ECOLOGICAL DESCRIPTION OF PLANTS
FOR BIOLOGICAL FLORA

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INTRODUCTION

Some investigations and considerations of the ecological aspect of plant forms and floras criticizing the concepts of life-form and plant climate have been planned and conducted by the author and his collaborators (Numata 1951, Numata and Asano 1956, 1959, Numata 1957, 1971, 1976). In 1958, the "Biological Flora of Chiba Prefecture" was edited and published by the author and his collaborators. A new enlarged edition appeared in 1975. The object of such a study was not only to make a floristic list for a district but also to elucidate the ecological background of a local flora and the species and community ecology of plants.

Describing the distribution of such plant species as the British Flora (Perring and Walters 1962), and the dynamics of plant communities and their environment with the description of life-forms from the phytoclimatic viewpoint is an important subject of plant ecology. The "Biological Flora of the British Isles" edited by Clapham, Godwin and Richards, and a series of outlines of ecological life history studies appearing in "Ecology" under the sponsorship of the committee on Ecological Life Histories were most helpful references for our study. Plant taxonomists and geographers have made many floristic lists, and they have endeavoured to make ecological observations and descriptions, especially to develop a standard method describing the biological types of plants in a broad sense as well as plant communities (Dansereau 1951). Through those studies, the social life of plants could be interpreted correctly in detail from various angles.

Biological type classifications modifying or extending Raunkiaer's system were proposed in Japan by the author (Numata 1947, 1950, 1954, 1976, 1990) for the migrule form and the growth form, by Yano (1963, 1965) and Karizumi (1979) for root systems, by Horikawa and Miyawaki (1954) for weeds, by Hosokawa (1949) for epiphytic plants, by Horikawa and Ando (1952), and Nakanishi (1962) for the growth form of bryophytes, by Segawa (1954) for marine algae, and by Omura (1950) for the growth form of epiphytic lichens. Historical studies on the development of life-form concept and its criticism were done by Du-Rietz (1931), Adamson (1939), Boysen-Jensen (1948), Cain (1950), Gams (1950), Numata (1951), Gimingham (1951), Dansereau (1951), Numata (1953), Yoshii (1954), Schmid (1954, 1956), Meusel et al. (1965), Numata & Asamo (1956, 1989, 1969) Numata (1976), etc. Besides these, Schennikow's historical review and criticism of the authors of life-form systems, including Lapschina, Wiljams, Wyssozki, Kasakewitsch, Keller, Sukatschew, and Poplawskaja (Schennikow 1953) were also noticed.

Among taxonomical illustration, Flora Hawaiiensis (Degener 1933 – 63) shows ecologically excellent figures.

The author has studied the biological types of vascular plants since 1947,
and has felt it necessary to establish a standard method of describing biological types. Here he will discuss several points in biological descriptions and propose a new method of description. It is also an introduction for our monographs on the biological description of vascular plants "Biological Flora of Japan" (Numata & Asano 1969). Also, the author and his collaborator (Numata and Yoshizawa 1968) prepared a new book "Weed Flora of Japan, Illustrated in Colour" and "The Ecological Encyclopedia of Wild Plants in Japan" (Numata ed, 1990) with the description of life-forms.

CRITICAL NOTES ON LIFE-FORM CONCEPT

The author (Numata 1954) has classified phytosociological characters into two groups, homograde and heterograde. The biological type belongs mostly to the latter, and it is a qualitative and discrete characteristic following the logic of "either, or". In general, the types are classified into several groups only when they have such heterograde characteristics. The biological type is usually considered as the classification of physiognomical and morphological forms, and its methodological viewpoint will be successful of not according to the nature of the objectives to be classified. Dynamic and continuous characteristics correspond to the quantitative logic of "more, less", and there the classification of types will not be successful or conventional, though only the topological order of types will be shown. The central ideas of Raunkiaer's system is a homograde and quantitative nature for the highest position of dormant buds as the adaptation to survive in the unfavorable season. Therefore, the classification of such life-forms is rather conventional. For example, the limits of highest dormant buds of microphanerophyte is 2–8 m in Raunkiaer (1907), while they are 2–7 m in Gates (1949) without any special reason, though there was a difference in calculation between feet and meters. Such a fact shows a conventional character in life-form classification. On the other hand, the classification

1) Homograde and heterograde in the statistical meaning correspond to the statistics of variables and attributes respectively.
becomes clear when it is done by some discrete characteristics, such as the author's disseminule form based on modification for the migration of propagules. The viewpoint mentioned above is necessary in general, but there are cases where some continuous characteristics ought to be classified into groups. In those cases, it is desirable that the life-form classification be done on the basis of physiological necessities (Howard 1906, Burström and Krogh 1946, Oizumi 1951, 1952). Then the classification will not be conventional nor artificial. In the characteristics of the life-form of, for instance, Raunkiaer's dormancy form founded on the highest position of perennating buds, the scientific reason for life-form classification ought to be shown through physiological and autecological studies of perennating buds. That Raunkiaer's life-form system has come to be a useful and general method is because those characteristics correlate closely to the essential phases of plant life and the physiological response types or metabolism types of plants. Therefore the biological spectrum of those life-forms is considered to be an expression of the plant environment, especially of plant climate (Hosokawa 1966). It is, on the other hand, a convenient tool for field surveys to utilize morphological characters. Raunkiaer's system is better from this viewpoint than one such as physiological "Anpassungsformen" (Lundegårdh 1925). It is concluded that the life-form system as a means of field survey ought to utilize some visible, classifiable, and clear-cut characteristics, while its biological meaning ought to be given according to laboratory or experimental ecology.

What characteristics should be taken up for the description of vascular plants from the viewpoint of biological types? Illustrated books of plants published to date are used to solve some biological questions, but in such books written by taxonomists, only important characteristics for taxonomical classification are taken up, while ecological characteristics important for the present life of plants, particularly of vegetative organs, such as roots, stems and leaves, the protective nature of buds, the method of dispersal

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1) It is a botanical expression of climate and not the climatological climate. Namely it is an evaluation of environment in terms of plants.
of propagules, and the habitat conditions are not described sufficiently. Therefore, an illustrated monograph of plant forms from the ecological standpoint mentioned above is planned.

**ECOLOGICAL DESCRIPTION OF PLANTS**

Here some special points in the biological description of vascular plants will be discussed as follows:

1. Environmental conditions

(1) Climate First, places of growth of the range of distribution of species ought to be interpreted in relationship to a climate classification, such as Köppen (1884, 1931), Kira (1945), Thornthwaite (1948), Tuhkanen (1980) and others. It gives an orientation to plant species and vegetation from the viewpoint of macroclimatic types all over the world (cf. Ozenda 1964, IUCN, UNEP, WWF 1980). Smaller-scale classification of climatic types is desirable for local biological flora. Moreover, if local or microclimatic conditions are known, they ought to be described, too. The effective and limiting environmental factors for species are different according to biological level (Numata et al. 1957, Numata 1967, 1971). For example, the first factor for bamboo growth in Japan is the temperature at the macro-level (formation and/or association level), monsoon wind and precipitation at the meso-level (subassociation or consociation level), and the soil depth and water balance at the microlevel (sociation or stand level) respectively. If the important climatic conditions related to the life cycle of a plant are known, it will be desirable to describe them because they are often decisive factors for its distribution. For example, the germination of the spores of a fern has a range to temperature for the normal growth of prothallium. The natural distribution is impossible outside such a range of temperature. Most evergreen ferns do not grow north of the Izu Peninsula due to frost damage (Nishida 1952). These important conditions influencing the life cycle of a plant are mostly microclimatic, and it is vital to describe these limiting ecological
factors. Searl (1953) defined the term "plant climate" or "plant microclimate" as the climate from the lower limit of the root zone to the top of the vegetation, especially the earth temperature effective for the germination and growth of plants. It is generally concerned with the intensity and frequency of such factors, as Boyko (1949) discussed for the climatic extremes as decisive factors for plant distribution. For that consideration, phenological observations must be done. From the standpoint of local climate, the northern limit of the frostless zone is well known as the *Crinum* line (Koshimizu 1938). It corresponds to the isotherm of 6°C of the monthly mean temperature in mid-winter. Such a fact is sometimes related to a climatic belt.

(2) Substratum: Soil and Physiography  The soil types in a wide sense correspond to the climatic types (Muckenhirn et al. 1949, Matsui & Ogawa 1987). It is desirable to describe several noticeable points concerning the characterization of an area from the viewpoint of major zonal soil groups, local soil types, hydrogen ion concentration, water table, and so on. For instance, there are plant indicators of soil reaction, such as *Camptosorus sibiricus* as a calciphious plant, *Equisetum arvense* or *Microlespedeza strata* as an acidiphilous plant, *Dieranopteris dichotoma* as an aluminium accumulating plant, and *Athyrium yokoscense* as a cadmium accumulating plant, etc. Listing the soil reaction classes of plants by Ellenberg (1951) is very useful for our ecological study, because they have different meanings from pH itself. The measurement of the environment by physico-chemical instruments is very useful too, because it is defined "eindeutig", however it does not show biological evaluation in terms of living things, and the mass effect of such factors during a period (Numata 1958, 1967, Sochava 1971). Thus the plant, in general, is apt to be widely adaptive (euryözisch) in the central area of distribution, and narrowly adaptive (stenözisch) in the border region. For example, *Cynodon dactylon* is a conspicuous dominant plant widely distributed in tropical and subtropical pastures, but it is a restrictedly distributed coastal plant in the warm-temperate region of Japan (Numata 1965). This is a very important fact ecologically.
Special substratum, such as rocks, trees, etc. should be noticed, too. The topography, in a case such as a slope-liking fern, Woodwardia orientalis, must be particularly described. Microrelief is also important for the habitat-segregation of Ranunculus bulbosus, R. acris and R. repens in permanent grasslands (Harper and Sager 1954). Physiographic conditions, sunny or shady, plain or mountainous, wet or dry, etc. must be described.

2. Communities

Besides the physical conditions mentioned above, the interspecific relationship is important. Plants, as a rule, live in a coactive relationship with other species, especially the fidelitic relationship according to plant sociology and the dominance-subordination relationship according to quantitative ecology because they are components of some types of synusia, such as a forest floor or mountain grasslands, etc., with a floristic relationship, particularly the coexistence of species. To indicate such a fidelitic or competitive relationship, the coexistence of a species as a floristic connection would be better if it is described. Its background should be coevolution of plants and animals, The floristic history, especially, to be native or introduced, and to be a weed, ruderal or wild plant must be noticed, too.

3. Biological types

(1) Life-form or dormancy form The life-form concept was first established by A. von Humboldt (1806). After that, there are mainly two ways of formulating life-forms based on taxonomical and ecological (landscape ecolgical or physiognomical) criteria. The life-form classification based on the mode of dormancy during the unfavorable season (Raunkiaer 1907) is a typical life-form system using ecological criteria. Raunkiaer's system for dormancy forms will mainly be adopted as the life-form (Raunkiaer 1907, Ellenberg and Mueller-Dombois 1967). However, there are cases when it is necessary to modify it or add some forms to it, for example on epiphytic, and aquatic plants. Fosberg's physiognomical system was used as the
standard for describing the check sheet of IBP (Fosberg 1967) The ten life-forms which Raunkiaer (1907, 1916) took up to express a macroscopic plant climate are still useful at present, while in many cases their subdivisions are more useful for expressing the local environmental conditions of plants. In such a case, Raunkiaer's thirty subdivisions can be adopted, where the classification of plant function as deciduous, semi-deciduous, evergreen, evergreen-succulent, or evergreen leafless (Dansereau 1951), and the differentiation of summer annual, winter annual, and biennial plants are also noticed. In addition, the morphological characteristics, particularly, the protective structures of buds (Oizumi 1951, 1952) ought to be described.

In the classification of the life-form of vascular epiphytes, there are several systems such as those of Pessin (1925), Oliver (1930), Pittendigh (1948), Simmonds (1950) etc. since Schimper (1888), (Curtis 1952). In Japan Hosokawa (1949) divided epiphytes into two groups, Epiphyta typica and Falsiepiphyta, and fourteen subtypes. Hosokawa said that his system was a suitable method for studying forest communities in warmer areas synecologically. Several systems proposed up to now are mostly difficult to use or not clear in definition. Among these, Cowles's classification is better (Coulter et al. 1910). That is,

Hemi-epiphytes: E(h) ⋯⋯ plants epiphytic for a part of their existence.
Pseudoepiphytes: E(p) ⋯⋯ ordinary plants growing on the soil found
in the crotches of trees, where a little soil has collected.
Lithophytes: E(l) ⋯⋯ forms growing attached to rocks or shells.
Schimper (1891) divided the rock plants into chasmophytes (plants
rooting in crevices) and lithophytes (plants living on the naked rock).
But Warming (1909) following Schimper emphasized that there were
no true lithophytes among higher plants (cf. Zohary and Orshansky
1951).

True epiphytes: E(t) ⋯⋯ epiphytic plants restricted to trees.
Moreover, concerning the true epiphyte, it is desirable to described
all with E(t), its growing position as crown (C), crown base (CB), trunk
(T), trunk base (TB), for example E(t) − C. The host specificity is notice-
able, too, including parasitism. Concerning aquatic plants, Dansereau's
system is better (Dansereau 1945), though it is not so different from the Braun-Blanquet’s system (Braun-Blanquet 1951, 1964). In his “nouvelle classification des formes biologiques des plantes aquatiques”, he divided the aquatic plants into three large groups, helophyta (plantes palustres), hydrophyta (plantes aquatiques), and adnata (fixées sur roches, débebris ou plantes). Hydrophyta are divided into natantia (non fixées au sol, autrement), and radicantia (fixées au sol), radicantia into emersa (au moins partiellement émergées), and submersa (ayant tout au plus quelques feuilles flottantes). They will be symbolized as He, Hy(n), Hy(re), Hy(rs), and Hy(ad) not according to his symbols. The author does not adopt Dansereau’s more detailed subdivision, such as foliacea, junciformia, nymphaeoida, vittata, rosulata, and annua. Concerning annual aquatic plants, it will be necessary to treat them as both Th and HH in the biological spectrum. Namely, it must be modified so that annual plants are all Th, and HH belonging to the cryptophyte in Raunkiaer’s system. Penfound (1952) indicated that herbaceous vascular hydrophytes belonged to the following Raunkiaer’s life-form classes: Th, HH, H, and Ch on the basis of the position of their perennating buds. Moreover, Iversen (1936) classified Hydrotypen (epharmonic type as to the water factor) along the line of Warming (1909) and Drude (1913) such as Terriphyten, Telmatophyten, Amphiphyten, and Limnophyten from the viewpoint of the position of assimilalation - tissue and the structure of aerenchyma, and subdivided them as the wilting form. These are akin to the habitat form with his Hygrobientypen as the soil water classes.

There are several problems to be discussed in the field survey and statistics of biological types of plants (Numata and Asano 1956, 1959). The important ones among those are as follows:

a) For Japan covering four macro-climatic regions, it will be of small ecological value to collect statistics as a whole unless those macro-climatic areas are stratified.

b) There are some cases in which it is difficult to judge the biological type to which a plant belongs. Particularly the individual variation of the highest position of perennial buds and the influences of micro-climatic conditions
based on topography are to be noticed.
c) The ecological meaning of the biological spectrum according to the num-
ber of species is restricted within narrow limits. The spectrum according
to the frequency or dominance should sometimes be used (Suganuma 1966,
Numata and Shinozaki 1967, Sakura and Numata 1976, 1980, Tsuchida and
Numata 1979).
d) The concept of phylogenetic type is not fully excluded even in Raunkiaer’s
life-form system. Abundance of geophytes in the monocotyrous plants,
for instance, exerts an influence upon the species spectrum (Numata and
Asano 1961, Cooper 1956).
e) The sampling techniques in modern statistical science have not been
systematically introduced in the former statistics of biological types. The
sampling method will be useful also in the vegetational analysis.

In the description of plants, some observations from the standpoint
of the life-form were uncertain. Some of ambiguous types of life-forms
must be discussed in detail (Numata and Asano 1956).

After Raunkiaer, “Geophytes include land plants the surviving buds or
shoot-apices of which are borne on subterranean shoots at a distance from
the surface of the ground” (1934). In contrast, “all hemicryptophytes have
their surviving buds or shoot apices situated in the soil-surface”, and
“the buds do not come above the surface of the ground”. The difference
between the expressions “at a distance from the soil-surface” and “in the
soil-surface” is sometimes confused, especially in shallow geophytes. As
many individuals of doubtful species as possible were measured in different
habitats (Numata and Asano 1959). That explains why there are variable
species such as Desmodium racemosum and Vicia unijuga, and less variable
ones, such as Ligularia tussilaginea. In the former a geophyte, in the
statistical meaning, is sometimes like a hemicryptophyte or a chamaephyte.
And the type of life-form of the species forming a dead centre is too often
apt to be misjuged in a season when the clonal connection breaks. The posi-
tion characteristic of the surviving bud of variable species is considered to
some extent as an indicator criteria, but its value as an indicator is small.
Finally, some considerations concerning cases in which it is difficult to judge the biological types mentioned above will be described. Especially cases where it is difficult to judge whether $R_3$ (a type of rhizome plants) or $R_4$ (non-clonal growth) in the radicoid types proposed by the author have been taken up as follows:

a) Tuberous enlargements of the rhizome having conspicuous scars left with the fall of the erect stems of previous seasons. We are apt to judge this as $R_3$ by only one erect stalk of the current season. It is similar to "monophyadische Innovation" (Troll 1964), e.g. Polygonatum, Smilacina, Panax.

b) A distinct rhizome from which a single erect shoot develops each year, and the remnants of similar shoots of former seasons are not clear, e.g. Paris, Ephippianthus, Tricyrtis, Streptopus, Clintonia, Ainsliaea.

c) An obliquely ascending rhizome similar to the lowering of a rosette plant from year to year by the root-contraction. The scale leaves of former season partly remain, e.g. Viola bisetti, Viola vaginata, Coptis, Plantago.

d) A breadlike chain of tubers, the so-called moniliform. It is a special form of $R_3$, e.g. Calanthe, Cremastrina, Bletilla striata, Cymbidium nagifolium, Gemmingia chinensis.

e) A horizontal rhizome with short internodes. It is similar to c) except for the characteristic of a geophyte, e.g. Anemone.

f) A variation of $R_3$ with a vertical rhizome of G or H, different from the horizontal or obliquely ascending one, e.g. Adenophora remotiflora, A. triphylla var. japonica, Plantago, Ajuga nipponensis, Cynanchum japonicum, C. paniculatum, Anemone narcissiflora, Asparagus schoberiodes, Caerx morrowii.

g) An obliquely ascending rhizome from the sides of which a few erect stems rise, e.g. Atractylodes, Osmorhiza, Spuriopimpinella, Thalictrum.

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1) The subterranean organ of angiosperms also deserves taxonomic attention (Shimizu 1989). He classified the plants according the character of rhizomes, such as 1) plants with simple rhizome (horizontal and vertical), and 2) plants with compound rhizome (typical, stoloniferous and vertical).
Cimicifuga, Hepatica, Anemonopsis, Erica.

h) A type of R₁ which has the scars of old stems close to the base of a living aerial stem and enlarged reserve roots at the tip of the rhizome, e.g. Trichosanthes cucumeriodes, Scrophularia buergeriana, Gynostemma pentaphyllum, Stellaria paniculogera.

Besides these, ambiguous types of dormancy forms particularly concerning hemicryptophytes, chamaeephytes and geophytes are as follows:

a) Some winter annual species such as Erigeron annuus are sometimes hemicryptophytic in warmer parts of Japan, because new buds grow from the overwintered stem base. Erigeron philadelphicus usually has long rhizomes of R₁H.

b) One of evergreen lianas, not climbing, and a creeping chamaephyte such as “Spaliersträucher”. The highest perennating buds are lateral buds on the creeping stem from which some adventitious roots grow, e.g. Rubus buergerii, R. hakonensis.

c) An evergreen herb as a rosette-like hemicryptophyte. No terminal perennating bud is formed, e.g. Ainsliaea apiculata.

d) In Achyranthes japonica Nakai and A. longifolia Makino, dormant buds are found on the aboveground stem base, just under the soil surface, and away from the soil surface. Therefore it may be named Ch, because of the buds located furthest above the ground. But those aboveground buds usually wither later, and the really active buds are those under the soil’s surface. These species should be named H.

e) A geophyte with an obliquely ascending rhizome. When a tuberous enlargement is near the soil surface, it is apt to be misjudged as a hemicryptophyte, e.g. Isodon inflexus.

f) A rhizome geophyte which is apt to be misjudged as a hemicryptophyte for its large scaly buds often appearing on the soil surface, e.g. Agrimonia pilosa var. japonica.

g) A tussock-like rhizome hemicryptophyte which is apt to be misjudged as a geophyte or chamaeephyte, e.g. Carex morrowii, Carex multifolia.

h) A geophytic perennial herb. Since the perennating bud on the basal
portion of an aerial stem grows in November to a rosette-like plant, it is apt to be misjudged as a hemicyryptophyte or chamaephyte, e.g. *Rhynchospermum verticillatum*.

The vegetatively propagated plants with rhizomes (R₁ - R₃) are divided into 1) a clonal growth (perennial) connected to the mother plant, 2) a clonal growth (perennial) separated from the mother plant by a dead centre, and 3) establishing an individual (annual) separated from the rhizomes. 1) is a ramet, and 2) and 3) are ortets. 2) is a perennial ortet, and 3) is an annual ortet.

*Cacalia delphiniifolia* has several dormant buds already during the summer. The buds begin to grow in the autumn from the portion attached to the mother plant to become rod-like rhizomes on the tips of which rather large dormant buds and roots develop. This is the R₃ type clonal growth. In November, the mother plant withers, and the grown rhizomes radiating from the mother plant are cut off. Then several new individuals are established in late spring. When we notice only aerial shoots, they seem to be like an annual. We called this life-form “a vegetatively propagated winter annual (or pseudo-annual)” Th(v), i.e. an ortet-type winter annual. *C. tebakoensis, C. makineana* (*Miricacalia makineana*), *C. hastata* var. *farfarræfolia* and *Syneilesis palmata* are of this type. Troll (1964) described two kinds of variation in “Sympodien-bildung bei der Innovation von Rhizomgeophytten”. One is a “pleonarthrische Rhizome” with a dead centre of *Primula, Pulmonaria, Caltha, Ranunculus*, etc., and the other is a “monarthrische Rhizome” which appears as “abgebissenes Wulzelstock”, i.e. “rhizoma praemorsa”. The latter will be a kind of Th(v). However, there are two types of Th(v) originating in the rhizome as *Cacalia* spp. mentioned above and in the stolon as *Valeriana flaccidissima*, etc.

In spite of *Cacalia, C. adenostyloides* and *C. nikomontana* are not Th(v), but they are rather perennial herbs with separated rhizome, i.e., G(s). *Senecio nikoensis* is described as a winter annual in Makino’s New Illustrated Flora of Japan (1961). However, it is not a usual winter annual but rather a Th(v).
Valeriana flaccidissima is usually described as perennial herb, however this is also Th(v). In the case of Cacalia type plants, they are Th(v) with rhizomes (R3), but V. flaccidissima is Th(v) with stolns (R4). V. flaccidissima has many stolons with new buds on the tips of stolons. In June the mother plant dies and the stolons are disconnected from the mother plant. At that time the buds on the tips grow roots and become independent individuals passing the winter that way.

Patrinia villosa Juss. is the same type with V. flaccidissima, however Patrinia scabiosaefolia Fisch. is quite different being an R3 type perennial. Briefly then, under vegetative propagation there are:
1) perennial ramets,
2) perennial ortets, and
3) annual ortets

3.1) rhizomatous: Cacalia type and,
3.2) stoloniferous: Valeriana type.

In aquatic plants, Hydrocharis dubia is similar to the annual ortet, but usually described as a perennial plants of Ch, H, G, and HH, the perennial ramet might originally have been a normal form, while the perennial ortet and the annual ortet are assumed to be derived from the perennial ramet under severe environmental conditions.

(2) Migrule form The author proposed another life-form system, the migrule forms consisting of the disseminule forms and radicoid forms (Numata 1947, 1950, 1954). This is the ecological typology of reproductive organs, such as fruits, seeds, roots, rhizomes, etc. that contribute to the migration of plants.

The migrule form is one of the biological types (the term used first by Raunkiaer 1907) or biological forms (the term usually used in France) in a broad sense. It is also regarded as an extension of the life-form concept. It contains two sides of vegetative form and a kind of reproduction form, but it is a purely ecological group concept. The basis of this idea is the type of dispersal or migration of plants, that is, a kind of reproduction
form such as seed, fruit, root, rhizome, stolon, etc. The "migrule"\(^1\) is an organ of migration which consists of "disseminule", such as seeds and fruits, and "radicoid"\(^2\), such as roots, rhizomes, and stolons.

The disseminule form (D) is grouped into five classes (D₁ - D₅) from the viewpoint of the potential ability of dispersal or migration of seeds and fruits as shown in Table 1.

**Table 1. The classification of the disseminule form**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Agents of migration</th>
<th>Modification of migration</th>
</tr>
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<tbody>
<tr>
<td>D₁</td>
<td>wind and water</td>
<td>samara, pappus, parachute, plumed, dusty, very small seeds of micorrhizal type, and field roller</td>
</tr>
<tr>
<td>D₂</td>
<td>animals and man</td>
<td>spiny, hooked, viscid, and freshy fruit in a wide sense</td>
</tr>
<tr>
<td>D₃</td>
<td>mechanical propulsion</td>
<td>dehiscent fruit, dry fruit, hygroscopic fruit, and turgescent fruit</td>
</tr>
<tr>
<td>D₄</td>
<td>gravity</td>
<td>nut, acorn, and brood bud (bulbil)</td>
</tr>
<tr>
<td>D₅</td>
<td>growth</td>
<td>only vegetative propagation</td>
</tr>
</tbody>
</table>

**Table 2. The classification of the disseminule form**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Radicoid</th>
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<tbody>
<tr>
<td>R₁</td>
<td>rhizome</td>
</tr>
<tr>
<td>R₂</td>
<td>extent of clone</td>
</tr>
<tr>
<td>R₃</td>
<td>d &gt; 100 l</td>
</tr>
<tr>
<td></td>
<td>100 l ≥ d &gt; 10 l</td>
</tr>
<tr>
<td></td>
<td>10 l ≥ d</td>
</tr>
<tr>
<td>R₄</td>
<td>adventitious roots growing</td>
</tr>
<tr>
<td></td>
<td>at the nodes</td>
</tr>
<tr>
<td>R₅</td>
<td>root, tuber, bulb, and corm</td>
</tr>
</tbody>
</table>

1) In the Clementsian sense, migrule, propagule, disseminule, and diaspore all have a similar meaning, but of those terms, the author modified, migrule and disseminule as above.

2) From the ecological point of view, the organs having a function similar to roots in the vegetative propagation have been termed radicoid (radix + oid).
The radicoid form (R) is grouped into five classes (R₁ - R₅) from the viewpoint of the extent of clonal growth, as shown in Table 2. R₁ - R₃ are rhizome plants the largest width of which is d cm when the area of extent is assumed to be a circle, and the average height of the aboveground part is l cm.

Moreover, it is desirable to describe the average weight of seeds or fruits, seed production, the viability and germination of seeds, and the mycorrhizal infection of radicoid, etc. About the root form, the author (Numata 1950) has classified R₁ (fibrous root) and R₅ (tap-root) and now adopts the following three subtypes of R₅. That is, the ordinary primary root with laterals: R₅(p), vigorous lateral roots, following the removal of the primary root: R₅(l), and a much enlarged primary root: R₅(e). Karizumi (1957, 1979) and Yano (1960, 1962, 1963, 1965) classified the root system form based on the depth and morphology of the root system. The author proposed a method of describing the competitive and complementary association of the underground part of different species by using several symbols (Numata 1950). From a viewpoint of the author's disseminule form as a part of the migrule form, "types de dissemination" (Sissingh 1952) and "Verbreitungstypen" (Muller 1955) are similar to the disseminule form. Regarding the evolutionary step of disseminule forms (organs and methods of dissemination), there have been several assumptions, however they are not so comprehensive.

In a tropical rain forest on Mt. Kinabalu in Borneo, 35 - 40% were fleshy fruits belonging to D₂ (zoochore), 25 - 28% were D₁ (anemochore) and the rest species were D₄ without any special modification for dispersal. In a rain forest in South Nigeria, 46% of emergent trees were D₁ and 46% were D₂, while of trees of in the lower stories 7% were D₁ and 71% were D₂. However, in a secondary forest in the same place after felling, D₁ was 56% of emergent trees, 48% in upper stratum lianas, 25% in the upper tree layer, 2% in the lower tree layer, and 0% in the shrub layer and lower lianas (Pijl 1969). Based on the facts mentioned above, a disseminule form like D₁ is actually an adapted characteristic related to the community structure. In the evergreen broad-leaved forest without emergent trees in the warm-
temperate region, there are very few anemochores in the canopy tree layer (Numata & Tanaka 1982). Not only the modification for migration, but also the weight of disseminules is an important factor of its dispersal power. Though the variability of seed weight is rather large, the weight class categories are of exponentially increasing magnitude in the ratios of averages.

Seed weight is clearly associated with habitat conditions. The heavier disseminules in the closer and taller vegetation types represent an adaptation to their environments. The disseminules belonging to D1 include those of Orchidaceae, Droseraceae, Orobancaeaceae, Burmanniaceae, etc. which seeds are very light having small food reserve. The nutrients are supplied by parasites, semi-parasites, mycorrhiza, etc. Anemochores are found in initial stages of secondary succession in open habitats, and in weed vegetation in crop-lands. The rate of light anemochores is 40% in weed vegetation and 60% in alpine vegetation. Both of these are open habitat, however there is an exception. In a study on the autecology of dominants in the pioneer stages in secondary succession (Hayashi & Numata 1968), the first-year pioneer species Ambrosia artemisiifolia var. elatior on the denuded land had rather heavy fruits dispersed by birds or rain-wash (Ridley 1930). In general, first-year pioneer species such as A. artemisiifolia var. elatior and Polygonum persicaria are of the bird-dispersed type with rather heavy seeds while the second-year pioneer species such as Erigeron annuus, E. canadensis, etc. are of the wind-dispersed type with very light seeds. After the Erigeron stage, the weight of dissipinules of the dominants follows Salisbury’s rule. Heavy disseminules of A. artemisiifolia var. elatior having much stored-up food and a vernalization character due to low temperatures in the winter are suited for rapid occupation of the ground surface in early spring after volley germination (Hayashi & Numata 1967). The second year pioneer species of Erigeron are of the partial rosette type as mentioned earlier, and photosynthesis of the rosette in the winter compensates for a small food reserve of light seeds.

Many examples of disseminules dispersed by animals, i.e. 1) by being eaten and 2) by sticking to animals, are shown in Ridley’s book. A conspicuous example in Japan is the extention of pastures dominated by Zoysia
japonica. This is a typical shortgrass pasture which is established by cattle-raising. The Zoysia seeds are more fit for germination after passing through cow's stomachs. In the Fagus crenata forest used for grazing, an undergrowth of Sasa is often replaced by a lawn of Zoysia. It is ecologically important that the dissimine form of the dominant of tallgrass meadow. Miscanthus sinensis is anemochore, and that of shortgrass pasture, Z. japonica is zoonchere. The Miscanthus meadows are used for mowing and the Zoysia pastures are used for grazing. Therefore the evolution of dissemiple forms may be accompanied by biotic factors as shown in the evolution of other growth habit of grasses (Barnard & Frankel 1964).

(3) Physiognomy The life-form classification originated in physiognomical studies of plant forms by A. von Humboldt (1807), but the dormancy, and migrule forms mentioned above have not been established only from the physiognomical viewpoint. Dansereau (1951) has taken up the leaf shape and size, leaf texture, and coverage as physiognomical features. But his coverage (barren or very sparse, discontinuous, in tufts or groups, and continuous) is a mixed expression of sociability and dispersion. Therefore, the author takes up sociability as a quantitative characteristic of vegetational analysis. His criteria of sociability are the size of aggregation with radius R, the individual size with average radius r when the area of extent is assumed to be a circle, and the average distance between individuals d.

When A = R/r (R, r> 0) and B = d/r are assumed, the sociability index is S = A/B. Now sociability is grouped in six classes as follows:

S₁ — growing isolated — R = r, d>100 r,
S₂ — growing in a small group — R ≤ 5 r,
d: indifferent,
S₃ — growing in a close colony —
5 r < R ≤ 50 r, d ≤ 5 r,
S₃′ — growing in an open colony —
5 r < R ≤ 50 r, d > 5 r,
S₄ — growing in a close colony — R > 50 r,
d ≤ 5 r, and
S₄′ — growing in an open carpet — R > 50 r,
d > 5 r.
These sociability classes are adopted to individual patches in vegetation, and to express the distribution of such patches, and the sociability classes are combined, for example as $S_2 - S_1$. Here the gregariousness of individuals is expressed by $S_2$, and that of patches by $S_1$. Thus the sociability figures are used as a means of describing the heterogeneity of plant distribution. And they will be far more quantitative and objective than usual methods (Gates 1949, Oosting 1950, Braun-Blauquet 1964, etc.). To express the mode of distribution more quantitatively and exactly, the index of dispersion or coefficient of homogeneity (Cottam and Curtis 1949, Numata 1949, 1966, 1971, Morisita 1959, Greig-Smith 1964, Iwao 1968) must be calculated.

Besides sociability as a tendency to grow and distribute on the ground, the outline and external aspect of plants, particularly the branching habit, the bark feature, the crown shape of trees, shrubs, and herbs are also important. They are various components of physiognomy, and, in general, will be called from the shoot habit or growth form. As discussed by Gimingham (1951), the term 'life-form' and 'growth form' have frequently been used synonymously in the past, but in the present account "growth form" means solely the 'architecture' of the plant referring in particular to the form, method of branching and arrangement of the shoot system, and, when possible, the underground system. Coulter (1911) classified the types of stems bearing foliage leaves into five groups, 1) subterranean, 2) procumbent, 3) floating, 4) climbing, and 5) erect types. He said "Among stems of the erect type the tree is the most impressive, and it has developed into a great variety of forms or habits".

He explained pine, elm, oak and weeping birch types, etc. in terms of their life relationship, especially to light. Uehara (1925, 1951) and Suzuki (1952) have indicated a similar classification of tree forms, but here the system of vegetation form, such as that of Griesbach, will not be adopted. Concerning the physiognomy of trees, the characteristics of bark should be also noticed (Schwankl 1956).

The author's tree form system consists of the following three factors:

1. Trunk type: erect (e), procumbent (p), and climbing (c):

2. Branch type, particularly its angle against the central shaft: hori-
horizontal (h), upright (u), and downward (d):

3. External form of crown: conical (c), reverse-conical (rc), dome-shaped (d), globe-shaped (g), spindle-shaped (s), and their composed form.

The tree form is expressed by the combination of those symbols mentioned above. As the growth form (particularly of herbaceous plants), a simplified, modified and revised system of Gimingham (1951) and Whitehead (1954) was proposed (Numata 1955, Numata and Asano 1964). That is,

Tufted (t): dome-shaped tussocks or bunches of grasses and grass-like plants,

Branched (b): a much branched forms without a main axis,

Cushion (c): shoot-systems highly branched, and densely packed to form a hemispherical cushion,

Mat (m): closely interwound forms similar to a mat or sod,

Erect (e): plants with a main axis, branching restricted,

Prostrate (p): plants with prostrate stems,

Rosette (r): plants with a cluster of large radical leaves, without leaves on aerial stems,

Partial Rosette (pr): plants with a rosette form partially in their life history, then becoming an erect form,

Pseudorosette (ps): plants with a cluster of large radical leaves, also with leaves on aerial stems,

Climbing form (l): climbing plants in a broad sense including lianes,

Spiny forms (sp): plants with spiny or thorny stems.

Hanging (h): plants hanging on a slope.

These growth forms are used for analysing the structure of plant communities and judging their successional situations (Numata 1955, 1956, 1965, Numata and Suzuki 1958).

The rosette form (r) is characteristically found in light, open habitats such as pastures, arid fields, moors, and the crests of rocks. The rate of rosette species is 20% in short-grass pastures of Zoysia japonica, while 10% in tall-grass meadows of Miscanthus sinensis and 5% in dwarf-bamboo thickets (Numata 1965). The rosette is tolerant to trampling, so it can be
found in abundance in overgrazed pastures and on roadsides such as *Plantago asiatica* which is a ruderal plant. The rosette form is utilized as an early growth of the partial rosette form (pr) such as *Erigeron annuus* (the r and pr belong to H of Rauukiaer’s (1935) system, however it is not necessarily limited to H in my opinion. The partial rosette is essentially the erect form, however it has a rosette form during the first half of its growth period. During the latter half, radical leaves wither.

On the other hand, there is the pseudo rosette form (ps) with its erect stem having leaves and flowers as well as active radical leaves. Examples include *Aster scaber, Ainsliaea apiculata*, etc. The partial rosette is often a dominant of the second-year pioneer stage of secondary succession due to their two-step growth which consists of the early rosette and later erect forms.

The pseudo rosette is a constituent of tall-grass meadows and the undergrowth of forests due to the wide adaptability of both of its growth forms, rosette and erect.

Besides a series of r, pr and ps, there is another strategy of growth forms, the combination of r, pr and ps with the prostrate form (p) such as p-r (*Fragaria ananassa*, etc.) and p-pr (*Prunella vulgaris, Oenothera laciniata*, etc.). In the coastal sandy fields of central Japan, the replacement of *Oenothera erythrosepala* by *Oenothera laciniata* (both of these being naturalized plants) occurred after World War II. One of the causes of such replacement may be that p-pr is stronger than pr in the struggle for existence.

Most aerial stems usually grow erectly due to phototropism and apogeotropism. However, some of them tend to grow with a prostrate habit, particularly under biotic factors such as trampling and grazing. The orchard grass (*Dactylis glomerata*) typically has a bunch form without stolons, however some Welsh strains (S-26, S-37, S-143, etc.) bred for grazing, have a prostrate habit well adapted to the pressure of grazing.

Some ruderal plants also have a prostrate habit which has developed genetically under the long-term influence of human trampling. We can find the prostrate forms: *Portulaca oleracea, Polygonum arenastrum* and *Les-
pedeza cuneata var. serpens on roadsides or in gardens instead of Portulaca oleracea, Polygonum aviculare and Lespedeza cuneata with its erect habit which can be found in croplands or meadows where there is no trampling. However, such a prostrate form has no stolon or runner and we do not call it a true prostrate plant. Prostrate plants such as Ixeris stolonifera (p-ps) and Prunella vulgaris (p-pr) usually have stolons. Veronica persica has adventitious roots at the nodes of each stolon, however a closely related species V. arvensis does not grow such roots at the nodes of its prostrate stem. An aerial shoot with adventitious roots is a potential individual which can establish a new clone. Such a new potential plant (ramet) may be called an offset (Coulter et al. 1931). An offset may become an ortet later. The thickness and length of internodes of Ladino clover (Trifolium repens var. giganteum) correlate with the height and weight of the adjacent shoot, and their length correlates with the rate of emergence of their leaves (Kawanabe et al. 1962). Such a characteristic of the life history of stolons was used for the diagnosis of growth, particularly of the summer depression of Ladino clover. We studied the growth of habit Digitaria adscendens in relationship to its competitor with upland rice (Niiyama & Numata 1969). In an experiment with different densities of rice (5 cm, 10 cm and 15 cm intervals), the number of nodes with adventitious roots and the height of aerial shoots were largest in the stand planted at 15 cm intervals. Digitaria adscendens has tufted growth in its young stage, however it has a creeping habit with adventitious roots from nodes. It is not a prostrate plant originally, but it has a prostrate habit facultatively when grown along with other species. Digitaria adscendens seems to be a transitional form between the erect (tufted) and prostrate forms. Zoysia japonica sometimes has stolons, while a large part of them have underground stems. It grows stolon first, but they go underground later. A temperate bamboo, Phyllostachys bambusoides is originally a rhizome plant, however the rhizomes often go up into the ground. These are also transitional forms between the stolon and rhizome habit.

Climbing plants (or lianas) in a broad sense include twiners, tendril climbers, root climbers, rhizome climbers, hook climbers and leaners.
According to Darwin (1875), the tendril climber has a higher function as a climbing plant than the twiner. The former can climb up effectively on a lower consumption of matter. The hook climber with recurved hooks which hold the plant to support such as *Clematis termiflora* is considered to be higher in evolution than a tendril climber such as cucumber (Darwin 1875). The liana in the tropics sometimes acts as a strangler completely enfolding its host with a fusion of roots like *Clusia* and *Ficus* (Dobzhansky & Murça-Pires 1954). It is also known to act as a parasite with its sucking organs (haustoria) serving to hold it firmly to its host plant (ex. *Cuscuta*).

Herbaceous annual liana like *Humulus japonicus* is a pioneer plant in an open habitat, and herbaceous perennial lianas like *Cayratia japonica* are sometimes noxious weeds. Woody lianas such as *Wistaria floribunda* are especially associated with forests, sometimes being very noxious in the forest management. The liana needs support, therefore the rate of lianas is around 5% in shortgrass pastures of *Zoysia japonica* or *Pleioblastus distichus* var. *nezasa*, while it is about 10-15% in tall-grass meadows of *Miscanthus sinensis* or *Sasa senanensis* (Numata 1956).

"It is assumed that lianas have come from erect ancestors, and that their evolution was subsequent to that of trees, although potential lianas well may have existed before trees and even may have climbed over rocky cliffs. Probably the first lianas were leaners with twiners and tendril climbers developing later". (Coulter et al. 1931). Herbaceous lianas, particularly annual ones developed recently on the open lands after destruction of forests by man.

*Gymnostemma pentaphyllum* is a peculiar type of liana which climbs up shrubs and dwarf bamboo, comes down and stretches on the ground like a stolon after bearing flowers and fruits. Then the top of the liana burrows into the ground as a rhizome, being thick with overwintering buds. This may be a kind of geocarpy like *Arachis hypogaea* (Pijl 1969). *Parthenocissus tricuspidata* climbs up like a liana in a light forest stand, however it stretches on the ground under rather dark conditions. These examples are a kind of transitional form of liana.

Considering the growth form of plants, spinescence is also noticeable.
There are two different kinds of stem spines: reduced spinose branches as in *Malus sieboldii, Crataegus cuneata*, etc. and spinescent protrusions on the stem like a rose. These were illustrated in the Goethe’s “Metamorphosis of Plants” as exhibiting the shrinking of their leaves and extension of their stem. Some of the spinescent branches are explained as an adaptation as in *Ulex europaeus*, which results from harsh conditions, particularly morphological convergence by xerophytism. However, it does not account for all spinescent branches, because thorny lianas are extremely abundant in humid tropical forests (Coulter et al. 1931). The spinescent protrusions are not as related to harsh conditions as are stem spines. The origin of the spines is sometimes explained as being the results of natural selection under the influence of grazing animals. However, this is related to the survival of spinescent plants rather than to their origin. A thorny shrub, *Rosa multiflora* in seminatural pastures in Japan is very similar to the ecological status of *Cotoneaster microphylla* in semi-natural pastures in Nepal (Numata 1965). A thorny shrubs, *Rosa wichuraina* in the coastal grasslands of southern Japan is very similar to *Rosa rugosa* in the coastal grasslands of northern Japan. They are all ecological equivalents in similar seral stages, i.e. seral equivalents (Numata 1966).

Besides the growth forms mentioned above, the hanging form is very characteristic. For example, *Tricyrtis hirta* has a hanging form on slopes as well as an erect form on horizontal land. A fern of Blechnaceae, *Woodwardia orientalis* is usually found in its hanging form. This growth form might be ecologically related to the leaner.

Growth forms of plants are mostly genetically fixed, however they have some plasticity to environmental change, particularly in certain of their transitional forms. It is very difficult to trace the course of evolution of growth forms, but we can estimate it in relation to plant life in a plant community.

The **leaf shape and size** are sometimes useful as the external characteristics of plants. The leaf shape is related with leaf protection, namely the small and thick leaf is considered as the diminution of exposed surface. The leaf shape is classified into needle or spine (nl), narrow (na), broad
(bd), compound (c), and branched (br) modifying Dansereau's system (Dansereau 1951). The leaf size is classified into leptophyll (l), nanophyll (n), microphyll (mc), mesophyll (ms), macrophyll (m), and megaphyll (mg) based on Raunkiaer's system (1916). It is useful for analysing and comparing the structure of plant communities (Numata & Ohsawa 1970). The leaf texture is classified into filmy (f), membranous (m), sclerophyll (sl), and succulent (sc) (Dansereau 1951). The evergreeness and deciduousness of leaves, such as summer green (SG), winter green (WG), evergreen (EG), semi-evergreen (SEG) and deciduous (D) leaves are also very important ecologically. Moreover, the protective structure of leaves, especially connected with the epidermis, is grouped into heavy cutinization (c), wax coats (w), resin coats (r), epidermal hairs (h), scales of various patterns (s), and others (o).

The author discussed various biological types as above in relationship to the method of description. However, life-form is a typological concept of life-styles of plants including forms, structure, habit and function. But practically it is classified using visual and external features of plants. These life-form systems have mainly been used for the analysis of the structure and succession of plant communities by the author and his collaborators.

VARIATION AND EVOLUTION OF LIFE-FORMS

Regarding the evolution of large division of life-forms, the major steps of arborescent and herbaceous forms have been discussed by many people (Sinnott & Bailey 1914, Bancroft 1931, Takhtajan 1969, Stebbins 1974). The evergreeness and deciduousness (Axelrod 1966), evolutionary aspects of their growth habits, and seed dispersal characteristics (Stebbins 1974), etc. have been discussed.

The evolution of life-forms can be considered broadly from three main guidelines as 1) plant-habitat, 2) plant-plant, and 3) plant-animal (including man) relationships. Among these, the evolution of life-forms through the plant-habitat relationships has been discussed frequently.
The dormant form classification after Raunkiaer (1935) was based upon the distribution of temperature and water all over the world, plant-habitat relations have been classified into types of plant climates. The subdivision of deciduous plants, such as whole shoot shedders, branch shedders, and leaf shedders, depending on the part which withers during the dry season (Orshan 1953) is an extension of Raunkiaer’s system. The difference between the life-form spectra on the southern and northern slopes of mountains (Miller & Buell 1956, etc.) is an example of the plant-habitat relationship on a local scale. The evolution of weeds is usually considered from the standpoint of crop-weed competition, however in some cases such as the speciation of Echinochloa crus-galli Beauv., the plant-habitat relationship is most effective (Numata 1958). There are several varieties of barnyard grass as weeds of rice-fields vs. a barnyard millet as a crop (E. c. var. frumentacea Wight.), i.e. var. formosensis Ohwi, var. oryzicola Ohwi and var. praticola Ohwi in addition to Echinochloa crus-galli itself. These are different in growth form (erect and prostrate forms), leaf type (broad and short, and narrow and long), breadth and color of leaves, heading time, head type, awns, grains, etc. In rice-fields, E. c. var. orizicola does germinate when submerged under more than 5 cm of water, but var. praticola germinates under water-saturated or drier conditions (Numata 1958). Similar speciation in Echinochloa is observed in Czechoslovakia, too (Hejny 1951). The habitat segregation of Ranunculus spp. (R. bulbosus, R. acris and R. repens) in permanent pastures in England (Harper & Sager 1953) is similar to that of barnyard grass.

Plant-plant relationships are divided into two, intraspecific and interspecific. In the same way that the effect of insect density is classified into Allee type, Drosophila type, etc., some plant species like flax and rice endure dense planting, while others require more space for individuals to grow. A synecotype of mimicry, such as flax weeds, as mentioned above, is caused by natural selection resulting from competition with flax (Stebbins 1950) under ecological and phytosociological conditions. As seen in the experiment of Zinger (1909), the flax mimics of Camelina sativa individuals growing in competition with flax were larger those not subjected to such competition.
The crop mimicry of barnyard grass to rice was also developed under interspecific plant-plant relationships.

The evolution of life-forms through life in a community is referred to above in the description of anemochores related to the structure of tropical rain forests. The diversity of life-forms is an indication of the stage of development of plant communities. In experimental studies on the early stages of secondary succession on denuded quadrats (Numata 1956), the diversity of growth forms increased with time. There were three growth forms: e, pr, and p in the denuded quadrat in the prevernal aspect, and t and b were added during the summer aspect. During the following year, the community had more two growth forms r and l. Social adaptation by Neger (1913) is somewhat similar to this situation of growth forms. Prevernal plants are usually seen under deciduous forests, such as *Scilla non-scripta* in England (Blackman et al. 1946) and *Erithronium japonicum* in Japan. The seasonal habit of plants is a kind of life-form which is related to plant association. The characteristic species and the differential species are the consequence of the combination of life-forms in the broad sense.

Finally, plant-animal relationship also contribute the evolution of life-forms. Predator selection affects the differentiation of the growth forms of *Phleum pratense* such as the erect form in meadows used for mowing and the decumbent form in pastures used for grazing. The richness of toxic and thorny plants such as *Rhododendron japonicum*, *Rosa multiflora*, etc. in Japanese pastures has been caused by cattle-raising. There are similar vicarious taxa with similar growth forms in pastures of different countries. For example, *Rhododendron arboreum*, *Cotoneaster microphylla*, etc. were seen in pastures in Nepal (Numata 1965). Some or the present growth forms of plants would be established by the “interrelated evolution” between plants and animals, as shown by Newbiggin (1936).

In the climax grassland like in western United States of America, grasses evolved as species and life forms since the Tertiary Period under the influence of grazing animals. Increasing the contents of silica, lowering the position of growing point, etc. were characteristic. Such evolutionary changes were occurred in the grassland ecosystem including grazing animals.
as an important biotic component. Plant evolution has been often considered only from the phylogenetic viewpoint of the plant world. According to the examples, we can understand the evolution of various interrelationships of plant-habitat, plant-plant and plant-animal (including man) in the framework of biome or ecosystem. Under such a situation, the evolution of life-forms occurs as one side of the evolution of taxa.

To demonstrate the evolution of life-forms directly is very difficult, however we can estimate the course of evolution considering the diversity of life-forms along with the complex interrelationships between species and environment geographically and historically.

**SUMMARY**

1. The author has studied the biological types, of vascular plants since 1947 as the basis of biological flora and structural and successional analyses of plant communities, and has come to consider that it is necessary to develop a standardization concerning the method of describing such biological types.

2. The growth forms of plants, r, pr, ps, p, l, sp and h, are considered in their ecological meaning, their combination, and relationships to vegetation types and habitat. Ecolological equivalents in similar seral stages, and the growth form composition corresponding to seral stages and community structure are most important to consider evolution of growth forms.

3. The migrule forms, particularly the disseminule forms, show adaptation in relation to the structure of communities and succession, biotic factors in grasslands, etc. The Salisbury's rule on the weight of propagules related to succession has an exception in the first year pioneer species such as *Ambrosia artemisiifolia* var. elatior.

4. The Raunkiaer's dormant forms are usually of genetic characteristic, however sometimes it is flexible to environmental conditions. The clonal growth is divided into perennial ramets, Th(v) (annual ortets) and G(s) (perennial ortets). Th(v) is further divided into rhizomatous ortets (*Cacalia*
type) and stoloniferous ortets (Valeriana type).

5. Other life-forms such as crown forms, branching habits, sociability, etc. are also referred.

6. Variation and evolution of life-forms are discussed broadly from three main guidelines as 1) plant-habitat, 2) plant-plant, and 3) plant-animal (including man) relationships, particularly on some examples on deciduousness, varieties of weed in cropland habitat, intraspecific and interspecific relationships of plants, predator selection, etc.

7. The biological type classification becomes clearer when it is constructed on some discrete characteristics, such as the author's disseminule form based on modification for the migration of seeds or fruits. And, it is convenient as a useful tool in field surveys to use morphological characteristics, meanwhile its biological meaning ought to be partly given according to laboratory ecology.

8. The following important points in the biological description of vascular plants have been discussed:

1) Environmental conditions related to plant distribution
   i. Climate ...... Climatic types, meso- or microclimatic conditions, and limiting factors.
   ii. Physiographic conditions ...... Soil types, pH and other chemical conditions, the water table, and topographical features.

2) Communities

The coactive and interrelated relationship of a species with others and the phytosociological status of species, especially the fidelitic relationship, dominance - subordination relationship, and vegetation type.

3) Biological types
   i. Dormancy forms ...... Raunkiaer's life-forms and their modification.
   ii. Migrule forms ...... The author's disseminule forms and radicoid forms.
   iii. Physiognomy ...... Sociability classes and indices, growth forms of trees particularly their branching habits, bark features, and crown shapes, and of herbaceous plants, leaf shape and size, leaf
texture, and the protective structure of leaves.

LITERATURE CITED


Dansereau, P. (1951) Description and recording of vegetation upon a structural basis. Ecol. 32: 172-229.


Bull. Educ., Kobe Univ. 27: 141-220.
Nakano, H. (1930) Plant Communities and Their Succession. 124 pp., Iwanami-Koza (Biol.), Tokyo.
Numata, M. (1947) On the reproductive type of plants. Seibutsu (Biology) 2: 121-123.
Numata, M. (1951) A typological method in biology, especially on the life-


Numata, M. & Asano, S. (1959) Variation in the depth of the underground part of geophytes. Some considerations concerning the biological


Uehara, K. (1925) Trees in Gardening. 458 pp., Yokendo, Tokyo.
Zinger, H. B. (1909) On the species of Camelina and Spergularia occurring