CLASSIFICATION AND ORDINATION: THEIR NATURE AND ROLE IN TAXONOMY AND COMMUNITY STUDIES[1]

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Abstract: The origins of classification and ordination in human thought are discussed. It is shown that the genetic and evolutionary history of organisms leads to the separation of discrete classes in a hierarchical structure, whereas the same is not true of communities. It is argued that the model selected for classification or ordination should have the fewest parameters needed to account for non-random variation. One-dimensional ordination should be followed by tests of discontinuity. If discrete classes are discovered, they should be analysed separately, and ordination in higher dimensions of the whole data set should proceed only in their absence. The value of the nodum as a concept in community analysis is emphasized.

Introduction

Classification and ordination are methods of simplifying the protean nature of the observed world. Both reduce the enormous multifariousness and heterogeneity of phenomena to terms which the human brain can encompass, and to which thought processes can be effectively applied. But, whereas classification establishes a set of classes, allots individual phenomena to them, and thereafter thinks of the phenomena in terms of their class membership, ordination establishes a coordinate system, places each individual phenomenon within it, and then thinks of the phenomenon in terms of its coordinate position.

Both classification and ordination are very primitive thought processes. They lie very close to the origins of intelligent thought, and must occur in most vertebrate groups – perhaps even the invertebrates – though animal psychologists have as yet devoted little attention to the question.

The origins of classification

In a baby, the development of classification can readily be conceived. Initially, the sensory world consists of a sequence of sensory impressions, in which a rich visual display occurs simultaneously with auditory, tactile, olfactory and gustatory sensations, and all of these elements of the sensory pattern are subject to continuous change.

In the course of the baby's first few days of life, he learns that a certain pattern in the visual field – or a sequence of patterns – often occurs simultaneously with distinct auditory, tactile, olfactory and gustatory sensations – and some more deep-seated and highly satisfactory sensation, too. So the baby performs his first exercise in classification, and recognizes these sensory events or sequences as constituting a class, to which (if he could speak) he would give the name «Mother». The sensory sequences vary substantially, but have enough in common to be distinguishable as a group from others resembling them in one way or another.

As time goes on, other sets of sensory sequences attain class status in his mind, the linguistic equivalents of which would be «Father», «brother Robert», «sister Anne», «Pussy» and «Fido».

A little later, a further hierarchical level of classification develops in the baby's mind. These classes of recurrent sensory petterns to which we have given the names «Mother», «Father», «Robert» and «Anne» are grouped in the baby's mind into a higher class which he will later call «people», «Fido» and «Pussy» into another class which he will later call «animals». Cross-classification may even enter into it. «Mother» and «Father» will become «grown-ups», whereas «Robert» and «Anne» are «children», while

[1] The text of an invited lecture delivered at the First International Summer School of the International School of Vegetation Science at the University of Rome, June 1983 (see N. C. Kenkel's report in Vegetatio 55: 127-128).

«Mother» and «Anne» are «females» and «Father» and «Robert» are «males». Thus, classification is well developed in the baby's mind during its first few months.

In the thought processes of the adult, classification is closely linked with language; in fact, most uses of language imply that the objects of thought can be classified – whether into classes of sets of sensory patterns given proper names («Mother»), or classes of such classes, for which common nouns are used («people»). Adjectives, adverbs and verbs similarly represent classes of attributes or actions. And, just as the classes implied by the units of language reflect the classes recognized by thought, the latter can be influenced and modified by language – a fact of which advertisers and demagogues make much use.

All classification calls for the recognition of differences among the objects classified – differences in respect of one variable at least, or, more often, correlated differences among many variables. If only a single variable is involved, and that variable is binary, the problem is clear-cut – each of the alternative values results in the object being allotted to a particular class. If the variable has a number of alternative values, any of a set of these values may determine the allocation of the object to a particular class. If the variable is continuous, the problem becomes more complex, in that the possible values need to be divided into discrete ranges in order that one or more ranges may determine class allocation.

If more than one variable is in question, the relative weight to be accorded to possible conflicting evidence from the different variables in determining class allocation needs also to be considered.

Once the allocation of an object to a class has been determined, it may be possible to use the class membership to predict other variables in that object – other variables which have known values or ranges in other members of the class. In fact, this predictive ability is one of the main values of classification. Even to the baby, the visual and auditory sensations which enable him to allocate the current sensory pattern to the class «Mother» enable him then to take the action necessary to obtain the tactile and gustatory satisfactions he needs – he cries!

Ordination vs classification

While classification rests on the relationship of equality (= o), ordination in principle rests on that of inequality (> or <). Class membership depends on whether an object has or has not a particular set of attributes; position in an ordination depends on the values of continuous variables (or sets of discontinuous variables represented by continuous ones). When the concept of relative magnitude first enters a baby's pattern of thought is an interesting question; but it is almost certainly later than the more primitive notions involved in classification. Ordination has no direct reflexion in language like classification; it finds its counterpart in number, or in graphic representation (drawing, mapping).

In principle, the information provided by the position of an object in an ordination is infinitely greater than that provided by its membership of a class. To define which of (say) eight classes an object belongs to requires just three bits of information. But the coordinate of an object along just one axis of an ordination can be expressed in principle by a binary number with an infinite series of bits, and could thus be used to code any message, no matter how long and complicated. Thus, when continuous variables are used in classification rather than ordination, there may be an enormous loss of information[2].

This distinction may be illustrated by an example from geography. One may express the location of the village of Battle, for instance, by saying that it is in England, or in the county of East Sussex. These would be classificatory statements. But one could also express its location by saying that its latitude is 50°55'N, its longitude 0°29'E. That is an ordination statement, and clearly contains the same information as those based on classification, and much more.

It should be noted that classification – the allocation of individuals to classes – implies nothing about any possible relationship between classes, or between individuals within classes. The classes are recognized as discrete groupings – that is all. And the characters of the individuals are submerged in the characters of the class – their individuality is lost. This applies to the primary process of classification itself. By further operations it may be possible to construct a scheme analysing the relations between individuals constituting a class, or showing interrelations among the various classes. But this is secondary to, and not part of, the primary process of classification.

In particular, quantitative relationships are not part of a classification scheme *sensu stricto*. The relations «greater than», or «between», are foreign to the process of classification. If quantitative characters are used in classification, they need to be subdivided into discrete ranges, each of which is treated in the same way as an alternative value for a qualitative character, and the information contained in their *order* is lost. Classes may themselves be classified, into super-classes or groups of classes. Such an arrangement of classes is often represented by a dendrogram. It should be noted that the essentials of a classification represented by a dendrogram are unaffected by any distortion of the dendrogram. Provided all the links remain intact, the same classificatory message will be conveyed. A dendrogram represented in two dimensions, with all the branches ending at the foot of the page, suggests an order of classes, at each level of the hierarchy, which is not inherent in the classification process. Any *arrangement* of classes, so that the classes appear in sequence, statements that one class is more similar to a second than to a third, or a conclusion that one class is between two others, is a departure from pure classification, and the admission of an

[2] Though the *potential* loss of information is enormous – infinite, in fact – in practice the loss is limited by the presence of substantial random variation in the data, and hence uncertainty in the ordination coordinates.

element of ordination. Such hybrid procedures may indeed have considerable value.

Before considering applications of classification and ordination, it may be as well to review the purposes that they may serve. Basically, one is usually concerned to simplify thought and communication, by replacing the many individual phenomena constituting a class by a single designation, or (in ordination) using a single number (or a small set of numbers) to represent a very complex object. Another purpose, not identical with this but closely linked with it, is prediction – class membership or position in an ordination may enable statements to be made, with good chances of accuracy, about attributes that have not been observed in the particular object in question. Apart from these rather pratical purposes, one may also wish to elucidate the structure of variation in a data set for its own sake, or to test some hypothesis. Particular purposes may lead to particular classifications – a clothing manufacturer may, for instance, classify his potential customers into ten or twenty categories by size and shape only, ignoring all the other ways in which they may differ among themselves. In what follows, however, it will be assumed that the purposes are to predict unspecified attributes, and to elucidate the structure of variation.

Classification and taxonomy

Before considering applications of classification and ordination in community studies, it may be appropriate first to look at the treatment of heterogeneity among individual organisms. Here we have entities that are distinct and well-defined (except sometimes in the case of clones), differing from one another in many observable and recordable types of character. One reason for considering these first is that records of biological taxa in communities are often the data on which community studies themselves depend.

Individual organisms could in principle be classified on the basis of any character (or group of characters) in which observable differences are manifested – size, shape, colour, age, sex, etc. But luckily there is a basis for classification which successfully combines a great many character differences and which consequently can serve many purposes; this is the biological species. In organisms of importance to man, biological species were recognized from a very early stage – at least from the dawn of language. Thus, there are common words for dog, fox and wolf, for sheep and goats, for wheat and barley. It was recognized that a large number of animals could be considered as a single category, «wolves», and had many characters in common which they did not share (at least in the same combination) with other animals outside that category. Saying that an animal was a «wolf» implied many other statements about its attributes and behaviour, so that such a statement of class-membership was useful both in private thought and in inter-personal communication. And the same was true throughout the living world. When scientific study of organisms began, these categories embodied in common language were recognized as species. The biological species is a natural unit of classification in that it combines information on (and permits prediction of) many attributes of al types. But it is natural in another sense, which illuminates this concentration of recognizable character differences, It has arisen because genetic systems and natural selection favour the accumulation of differences, including those contributing to genetic barriers. And genetic barriers themselves imply further accumulation of genetic differences. Thus, differentiation among populations of organisms is a self-accelerating process. As two populations, previously united, begin to differentiate, so the pressure to differentiate further increases until genetic barriers are set up, to reinforce the reductions in gene flow through niche or geographical separation. Once genetic barriers exist, and evolution is taking place independently within the two populations, simple accumulation of differences heightens the barriers, and positive selection to reduce gene flow begins.

This inbuilt propensity to differentiation and to accumulation of associated character differences makes the biological species quite exceptional among objects of thought. And it clearly makes the process of classification particularly appropriate to individual organisms. It is to be *expected* that they will «cluster» – that the groupings of attributes one sees in them will be discrete and well separated.

Since biological species above the level of bacteria are genetically isolated apart from rare episodes of allopolyploidy and the like, evolutionary convergence can never be more than apparent. The historical interrelations among species can never constitute a network, but must be a dendrogram. Evolution above the species level involves further accumulation of attribute differences. Thus, classification of biological individuals naturally becomes hierarchic. Species are grouped into genera, families and orders, as the time since their separation which has been available for the accumulation of differences lengthens. Evolutionary relations are represented by a dendrogram (cladistics), and the observable sets of characters also group similarly (phenetics).

Situations in taxonomy where ordination recommends itself as an alternative to classification are fewer. One clear case is where hybrid swarms exist, and an ordination could be expected to sort out the different species contributing to the swarm.

Classification of other subject-matter does not lend itself so well to hierarchical arrangement of classes as the taxonomy of biological individuals. The naturalness of the hierarchical arrangement in this case derives from the way in which organisms have evolved. Where this does not apply the relationships between classes may be quite different; they may, for instance, take the form of a network, or of some kind of cross-classification based on different character groups which are not, or only poorly, associated.

Classification or ordination applied to communities

The subject-matter of ecology differs greatly from that of taxonomy. Ecosystems, or plant and animal communities, are not discrete entities like organisms. They are usually diffuse objects, which can become the subject of study only by a sampling process. Thus, the entity which is the subject of classification or ordination is delimited arbitrarily. It has often been stated that there are in nature homogeneous stands of plant communities, and that samples for study should be taken within these homogeneous stands. Even so, the boundaries of the homogeneous stands would themselves be subject to arbitrary definition involving the observer's judgment. But in fact homogeneity is not an absolute concept, but relative. There are degrees of homogeneity in vegetation, and judgment is exercised in determining where the limits of the «homogeneous» area to be sampled lie. This discussion merely serves to emphasize that the ecological entities which may be the subject of ordination or classification are, unlike biological individuals, arbitrarily defined segregates, rather than natural objects.

Since the basic data for community studies are samples; in time as well as in space, and since the attributes of a community change continuously both in time and in space, random variation needs to be taken into account much more than in the taxonomy of organisms. Variation between communities which can be attributed to different class membership or to different position in an ordination needs to be distinguished from the irrelevant random variation which overlies it – the «noise», as it is often called.

As has been shown, biological individuals are intrinsically characterized by a large number of correlated attributes, as a result of genetic and evolutionary processes. The same processes do not operate on ecological communities. These communities are combinations of populations, each of which has its own genetic and evolutionary history. In many cases these histories have substantial overlaps – some of the organisms have been parts of one another's environment over lengthy periods of evolution, so that the process of evolution has taken their mutual presence into account. This is most obvious in direct interspecific relationships – as between a plant and its preadapted pollinator, or a herbivore with enzyme systems specially adapted to deal with protective substances formed by its preferred (or exclusive) food plant. But doubtless the same process of mutual evolution has served in part to knit together all the organisms constituting a community which has continued in existence through geological time. In this sense, the community has «evolved», and communities including a number of the same species have a certain «genetic» association.

It has been pointed out that speciation depends to a considerable extent on the fact that accumulation of genetic differences between populations is a self-accelerating process – that once a genetic barrier exists, there are evolutionary advantages in making it less penetrable. An analogy at the community level would be if the degree of mutual adaptation of the various species were such as to make it difficult for a «foreign» species to become established. This seems an interesting theoretical possibility which is worthy of experimental test, but has not so far been demonstrated. The fact that many species, including dominant or *edifikator* species, are common to two or more communities seems *prima facie* to make it unlikely.

The «evolutionary» process outlined above, though it seems likely to play some part in the development of communities, cannot be by any case universal. Clear exceptions occur where new organisms have entered a geographical area during historical times. In Australia, for instance, probably over half the present animal biomass is of species which did not exist in the country two centuries ago, and the same is true for a substantial proportion of the plant biomass. The communities of mixed natives and exotics have often attained equilibrium; but it is an equilibrium in which mutual evolution has played little part. Even the rather sketchy analogy between interrelationships among communities defined by constituent organisms and those among species defined by attributes breaks down here, and there is no *a priori* reason to expect discrete separation of community groupings as there is of species, or a hierarchical structure of different community types.

One may conclude that analogies between the classification of biological individuals and that of communities should not be pressed too far. The fact that classification techniques are an appropriate conceptual tool for handling biological variety at the individual level does not imply that the same is true at the community level. The latter question needs to be examined independently. Classification of ecological samples or stands does not have the same natural basis as that of biological individuals. They *can* of course be classified – as virtually any objects of thought can be classified – but it is not to be expected that the various attributes (quantities of different species present, etc.) will be as closely associated as the attributes of individuals of the same species, or as predictive of one another.

Above the base level (the species and the Association, say), the analogy is even more remote. As has been said, there are reasons for assuming that species will fit into a hierarchical system; there are no such grounds in respect of associations. They *can* be so fitted, of course; but it is unlikely to be a particularly valuable approach. An association once formed is not discrete; in biological species, exchange of genetic material (for instance, by allopolyploidy) is *ex hypothesi* a rare event; but associations exchange their component species with ease. There is consequently little reason to assume that differences between associations will fit into a hierarchical structure – which is virtually assured for the biological species by the progressive accumulation of genetical differences in the virtual absence of interchange.

The agglomerative and divisive procedures for numerical classification, which are often used because of their ready availability in «packages», appear to prejudge this issue. They result in a dendrogram, which is *ex hypothesi* a hierarchical structure; even if the primary classes recognized are «natural», it does not follow that the combinations to which these procedures lead are a suitable way of treating their diversity, where (as in communities) hierarchical structure is not inherent in the concept.

Another distinction between biological individuals and communities is that the latter tend to intergrade continuously. In space, sharp boundaries are the exception – there is usually a zone (an ecotone) of more or less gradual transition. In time, one is concerned with succession. Successional sequences may include periods of more rapid change separated by periods of relative stability; but the changes generally go on continuously. Moreover, the same advanced stage in succession can be the product of various sequences. Even in succession, relations among community types are multidimensional.

Thus, in community studies (unlike taxonomy) there is no *prima facie* reason for choosing classification, as against ordination, as the approach to simplifying observational complexity. Choice should be pragmatic – which is more practical? How well do the different approaches work? And this presupposes a purpose or set of purposes. Most commonly, as indicated above, the purpose can be expressed in terms of prediction. The value of a classification or ordination is shown by how well one can predict unknown attributes, given a class membership or set of coordinates.

In taxonomy, the purpose of classification extends beyond the prediction of unknown attributes to the identification of biological relationships. Unless it is claimed that communities have evolved from one another as complete and discrete entities, this purpose (for which classification would certainly seem better adapted than ordination) cannot also apply here. In community studies, we are concerned with phenetics, not cladistics; and ordination has as good a *prima facie* claim as classification.

I have referred to the «naturalness» of a classification – a concept which does not necessarily have anything to do with an evolutionary background, but refers to the degree of association of attribute values. The concept may be elucidated by a description in terms of ordination. If the points in an ordination are tightly clustered, so that «distances» within a cluster are much «shorter» than between clusters, the primary classes represented by these clusters are «natural». If the clusters themselves are clustered, with empty or sparsely populated interspaces, the next level of a hierarchical classification is also «natural». The «naturalness» of a classification can also be expressed in terms of information, in the technical sense. If a substantial proportion of the information in respect of a number of attributes is contained in the class membership – in the between-class comparisons – then the classification can be claimed to be «natural».

The simplest form of distribution of points in N-space is a uniform one – which would be meaningful in an ecological ordination if the axes had been scaled so as to be of finite length. Usually they are infinite, in which case the simplest conceivable distribution of a finite number of points is in a hypersphere about a single centre or nodum. Since the scales of the axes are usually arbitrary and can be varied at will, a hyperellipsoid is indistinguishable from a hypersphere. More complex distributions would involve multiple noda, with non-uniform distribution of each cluster about its nodum. Where more than one axis is involved, concentrations of points may form strands or networks of infinitely varied pattern linking the various noda; or the heterogeneity could take the form of relatively empty pockets within a homogeneous matrix. Such conceivable heterogeneous distributions would have their counterparts in the interrelations between clusters recognized in the course of classification; but conceptualization is greatly facilitated if intuitive ideas of space are invoked, as can be done by ordination (so long as there are no more than three axes).

It should be emphasized that classification is perfectly valid even where there are no «natural» classes. A uniform distribution of points in N-space can be divided by arbitrary hypersurfaces into arbitrary regions, and each region can be given a class-designation. It may be found easier to refer to these regions by a class name, as is commonly done in geography, where the constant use of latitude and longitude would be cumbersome and inconvenient.

In dealing with community diversity, the first question may be whether «natural» classes exist, and how discrete they are. This may be best answered by ordination, either covering the whole data set, or a subset including just the points which are suspected of belonging to two distinct clusters. If the clusters are discrete, then a statement that a point belongs to a particular cluster may contain enough information about it – about the ranges within which the value of each attribute (such as the quantity of a given species) lies – for the purpose in question. The coordinates of the point in the ordination will contain more, but the extra information may be irrelevant, or may largely be random «noise».

Community and environment. Direct and indirect ordination

The purpose of classification or ordination may be just to simplify the great variety of community types, and facilitate thought and discussion about them. For this purpose, either may be appropriate – classification more particularly if «natural» classes exist. But one may also be seeking to explore the relationship of community composition and structure to environmental variables, or to develop a means of identifying environmental characters by the ecological communities present.

Where it is possible to designate in advance one or more environmental variables of interest, and to measure them, «direct» ordination is possible. Then the community variation, as a set of dependent variables, is brought into relationship with the environmental attributes as independent variables – either individually, or combined through Principal Component Analysis, say, or by a process such as canonical correlation. «Direct» ordination is virtually a form of regression. Similar procedures based on classification could also be developed; but since almost all environmental variables are continuous, it would be necessary to divide the environmental N-space by hypersurfaces in order to create discrete cells with which the community classes could be brought into relationship.

Where there are no records of environmental variables, ordination must be «indirect». Though the axes of the ordination are based only on observable features of the community (such as the quantities of different species present), it may be possible to relate them intuitively to environmental variables, or groups of variables such as might be subsumed under such descriptive words as «aridity» or «oligotrophy». Similarly, a classification of communities developed without regard to environmental variation can be used to indicate environmental features, just as the presence or absence of individual species («indicator species») can. However, the fact that environmental variation is continuous constitutes a *prima facie* case for the selection of ordination rather than classification where environmental indication or prediction is the main purpose of studying community variation.

Choice between models

It often happens that a choice exists between different models for simplifying observational data. Often this takes the form of a «stopping rule» — How many classes should one distinguish? How many axes are needed? Clearly, classification can proceed until every individual sample is the sole member of a separate class; ordination can result in as many axes as there are measured attributes. In this case, the goal of simplification is not attained — the final result is no simpler than the original data. But where should one stop? And can one apply a similar criterion (whatever it may be) to the choice between classification and ordination?

A good general principle is economy — economy of means, economy of concepts, economy of parameters. This was expressed by William of Occam some six hundred years ago in the maxim known as Occam's Razor: «entia non sunt multiplicanda praeter necessitam» (new entities should be postulated only if absolutely necessary). In other words, the simplest adequate explanation or model is the best.

As already pointed out, all variables recorded by ecologists are subject to random variation. If two samples of the same community are taken, they will not be identical. Consequently, analytical procedures should only go so far that the residual variation (from the ordination axes, or the class means) could represent «noise» — unstructured random deviations from the mean of a hypothetical set of replicate samples.

In face of a set of community data, then, one's initial null hypothesis is that they are samples of the same community — that the variation among them is unstructured «noise», values of each variable being distributed simply (e.g. in Gaussian fashion) about a mean, and independently of all others. If one considers as the alternative to this null hypothesis that there are two classes, then (if the variables are continuous) each class will have its own mean and variance for each variable. If the n variables are again assumed uncorrelated within classes, this model has $4n$ parameters — $2n$ more than the null hypothesis. One binary variable describes class membership for each individual sample. If m classes are to be defined, and there are p samples, then $2mn$ parameters are required to define the classes, and to define the class membership of each sample requires

$$p\,[\mathrm{INT}\,(\log_2 m - 1) + 1]$$

values of binary variables.

Ordination on one axis requires a minimum of $2n$ parameters to define the relation of each attribute to the axis (more if the relation is non-linear), plus n further parameters to define the «noise» function, and p values of a continuous variable to locate the individual samples along the axis. If the ordination has q axes, these figures become $n(2q + 1)$ and pq respectively. Thus, the number of parameters to be fitted for a model with two classes is more than that for a linear ordination model with one axis, and the same number of variable values (binary in one case, continuous in the other) is needed to define the location of the samples. This fits in with the idea that, if one first fitted one axis of an ordination, one could then test for a discontinuity along this axis as a method of determining whether two classes should be recognized. A model with two classes is more complex than a linear model with one axis, where the variables involved are continuous.

Combined ordination and classification

If the whole set of samples is uniform, subject only to «noise» variation, the first axis of an ordination will be non-significant — will account only for such a proportion of the total variation in each attribute as could be a random sample of the overall variation. If the variance accounted for is significantly greater, then the different attributes are associated one with another. This *could* arise because the data are derived from more than one discrete class of communities, and tests for discontinuity may be applied. If these tests are positive, the classes may be separated. If not, a second ordination axis may be calculated. If this is significant, tests for continuity may again be applied, for a distribution which appears continuous when projected on one dimension may reveal discontinuities in two dimensions. Then, if no discontinuities are found, a third ordination axis may be tested, and so forth. At each stage, the simplest model not yet ruled out of court is tested, and additional complexity is introduced only as the necessity for it becomes apparent — in an exact application of Occam's Razor.

It should be noted that the ordinations discussed above have been linear. If at any stage the linear model is non-significant, it might be wise to test at least a parabolic model before increasing the number of axes; a parabolic model with one axis is simpler than a linear model with two axes (4n and 5n parameters respectively).

As is always the case with statistical tests, estimations of significance assume that the community samples are unselected. If they have been selected to conform to some pre-existing concept of community classes, clearly they will tend to be discrete, and the test becomes one of the efficiency of the selection process rather than of discontinuities in nature. And the same, *mutatis mutandis*, applies to tests of successive axes of an ordination. Selection is to be avoided at all costs if it is intended later to apply tests of significance.

If discrete classes have been discovered, there is little point in continuing with an ordination involving tests based on an assumption of continuity. Rather, the next step should be to test whether each of the classes recognized and separated is internally homogeneous. For each of them, one repeats the procedure described for the whole data set, the alternative possibilities of a secondary ordination or subdivision into sub-classes being considered for each primary class. When analysis on these lines has come to an end – when each ultimate class has been subjected to internal ordination, and residual variations from these ordinations are unstructured – the class centroids may then become the subject of a new ordination (with possible recognition of clusters of classes), so that the interrelationships among the classes can be elucidated.

In conclusion, I would like to draw attention to a concept in this field which has been undeservedly neglected – the nodum. In terms of the distribution of points in space, a nodum is the centroid of a cluster. It is a reference point in ordination space, a theoretical community type to which observed communities can be related. Instead of partitioning the space between classes, one identifies the noda and can then refer to an individual point by naming the nearest nodum, and the displacement of the point from it in terms of distance and direction. This would seem to combine some of the advantages of classification and ordination. Designation of a nodum often serves the same purpose as naming a class (in fact, the nodum may be regarded as a class defined by intension rather than extension), while the possibility that individual samples may deviate from this norm, perhaps in the direction of another nodum, is recognized. The nodum concept could facilitate thought in much the same way as the class concept, but without the strait-jacket exclusiveness of the latter.

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