss tundras 'lichen and moss heaths'. Churchill (1955: 609) uses the term 'heath' for the tussocky tundras of Alaska. Beschel (1963*b*: 102–3) described from Axel Heiberg Island beside 'mesic heath (*Cassiope tetragona, Trisetum spicatum, Potentilla hyparctica*)' also 'dry mesic heath (*Dryas integrifolia, Poa arctica, Thamnolia vermicularis*)', and so on. Often, expressions such as 'Dryas-heaths' and even 'Festuca-heaths', and so on are met with. The vagueness in the use of the term 'heath' can be explained by the fact that, in the English language, this word has two meanings: first wasteland, i.e., useless,

'wasted' land, and second dwarfshrub thickets of the heather family (Ericaceae).

The criterion of a closed vegetation cover, widely applied outside the USSR, forms the basis for the division of the Arctic into three major regions: the low-arctic, the middle-arctic, and the high-arctic. According to Polunin (1960: 382; cf. also Knapp, 1965: 92), a closed cover predominates in the low-arctic. In the middle-arctic, the vegetation cover is closed only over large parts of the lowlands; in the high-arctic, there is a patchy cover only under the most favorable conditions, usually with wide spaces between. More essential characteristics have been added by Rønning, who states that the low-arctic is where the vegetation is closed over large distances and is especially rich in grasses, sedges and shrubs; the middle-arctic is where the vegetation is closed only in lowlands and differs by the absence of such dwarfshrubs as *Betula nana* and species of *Vaccinium, Phyllodoce coerulea*, and others; the high-arctic, finally, is where the vegetation is met with only in patches or as widely separated, single individuals (Rønning, 1969: 29).

It should be noted that the degree of closedness of the cover is, to a considerable extent, related to the local and not to the circumpolar character of the vegetation. Thus, in the basin of the Khatanga and Anabar rivers in eastern Siberia 'spotty' tundras with barren nonsorted circles are distributed along the actual forest limit, and even within the northern edge of the open woodland there are spots of barren ground. Sochava (1933*c*: 361) wrote in a paper on the tundra of the Anabar basin: 'in the dwarfbirch-willow subzone, just as to the north of it, the spotty tundras are widely distributed. There is nothing in this subzone that can be considered less fundamentally distinctive than spotty tundras in the subzone of the arctic tundras'. At the same time, hummocky tundras with a closed vegetation cover have developed at the northern edge of the Yamal Peninsula, and so on. Also within the areas of the polar deserts, it is possible to find extensive patches with a closed cover of crustose, fruticose and foliose lichens, mosses and liverworts, in rare cases associated with flowering plants. Therefore, the extent of barren ground cannot be considered everywhere in the Arctic as a diagnostic characteristic for the distinction of major, zonal subdivisions.

The classificatory units of the Scandinavian school have also been utilized for the study of the vegetation within the limits of the Arctic.

Böcher (1954, 1963*b*; and others), studying mainly the sociations, used two parallel systems for their further unification. As the primary distinction of the higher units, he used principally a physiognomical classification: shrub communities, dwarfshrub communities, and so on (Böcher, 1963*b*: 268–72: etc.). Secondarily, he used groups of indicator species for the unification of sociations: Ar – areal-geographical, Cl – climatic, Hb – ecological, EG – ecological-geographical ones. By means of the indicator species he recognized 'groups of sociations' and 'vegetation types'. On the basis of these, he identified 'vegetation complexes' and 'vegetation areas', appearing similar to regional subdivisions (Böcher, 1954; 11–12). Proceeding from these units Böcher accomplished a profound, basic areal division of the vegetation of southwestern Greenland (Böcher, 1954).

Areal divisions based on physiognomic and floristic – physiognomic indicators have also been published: Porsild (1951: 11) divided the American Arctic into four provinces, Polunin (1951: 310) divided all of the circumpolar Arctic into ten sectors, and so on.

There exist also works on the classification of the arctic vegetation based on the methods of the Braun-Blanquet school. Thus, Hadač (1946) has described a number of associations from Spitsbergen and decided on their position in a system of units of higher rank; he included, for instance, the associations *Carisetum subspathaceae* Hč. and *Puccinellietum phryganodis* Hč. in the alliance *Puccinellion phryganodis* Hč., the order *Puccinellietalia phryganodis* Hč, and the class *Puccinellio–Salicornieta* Topa 1939, and so on. Rønning, when describing the *Dryas* tundras of Spitsbergen, placed them within the alliance *Dryadion* Du Rietz 1942 and the order *Seslerietalia* Br. -Bl. 1951 (Rønning, 1965: 11). Hofmann (1968) studied the vegetation of Spitsbergen with these methods; they have also been applied in Greenland (Molenaar, 1974) and arctic Canada (Thannheiser, 1975) and so on. However, the results of the classification according to the Braun-Blanquet school have not been used for the purpose of division into geobotanical areas.

Classification and division into areas of the arctic vegetation inside the USSR

Within the Soviet Union, the development of principles for the classification of vegetation aiming at a division into areas, has followed

along physiognomic (in combination with this or that life form) and floristic-physiognomic lines from the very beginning. Thus, Trautvetter (1851) divided the East European tundras into two 'districts': 'the district of the alpine willows' (the arctic tundras) and 'the district of the low-grown birches' (the subarctic tundras). The southern boundary of the polar (according to Schrenk, 1854), the northern (according to Zhitkov, 1913), or the arctic (according to Pohle, 1910, and Gorodkov, 1916) tundras has been drawn along the northern limit of distribution of shrub thickets. Pohle (1910) distinguished also within the limits he had outlined for the 'subarctic zones' of the tundras in the European North, regions of the type of provinces: 'the western region' (from Norway to the Timan) and 'the eastern region' (from Timan to the Urals).

During the nineteen thirties, more serious contributions to the problems of classification and differentiation of the vegetation were put forward by Sochava (1933*c*, 1934*b*, for the Anabar Basin), Andreyev (1935 and others, for the East-European tundras), and Gorodkov (1935*c*). The latter accomplished a geobotanical areal division of the entire USSR tundra zone. As the highest classificatory unit, Gorodkov used the vegetation type, established on the basis of physiognomic, ecological, and partly also phylocoenogenetic criteria: the vegetation on snow (algae on the melting snow cover), on skeletal soils of the arctic deserts, on boulder fields, tundra-type vegetation, tundra meadows, subalpine shrub thickets, hydrophytic and mesophytic flood-plain meadows and shrublands, shrub thickets, forests, and bogs. His highest unit for the geobotanical division was the zone, and the second rank was the subzone. In addition, he distinguished twelve provinces, dividing all the subzones in a longitudinal direction. This remarkable work by Gorodkov has received wide acclaim and has been used as a basis for the illustration of the arctic territories on small-scale vegetation maps of the USSR (Lavrenko, 1939; Sochava, 1949, 1964*a*; etc.).

Leskov (1947) has suggested another system for geobotanical division. Basically, it differs from the Gorodkov system by the rejection of the concept of zone as a taxonomic category in the system of differentiating units. Guided by the principles advanced by Lavrenko (1946: 63–4; 1947) and differing from Gorodkov in his approach to the classification of the vegetation, Leskov distinguished four regions

within the limits of the Soviet Arctic: (1) the high-arctic nival, (2) the arctic tundra, (3) the Euro-Siberian shrub region (including the European-West Siberian and Central Siberian provinces), and (4) the Beringian shrub region. The forest-tundras were included in the latter two. Subsequently, Norin (1957, 1961, etc.) formulated the concept 'forest-tundra type of vegetation' and raised the forest-tundra to the rank of a zone. Included in it was also the southern part of the subzone of the shrub-tundras, *sensu* Gorodkov.

An outline for a division, according to which the boundary between the arctic and subarctic tundras appears as the basic limit of first rank, was developed by V. B. Sochava. While using traits connecting the vegetation with important factors in the environment as well as with phylocoenogenetic criteria as diagnostic characteristics, he distinguished the 'arctic belt', including in it the arctic tundras and the polar deserts, and the 'humid' (Sochava, 1948*a*) or the 'temperate' belt (Sochava, 1952), uniting the subarctic tundras with the adjoining, more southerly areas. In the Soviet Far North three 'geobotanical fields' (subdivisions at the rank of province) were recognized within the limits of the arctic belt. The tundra areas of the temperate belt were divided into seven 'geobotanical fields'. This outline was later used with some alterations by Sochava for making a physical–geographical division of Asia into areas (Sochava & Timofeyev, 1968) and for drawing the northern boundary of the Subarctic (Sochava *et al.*, 1972: 3).

The contribution made by B. A. Yurtsev to the differentiation of the arctic vegetation cover should also be mentioned. Although the complex botanical–geographical differentiation by Yurtsev can be considered as floristic, since the characters of the flora appear as diagnostic traits, his results are of great importance for understanding the geobotanical differentiation, thanks to the fact that they take into account a wide array of descriptive characteristics: ecological, biological, coenological, and phylocoenogenetic ones (Yurtsev, 1968*b*) as well as the characteristics of the landscape related to the vegetation cover (Yurtsev, 1966: 17–19, etc.). Yurtsev distinguishes the botanical–geographical 'hyparctic belt' and the adjacent 'arctic' and 'boreal' belts. In spite of using different arguments, he draws the boundary between the arctic and the hyparctic belts just like Sochava along the southern limit of the arctic tundras, which confirms the great

importance of this line as a boundary of highest rank. Yurtsev divides the hyparctic circumpolar belt into five provinces.

The system of regional units, as applied by Lavrenko (1947, 1968), was useful to me (Aleksandrova, 1964, 1971*b*). However I suggest separating vegetation types not according to Lavrenko's ideas but to a complex of characteristics, including the specificity of the structure, the character of the typical synusia, and so on. A reconsideration of the principles for the delimitation of the vegetation types of the tundras and of the polar deserts has resulted in a division of the Arctic into geobotanical regions: the polar deserts and the tundras. The latter region is divided into two subregions: the arctic and the subarctic tundras. My own points of view are expressed in detail below.

The higher taxonomic units for the classification of the arctic vegetation

The difficulty, when classifying the vegetation of the Arctic, is primarily connected with the clearly expressed co-dominance of the majority of the plant associations developed there: very often mosses, lichens, herbs, dwarfshrubs and semiprostrate shrubs co-dominate in the same phytocoenosis. Because of this, the application of the principles widely used in the USSR for differentiating higher units of the vegetation on the basis of the dominating biomorph, meets with considerable obstacles.

Supporters of the distinction of the vegetation types according to the dominating lifeform consider that in the tundra zone there is no single, zonal type of vegetation. They try to distinguish the tundra associations into a few types: the lichen-, the moss-, the dwarfshrub- and the shrub-types (Leskov, 1947, and others). However, as a rule, as was mentioned above, there appear in the tundra associations as co-dominants some life forms among which it is difficult to distinguish the main dominant for which this characteristic is the single one of the essential zonal characteristics for the zonal, mesic associations of the tundra zone.*

* Translator's note. The expression 'zonal, mesic association, habitat, etc.' is here used for the Russian term 'plakor', derived from a Greek word for 'surface, flatland', and is used to describe the zonal type of growth on mesic habitats, neither too wet, nor too

The tundra type of vegetation was identified by Gorodkov (1935*c*, 1946*b*; etc.), but Sochava had already expressed himself categorically on the identification of the tundra type of vegetation. He wrote that 'the tundra is a type of vegetation, – a plant community in the wide sense of that word, characterized by the following properties: it is from time immemorial without trees; it is dominated by arctic–alpine plants (by these are understood also the hyparctic forms; that term was introduced later by Tolmachev, V.A.), or by mosses and lichens; it has a special type of soil formation ... and some other features' (Sochava, 1931: 127). Concepts of 'tundra types of vegetation' have been formed by many Soviet tundra geobotanists (Andreyev, 1954: 8, 12; Norin, 1966; etc.).

Katenin (1972*a*, *b*) distinguished the tundra associations of the East European forest–tundra into three vegetation types: the shrub-tundra type, the dwarfshrub tundra type, and the herbaceous tundra type according to the lifeforms of the plants which compose the upper tier of the community. The classification by Katenin appears logically well composed and better than many present ones, because of its factual basis. He has many comprehensive tables with complete species lists and each association is based on descriptions of two to sixty stands. However, the classification was worked out for the local conditions in the area which the author studied, and when proceeding northward and into areas with a distinctly continental climate, where the layers degrade and a horizontal mosaic develops, it becomes less applicable.

For the differentiation of vegetation types, I myself take into consideration a complex of diagnostic characteristics, including the combination of definite ecobiomorphs and geographical groups of species, the composition of the characteristic synusia, not necessarily the dominating one, but one closely connected with the type of community under consideration, and the characteristics of the structure. The types and subtypes described below can then be distinguished as somewhat deviating from those in my previous publications (Aleksandrova, 1971*b*). (An *ecobiomorph* is a life-form adapted to certain environmental (ecological) conditions; e.g. hekistothermal mesophilous

dry, neither too sheltered nor too exposed, and covered by neither too little nor too much snow.

dwarfshrubs, hekistothermal mosses, etc. Hekistotherms (DeCandolle, 1874) are plants able to grow and propagate in average July temperatures ranging from 2 to 10 °C. Yurtsev (1976) united these and some other groups of plants under the term 'cryophytes'.*)

1. *The tundra type of vegetation.* This type comprises co-dominant communities of hyparctic, arctic and arctic-alpine shrubs, dwarfshrubs, herbaceous perennials, mosses and lichens in various combinations. These plants belong to the hekistotherms and in part to the microtherm-hekistotherms and in relation to the moisture conditions to mesophytes (in a wide sense). The tundra communities have cryogenic mosaic composition and are developed on auto-morphic soils. As characteristic synusiae appear such with hekistothermic, semiprostrate shrubs and dwarfshrubs. Two subtypes can be distinguished: *a*) the *subarctic,* and *b*) the *arctic* one. The presence in the former of a characteristic synusia of semiprostrate, hyparctic shrubs (*Betula nana, B. exilis*, etc.) lacking in the second subtype appears as the basic diagnostic difference. When passing from the subarctic subtype into the subtype of the arctic tundras, the role of the hyparctic elements is sharply reduced, while the role of arctic and arctic-alpine species increases, and as the characteristic synusia there now appears the synusia of arctic–alpine dwarf shrubs. Below, these subtypes will be characterized along with the regional description of the vegetation.

2. *The polar deserts.* These are represented by plant associations of lichens (*Ochrolechia* spp., *Pertusaria* spp., *Toninia* spp., *Collema* spp., *Cetraria* spp., *Stereocaulon rivulorum* etc.), mosses (*Ditrichum flexicaule, Polytrichum alpinum,* etc.), and liverworts (*Cephaloziella arctica,* etc.) together with some hyperhekistothermal, arctic and mainly high-arctic, as well as arctic–alpine herbaceous plants (*Phippsia algida, Poa abbreviata, Papaver radicatum* s.l.), which have developed on auto-morphic high-arctic soils. (Note that I prefer to use the name *Papaver radicatum* s.l. for what in the literature, in relation to the area where it occurs, is called *P. polare* (Tolm.) Perf., *P. Dahlianum* Nordh., etc. and is often united into the collective species *P. radicatum*

* Translator's note: compare Löve & Löve, 1974, 1975.